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Paleontology of the Greenhorn cyclothem (Cretaceous: late Cenomanian to middle Turonian) at Black Mesa, northeastern Arizona

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ABSTRACT: Extensive invertebrate fossil collections from the Late Cretaceous (late Cenomanian–middle Turonian) Greenhorn cyclothem at Black Mesa in northeastern Arizona demonstrate that the thick clastic sequences of the western foreland basin preserve a much greater diversity of invertebrate fossils than that recognized from the carbonate-dominated central Western Interior Seaway. At Black Mesa, the Greenhorn cyclothem is the Dakota Formation, Mancos Shale and Toreva Formation. Invertebrate fossils have been recognized from the upper sandstone member of the Dakota Formation, the lower shale, middle shale, Hopi Sandy, and upper shale members of the Mancos Shale, and the Blue Point Tongue and lower sandstone member of the Toreva Formation. Based on recovered fauna, a total of 13 biostratigraphic subdivisions have been recognized. In addition, 77 chronostratigraphic marker beds (BM1, BM2, ... BM77) have been recognized. These consist mainly of bentonites along with laterally continuous concretion horizons, bioturbated marlstones, and sediment bypass intervals (calcisilts).

A total of 325 invertebrate taxa have been recognized in these strata, making this one of the most diverse middle Cretaceous faunas known from North America. One new bivalve genus (*Dakotacorbula*) is described and 11 new bivalve species (*Modiolus kauffmani, Modiolus coloradoensis, Pinna kauffmani, Gervillia navajovus, Oxytoma* (*Hypoxytoma*) *arizonensis, Limatula kochi, Pycnodonte newberryi umbonata, Gryphaeostrea nationsi, Gryphaeostrea elderi, Linearia* (*Hercodon*) *striatmarginata, Poromya lohaliensis*) and 12 new gastropod species (*Euspira stantoni, Turritella cobbani, Turritella kauffmani, Turritella codellana, Anchura hopii, Cerithiopsis sohli, Cerithioderma elderi, Gyrotropis nationsi, Charonia soozi, Pyropsis kochi, Paleopsephaea arizonensis, Acirsa kelseyi*) are described. *Tellina carlilana* is proposed as a new name for *Tellina modesta*, which was preoccupied.

INTRODUCTION

The middle Cretaceous (late Albian – middle Turonian) Greenhorn marine cycle (Hattin, 1964; Kauffman, 1969) has one of the most refined lithostratigraphic, biostratigraphic, and chronostratigraphic frameworks constructed for any Phanerozoic marine sequence. The Western Interior of North America contains perhaps the most complete and widespread exposures of strata of this age present anywhere in the world. Most detailed research on marine strata representing the Greenhorn marine cycle has been done on the pelagic carbonate-rich rocks deposited during peak Greenhorn transgression in the central and eastern part of the seaway of central Colorado (Cobban and Scott, 1972; Kauffman and others, 1969; numerous papers in Pratt and others, 1985), Kansas (Hattin, 1962; 1975a), western Oklahoma (Kauffman and others, 1977), and northern New Mexico (Hattin, 1987). These rocks have become a natural laboratory for developing and testing theories of basin analysis. To date, no comparably detailed analyses have been conducted on the thick clastic-dominated sequences of the western margin of the seaway.

On the western side of the seaway, in the area of the southwestern Colorado Plateau, a large V-shaped embayment formed at peak transgression ("Grand Canyon bight" of Stokes and Heylum, 1963). This embayment was structurally controlled in the northwest by thrusting along the north-northeast-trending Sevier orogenic belt. The orogenic belt was active periodically from the latest Early Cretaceous through Paleocene (Armstrong, 1968) and led to the formation of a deep foreland basin immediately to the east, into which thousands of meters of Paleozoic-derived and syngenetic volcanic sediment were deposited. The embayment was structurally controlled to the southwest by the uplift in the Mogollon highlands (central and southern Arizona) with erosion of northeastward-dipping, pre-Cretaceous strata occurring prior to deposition of the Late Cretaceous (Cenomanian) Dakota Formation (Harshbarger and others, 1957; Drewes, 1981; Dickinson, 1981; Bilodeau, 1986). Gravels deposited at the base of the Dakota Formation were primarily derived from Paleozoic strata (Repenning and Page, 1956; Gustason, 1989; Kirkland, 1990, 1991; Eaton and Nations, 1991; Elder and Kirkland, 1992). Arkosic sediments shed from the south make up a significant percentage of the coarse clastics by latest Cenomanian (Finnell, 1966; McKay, 1972; Gustason, 1989; Wolfe, 1989; Kirkland, 1990, 1991; Elder and Kirkland, 1992) through Turonian time (Franczyk, 1988) while the Sevier orogenic belt continued to supply lithic sediments from the west (Lawton, 1986; Eaton and others, 1987; Eaton and Nations, 1991; Elder and Kirkland, 1992). Within the embayment, reactivated northwest-trending basement structures (Peterson, 1969; Fursich and Kirkland, 1986; Kirkland, 1990) provided additional tectonic controls on Cretaceous sedimentation. Black Mesa is located near the center of this tectonically controlled embayment.

The Black Mesa basin is located on the Navajo and Hopi Indian Reservations of northeastern Arizona. The mesa forms a circular ring of cliffs approximately 100 km in diameter, held up by resistant strata of the Mesaverde Group at the center of the basin. Underlying the Mesaverde Group, extensive exposures of the Mancos Shale form a prominent slope rising from a lower cliff formed by the Dakota Formation. The exposures of Mancos Shale at Black Mesa represent open marine, clastic-dominated strata of the Greenhorn marine cycle deposited near the southwestern margin of the seaway and permit detailed comparisons of the shale-dominated western side to be made with the carbonate-dominated central and eastern side of the seaway.

Cretaceous strata were first described at Black Mesa by Newberry (1861) and were later described in some detail by Gregory (1917), who first applied the lithostratigraphic nomenclature of the San Juan Basin (Dakota Sandstone, Mancos Shale, and Mesaverde Formation) to Black Mesa. Reeside and Baker (1929) described the Cretaceous section on the northeastern side of Black Mesa, providing a useful biostratigraphic basis for correlations with other regions. In addition to providing further biostratigraphic data and demonstrating the northeast-southwest diachroneity on the upper and lower contacts of the Mancos Shale, Repenning and Page (1956) provided a basis for lithostratigraphic correlation that has held up with only minor modification. In so doing, they raised the Mesaverde to group status and defined (in ascending order) the Toreva Formation, Wepo Formation, and Yale Point Sandstone. Further refinements of Mesaverde nomenclature were made by Franczyk (1988). Regional correlations of the Mancos Shale at Black Mesa were made by Pike (1947), Peterson and Kirk (1977), and Cobban and Hook (1984).

Kirkland (1990, 1991) studied in detail three evenly spaced sites around Black Mesa: Blue Point in the southwest, Coal Chute in the northwest, and north of Lohali Point in the east (Fig. 1, Table 1). At each site, complete sections of the Mancos Shale were trenched until fresh consolidated rock was exposed. The sections were then swept clean, described in great detail (units as thin as 0.5 cm), then bulk sampled as one meter trench samples, and finally continuously sampled intensively for macrofauna (mainly mollusks). The detailed lithostratographic descriptions of these sections have been published in Kirkland (1990, 1991). Numerous additional sites were also examined around Black Mesa from which additional invertebrate collections were made (Kirkland, 1990) (Fig. 1, Table 1).

The Mancos Shale in this area can be readily divided into four members (in ascending order): lower shale member, middle shale member, Hopi Sandy Member, and upper shale member. Seventy-seven marker beds of varied local and regional utility have been recognized. As many of these marker beds have not, as yet, been recognized in correlative strata to the east, where systems of nomenclature already exist (e.g., papers in Pratt and others, 1985), a unique system of marker bed numbers for Black Mesa has been provided (e.g., BM1, BM2, ... BM77) (Kirkland, 1990, 1991). Where marker beds have been correlated to the central Western Interior, the equivalent marker bed numbers of other authors are given (Table 2). Biostratigraphically, the Mancos Shale can be divided into seven ammonite zones, with numerous subzones to make a total of 13 biostratigraphic divisions. These zones are based largely on the work of Cobban (1984) as modified by Kirkland and Elder (1985) and are defined on the basis of the abundant faunal data presented in Kirkland (1990) (Table 3).

This volume reports on the invertebrate faunas present in the Greenhorn cyclothem at Black Mesa.

THE DAKOTA FORMATION AND ITS CONTACT WITH THE MANCOS SHALE

The base of the Dakota Formation rests unconformably upon Jurassic strata. Williams (1951) reported a series of largely east-west channels cut into this surface. As described by Repenning and Page (1956), the Dakota Formation ranges from 15 to 40 m in thickness with no apparent regional trends and can be divided into three informal members: lower sandstone member, middle carbonaceous member, and upper sandstone member.

The lower sandstone member consists of medium- to coarse-grained, medium-scale trough cross-bedded, quartz arenite, commonly with chert pebbles concentrated toward the base. The member is discontinuous and is best developed where the Dakota Formation is thickest, where it may form cliffs as much as 20 m high, such as at the Coal Chute section. Sediments of the lower sandstone member of the Dakota Formation record river systems draining highlands to the west and are compositionally similar to Paleozoic sediments shed from the Sevier orogenic belt (Lawton, 1986). The member is largely preserved in southwest-directed paleovalleys (Kirkland, 1990).

The middle carbonaceous member is dominated by carbonaceous shale and siltstone, with interbeds of coal that thicken to as much as 2 to 3 m up section. The member contains thin interbeds of fine-grained quartz arenite, which may be flat bedded or inclined to form epsilon cross-beds. Thicker, flat-topped lenses of fine quartz arenite up to 2 m thick and 20 m across are also present locally, as are lenticular coal beds of similar morphology. Base level rise induced by rising sea-level resulted in fine sediments becoming trapped on the flood plain, leading to the aggrading fluvial deposits of the middle carbonaceous member. Continued sea-level rise resulted in a rising water table and the development of extensive coal swamps between the fluvial systems.

The upper sandstone member is discontinuous across Black Mesa. It is heavily bioturbated with no preserved primary stratification other than vague scoured surfaces. Both cementation and shell content increase toward the top of the member. Compositionally it has been described as a fine-grained quartz sandstone (Repenning and Page, 1956), but on close examination it is observed that the sandstones originally had a composition of a subfeldspathic to feldspathic arenite, with much of the feldspar being altered to clay or replaced by calcite (Kirkland, 1990, 1991). Locally the sandstone is underlain by a fossiliferous shale with minor sandstone beds. The capping sandstone has a maximum recorded thickness of nearly 3 m, and at Coal Chute on the northeastern side of the mesa a maximum of 9 m was recorded when the underlying fossiliferous shale was included. Brackish-water lagoons became established behind a system of barrier beaches that were emplaced by longshore drift.

The base of the Mancos Shale is late Cenomanian in age and rests disconformably on the the Dakota Formation. It is diachronous across Black Mesa, ranging from the *Metoicoceras mosbyense* Zone along the eastern side to the *Sciponoceras gracile* Zone along the southwestern side. Furthermore, marker beds BM1 through BM5 progressively truncate the underlying disconformity toward the southwest (Fig. 2). The amount of time represented by the disconformity at the base of the Mancos Shale can only be roughly estimated. The *Metoicoceras mosbyense* Zone has been recognized in the upper sandstone member of the Dakota Formation across Black Mesa. In southwestern Black Mesa the *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone rests on, or is in part incorporated into, the transgressive lag at the top of the Dakota Formation. The older *Vascoceras diartianum* subzone of the *Sciponoceras gracile* Zone has not been recognized in this area but is well defined on the northern and eastern sides of Black Mesa. Thus, at least in the area of southwestern Black Mesa, there appears to be an appreciable disconformity.

At Black Mesa, brackish and marginal marine deposits of the upper sandstone member are well preserved only on the southwestern side of gentle northwest-southeast-trending anticlines (Fursich and Kirkland, 1986; Eaton and others, 1987; Kirkland, 1990). Elsewhere, the Mancos Shale may rest on a variably developed shell-rich transgressive lag or, less commonly, directly on carbonaceous sediments of the middle carbonaceous member of the Dakota Formation with no readily apparent break (Kirkland, 1983, 1990; Fursich and Kirkland, 1986).

With southwestward movement of the coastline across the area of Black Mesa during the late Cenomanian *Metoicoceras mosbyensis* Zone, a series of northwest-trending barrier coastlines was progressively established parallel to the northwest-southeast-trending, deep-seated Precambrian structures (Kirkland, 1983, 1990; Fursich and Kirkland, 1986). With rising sea-level, sediments became trapped in the flooded river valleys with little sand reaching the coast through the paludal environments recorded by the middle carbonaceous member of the Dakota Formation. The feldspathic nature of the upper sandstone member suggests a

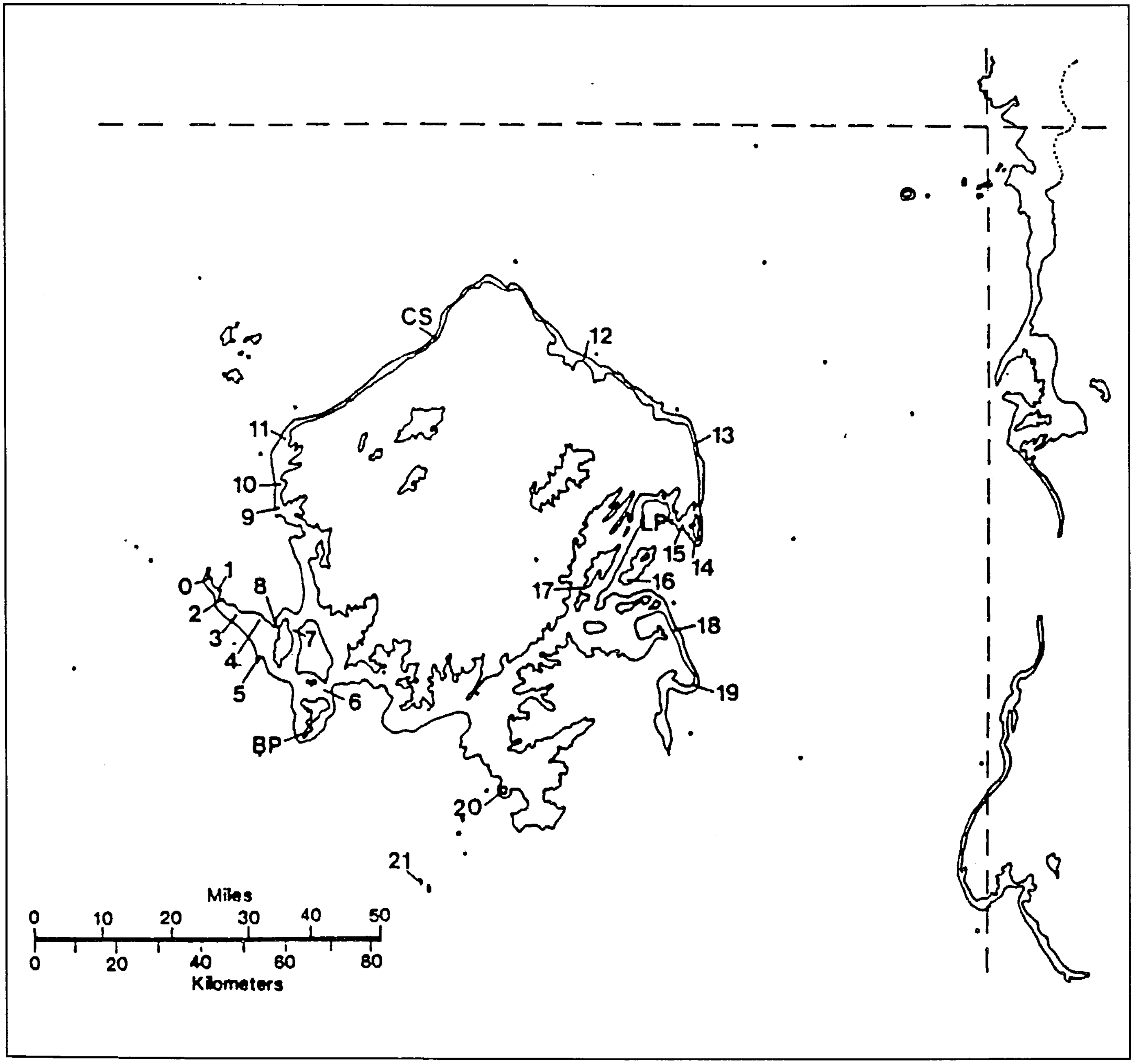

FIGURE 1. Distribution of outcrops examined during this study. Principal sections measured of the complete marine sequence of the Greenhorn cyclothem are Blue Point = BP; Lohali Point = LP; Coal Chute = CS (Kirkland, 1990, 1991). Partial measured sections for this study are 1, 6, 8, 9, 12, 13, 15, 18, 19, 20 (Kirkland, 1990). Other sites examined but not including measured sections are O, 2, 3, 4, 5, 7, 10, 11, 14, 16, 21. Museum of Northern Arizona locality numbers for collections from these sites and their latitude and longitude are given in Table 1.

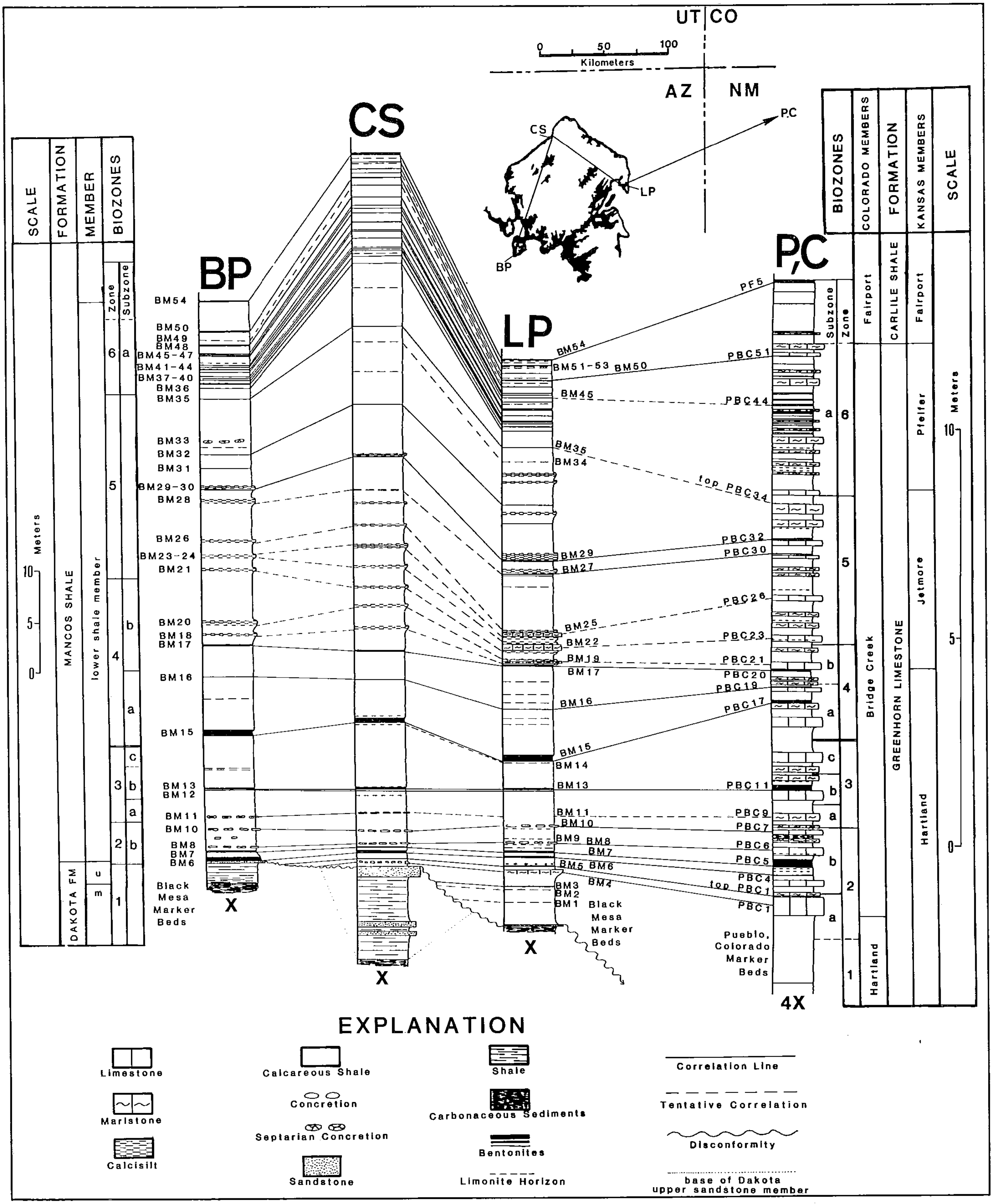

FIGURE 2. High resolution stratigraphic correlation of the lower sandstone member of the Dakota Formation through lower shale member of the Mancos Shale at Black Mesa, with correlations to the Pueblo, Colorado, section (PC). BP = Blue Point section. CS = Coal Chute section. LP = Lohali Point section. For key to biozone symbols see Table 3. Black Mesa marker bed numbers from this chapter; Pueblo, Colorado, marker bed numbers from Pratt and others (1985); for equivalent marker-bed designations see Table 2. From Kirkland (1991).

southwestern source in the Mogollon highlands. As the sandstones of the lower and middle members of the Dakota are lacking in appreciable feldspar, the sandstones of the upper sandstone member were largely accumulated by longshore drift from the south.

The sandstones at the top of the Dakota Formation at Black Mesa are inferred to represent relict bar sands. These sandstones are best preserved along the crests and somewhat landward (southwest) of the northwest-trending structural highs following the expected decrease in carrying capacity of currents crossing subtle topographic highs (Swift, 1985). Progressive deepening of the water column through the course of this reworking is suggested by the progressive replacement of *Rhynchostreon* by *Pycnodonte* as the dominant taxon up section through the upper sandstone.

The shales at the base of the upper sandstone member contain a diverse brackish water fauna discussed in detail by Fursich and Kirkland (1986) and Kirkland (1990). The sandstone at the top of the upper sandstone member is generally dominated by epifaunal suspension feeders, particularly by the oysters *Pycnodonte* and *Rhynchostreon levis*, with *Plicatula* and *Camptonectes*. Shallow (*Idonearca*, *Granocardium*, *Pinna*) and deep (*Aphrodina*, *Cyclorisma*) infaunal suspension feeders are locally common. Faunal distribution may be primarily controlled by taphonomic bias rather than ecology because of the preferential dissolution of aragonitic shells.

LOWER SHALE MEMBER OF THE MANCOS SHALE

The lower shale member of the Mancos Shale at Black Mesa extends from the base of the formation to the top of a thick bentonite (BM54) above a several-meter-thick interval of alternating bentonite and calcareous shale (Fig. 1). The member is thickest in the northwest, at Coal Chute, where it is measured as 66.88 m thick. It is 54.13 m thick at Blue Point and 54.64 m thick at Lohali Point (Kirkland, 1990, 1991). Fifty-four marker beds (BM1-BM54) that can be correlated as chronostratigraphic horizons over local to regional areas on the basis of their relative position to each other and to nine biostratigraphic zonal boundaries provide a basis for refined analysis of the sequence.

The numerous marker beds and zonal boundaries can be used to demonstrate a close correlation of the lower shale member to the Bridge Creek Limestone Member of the Greenhorn Limestone in central Colorado. However, this correlation includes the upper few of meters of the Hartland Shale Member of the Greenhorn Limestone and a few meters of the Fairport Member of the Carlile Shale (Fig. 2).

Lithologically, the lower shale member is dominated by olive-gray (5Y4/1), highly calcareous shale. At the base of the section the shale is silty, with silt content decreasing and carbonate content increasing rapidly from the base of the section. Overall, these shales are moderately to well bioturbated. The presence of calcareous silt and very fine sand, composed mostly of foraminiferan and inoceramid prisms, gives the shale a gritty texture. Marker beds are an important feature of this member and provide a convenient basis for further subdivision into a lower, middle, and upper part.

The lower part of the lower shale member extends upward to the top of BM17 and consists of calcareous shale with prominent bentonites and laterally persistent concretion horizons toward the base. Shell beds occur at several horizons, at and between biozone boundaries. At Lohali Point a disconformity at the Cenomanian-Turonian boundary is unusual because of the presence of a single discontinuous fine-grained sandstone bed 1 m across and 9 cm thick, which may represent a starved gutter cast. Most of this interval has been discussed in some detail by Elder (1987a, b, 1991).

The distribution of faunas within the lower part of the member is quite complex. Sageman (1985; Kirkland 1990) found the interval up to BM4 to have a low diversity fauna (3 to 5 taxa). It is dominated by epifaunal suspension feeders, notably *Pycnodonte* aff. *P. kellumi* near the base, with *Plicatula* present throughout the interval. Deposition of the basal Mancos Shale ensued when, with rising sea-level, water depth exceeded storm wave-base. During the *Metoicoceras mosbyensis* Zone, silty shale, notably lacking in sandstone and containing few macrofossils, was deposited along the north and east sides of Black Mesa while shallow marine sandstones containing a moderately diverse fauna continued to be reworked by storm processes in the southwestern part of Black Mesa. Sageman (1985), building on research by Pratt (1984) and Kauffman (1984a), has proposed that widespread dysaerobic to anoxic conditions at the sediment-water interface existed at this time across much of the seaway, in part, as a result of restriction of circulation of normal marine waters into the seaway by the deposition of shelf sands well out into the seaway (Twowells Sandstone Tongue of the Dakota Formation in New Mexico) leading to increased salinity stratification. The depauperate fauna of the basal Mancos Shale in the area of northeastern Black Mesa, assuming the postulated stratification of the water column, would reflect appreciable water depths below which little significant mixing of the water column occurred, thus indicating depths below storm wave-base. This view is further supported by the presence of bentonite marker beds near the base of the section and by a lack of discrete storm-deposited sandstones.

Faunal diversity increases markedly just below BM4 with development of the *Sciponoceras gracile* fauna. This fauna is the most diverse fauna recovered from the Mancos Shale at Black Mesa (more than 50 taxa) and perhaps the most diverse in the Western Interior (Koch, 1977; Elder, 1987a, b, 1989). The fauna is dominated by an almost equal number of infaunal and epifaunal suspension feeders, with lesser numbers of deposit feeders, benthic carnivores, and ammonites. Faunal diversity and abundance decrease throughout the *Neocardioceras juddii* Zone (to less than 10 taxa). Inoceramids first become abundant at the base of this zone; however, above this level, deposit feeders (mainly *Drepanochilus ruidium*) dominate, and suspension feeders become progressively less abundant. Strata at the Cenomanian-Turonian stage boundary are marked by a depauperate fauna, a short-term peak in organic carbon levels, and a marked increase in percent carbonate (Elder, 1987a). Shell beds up to the stage boundary are often dominated by sessile epifauna, with either *Pycnodonte* or *Serpula* forming laterally continuous biostromal accumulations. A short distance below BM15, faunal abundance increases with a dramatic increase in the abundance of the inoceramid *Mytiloides*. From this point upward through the lower shale member the fauna is dominated by epifaunal suspension feeders.

Sea-level rise and rapid transgression at the base of the *Sciponoceras gracile* Zone led to a warming and normalization of seawater as well as to the deposition of calcareous shale across the entire Black Mesa Basin (Kauffman, 1984a, b; Elder, 1987a, b) and marked the beginning of deposition of climatically forced limestone-shale cycles in the central part of the seaway (Barron and others, 1985; Elder and Kirkland, 1985). Concretions and shell-rich horizons through this zone reflect this cyclicity at Black Mesa, correlate to bioturbated limestones in the basal Bridge Creek Limestone Member of the Greenhorn Limestone, and represent periods of further normalization of marine conditions (Elder, 1987a, b, 1991). The presence of bryozoans and echinoids at Black Mesa, generally restricted from the seaway, supports normalized salinities and oxygen levels at these times rather than the somewhat depressed salinities normally reported for the seaway (e.g., Kauffman, 1969). Elder (1987b) provided evidence that concretion horizons and the shell beds present at most biozone boundaries record short-term sediment bypass events.

A second transgressive pulse is recorded by a slight disconformity (indicated by shell beds, siltstone, and calcarenite) at the base of the *Neocardioceras juddii* Zone. Once again water temperature increased and additional warm water taxa entered the seaway (e.g., vascoceratids); however, many of the species (particularly ammonites) characteristic of the *Sciponoceras gracile* Zone had become extinct, marking one of the major steps in the Cenomanian-Turonian extinction event (Kauffman, 1984a; Elder, 1987a, b, 1989, 1991). Furthermore, highly stenotopic taxa were once again excluded from the faunas. Faunal diversity continued to decrease throughout the *Neocardioceras juddii* Zone, with a striking increase in the abundance of the detrital-feeding gastropod *Drepanochilus*. This last taxon decreases in abundance before the top of the zone, reflecting further declining of environmental conditions through to the end of the Cenomanian as discussed by Elder (1987a). The presence of free-living epifaunal oysters throughout the upper Cenomanian indicates low sedimentation rates.

A third transgressive pulse is indicated near the beginning of the Turonian by sediment condensation in the offshore sections and a sharp increase in carbonate content. Faunal abundance also increases, indicating a marked improvement of environmental conditions (see also Leckie and others, 1991).

The middle part of the lower shale member extends from the top of BM17 to the base of BM36. It is characterized by alternating calcisilt and bioturbated calcareous shale, with minor bentonites toward the top. The base of this interval is highly condensed in the area of northeastern Black Mesa where resistant, bioturbated marlstones replace the calcareous shale. The presence of the Greenhorn Limestone Member in the area of northeastern Black Mesa reported by Peterson and Kirk (1977) probably refers to this interval.

Faunas in the middle part of the lower shale are mostly epifaunal suspension feeders dominated by common to abundant inoceramids of the genus *Mytiloides* and to a lesser degree the small encrusting oyster *Pseudoperna bentonense*. Another common epifaunal suspension feeder is *Phelopteria*. Various types of ammonites are common elements and may locally be abundant. In addition to encrusting inoceramids, the oysters often form multigenerational biostromes at the top of calcarenites associated with the calcisilt marker beds, indicating extensive exposure of these coarse substrates on the seafloor. Diversity through this interval ranges from 10 to 15 taxa, generally being somewhat less diverse to the northeast and consistently includes some infaunal suspension feeders (*Corbula*, *Cyclorisma*), the deposit feeder *Drepanochilus*, and the deep infaunal generalist *Lucina*. Carnivorous gastropods commonly make up a small percentage of the fauna in the southwest at Blue Point.

The alternation of bioturbated shale and calcisilt in the middle part of the lower shale member reflects the maximum influence of pelagic sedimentation found at Black Mesa. Marker bed correlations between Black Mesa and the central seaway suggest that the bioturbated shales correlate to bioturbated limestones, and the calcisilts correlate to calcareous shales. This suggests modification of previous models for correlation of these deposits (e.g., Kauffman, 1988). Limestone-shale couplets developed in the central Western Interior fit well the Gilbert-Fischer climatic-forcing hypothesis (Gilbert, 1895; Hattin, 1986a, b). Pratt (1984) reported that during dry climatic intervals the water column was well mixed and the pelagic carbonates were extensively bioturbated; during wet climatic intervals extensive fresh water runoff led to a salinity-stratified water column with reduced oxygen levels near the bottom and increased preservation of organic matter. Sediment bypass recorded by the calcisilt beds perhaps represents the repeated effect of storm-induced geostrophic currents below storm wave-base during wet climatic intervals. This may be one mechanism by which clay is transported into deeper basinal areas (Kirkland, 1990).

The decrease in faunal diversity from the more shoreward section at Blue Point to the offshore section at Lohali Point continues into the deeper parts of the basin, where inoceramids and ammonites dominate the fauna (Kauffman, 1969; Elder and Kirkland, 1985). This change in diversity reflects increased mixing of the water column in shallower parts of the seaway and stratification in the deeper parts.

The upper part of the lower shale member is particularly distinctive, being made up of alternating bentonite and calcareous shale. This interval has been referred to as the bentonite swarm (Eaton and others, 1987) and is also present just above the Bridge Creek Member of the Mancos Shale in the northern San Juan Basin of northwestern New Mexico and about 100 m above the base of the Tropic Shale in the southern Kaiparowits Basin of south-central Utah. This interval records increased volcanic activity, which may be responsible for a decrease in faunal abundance and diversity.

A sparse fauna (3 to 15 taxa per sample) composed of almost equal numbers of inoceramids and ammonites characterizes the upper part. Inoceramid spat are abundant at a number of horizons. The occurrence of horizons covered by inoceramid spat may indicate short-term intervals when the substrate was suitable for colonization, followed by mass mortality as conditions deteriorated.

MIDDLE SHALE MEMBER OF THE MANCOS SHALE

The middle shale member of the Mancos Shale at Black Mesa extends from the top of BM54 to the begining of a 15-to-20-m-thick interval of interbedded fine sandstone and noncalcareous shale marking the base of the Hopi Sandy Member, as described below (Fig. 3). The middle shale member is thickest in the southwest at Blue Point, where it is 54.69 m thick. It gradually thins to the northeast and is 42.4 m thick at Lohali Point (Kirkland, 1990, 1991).

Seventeen marker beds (BM55–BM71) are recognized in the middle shale member. The entire member lies within the range of *Collignoniceras woollgari woollgari*, with the only biozone boundary defined by the last occurrence of *Mytiloides hercynicus*. Correlations based on the marker beds are considered to be fairly reliable between the sections in northern Black Mesa, but correlations with southwestern Black Mesa are considered to be highly tentative at present. No attempt has been made to correlate these marker beds with sections outside the Black Mesa area, although based on the stratigraphic position of this member, in large part it correlates to the Fairport Member of the Carlile Shale in the central Western Interior.

Lithologically, the middle shale member is dominated by well-laminated, silty, olive-gray (5Y 4/1) shale, which is moderately calcareous except for a 20-m-thick interval extending from just above the base of the member to BM65 in the southwest at Blue Point. Calcareous shale is last re-

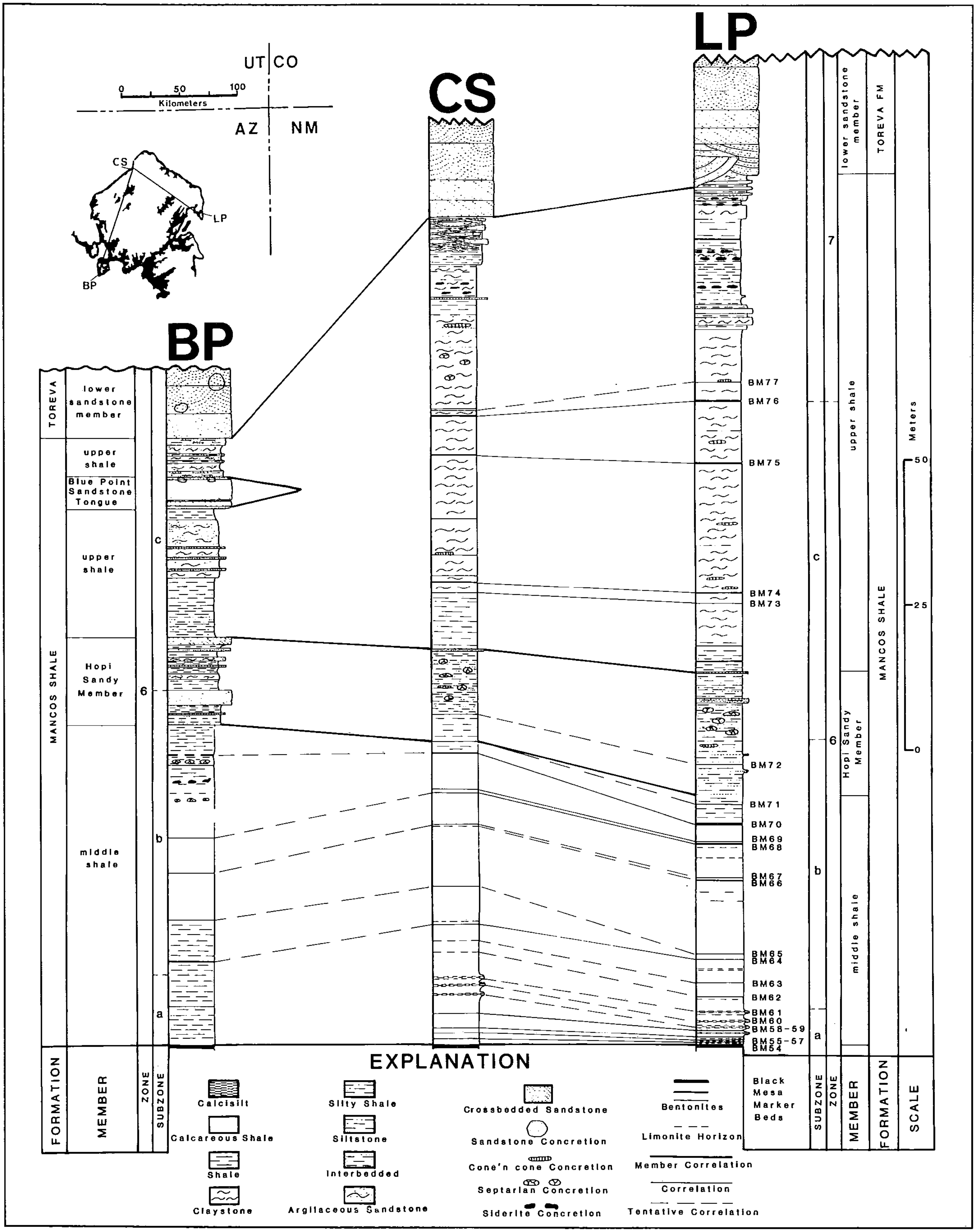

FIGURE 3. High resolution stratigraphic correlation of middle shale member of the Mancos Shale through lower sandstone member of the Toreva Formation at Black Mesa. BP = Blue Point section. CS = Coal Chute section. LP = Lohali Point section. For key to biozone symbols see Table 3. Black Mesa marker-bed designations from Table 2. From Kirkland (1991).

corded 2 to 10 m below the base of the Hopi Sandy Member. The rapid decrease in carbonate near the base of the member demonstrates a reduction in pelagic carbonate productivity associated with progradation of the shoreline from the southwest. The return to more calcareous shale in the middle of the member indicates a short-term reversal in this progradation. Progradation then continued through the rest of the interval (Kirkland, 1990).

These shales display graded bedding at a 0.5 to 2 cm scale, with the coarser, mainly silt-sized fraction consisting of fecal pellets, quartz, and fine plant debris. These sedimentary features are reminiscent of graded rhythmites as described by Reineck and Singh (1972). Uncommon thin (<1 cm) sandstones and starved gutter casts are commonly associated with ripple bedding and current-oriented fossils. These features are interpreted to represent distal storm deposits (Aigner, 1985). Thickness trends and the distribution of calcareous shale indicate that the sediment was sourced from the southwest.

Less common lithologies include intervals of bioturbated calcareous shale (particularly near the middle of the member in the southwest), bentonites, calcisilts, concretions, and dark noncalcareous shale. Thin bentonites are scattered through the member, being most common near the base in the northern sections. A few calcisilt horizons are found near the base of the member in the northern sections. Two horizons of septarian concretions, associated with bioturbated shale, are found near the top of the member in the southwest at Blue Point. These are separated by a few meters of finely laminated shale, which contains scattered siderite concretions and unaltered aragonitic fossils. The top of the member at Blue Point consists of approximately 6 m of dark, olive-gray (5Y3/1), noncalcareous shale with a few thin sandstone beds (< 1 cm) and small, largely uncrushed fossils. The shale forms a distinct dark band below the Hopi Sandy Member.

Faunas in this member are of fairly low diversity, with 10 to 15 taxa per sample at Blue Point decreasing to 5 to 8 to the northeast at Lohali Point. These faunas are dominated by epifaunal suspension feeders (mainly large *Inoceramus cuvieri* and encrusting oysters) with an abundance of the ammonite *Collignoniceras woollgari*. Infaunal suspension feeders (*Corbula, Cyclorisma, Turritella*), the deep infaunal generalists (*Lucina* and *Solemya*), and deposit feeders (*Nucula, Levicerithium*) are also present and generally increase in abundance and diversity up section through the member, with a parallel decrease in the abundance and diversity of epifaunal suspension feeders. However, infaunal taxa are much more common in the southwest as compared to the northeastern part of Black Mesa.

Although a significant infauna is present on the landward side of the basin at Blue Point, the preservation of finely laminated shale indicates that the sedimentation rate was high enough to limit the overall effect of bioturbation through much of the interval. An overall increase in sedimentation rate and decrease in substrate firmness are indicated by the replacement of epifaunal suspension feeders by infaunal suspension and deposit feeders. The great decrease in benthic abundance and diversity accompanied by a decrease in bioturbation in a seaward direction indicates continued unfavorable conditions in deeper parts of the basin. If these conditions involve reduced oxygen in the lower part of the water column, water depth increased significantly from the southwest to the northeast. This suggests the presence of a slope on which storm-induced turbidity currents may have deposited the graded rhythmites observed in this member.

HOPI SANDY MEMBER OF THE MANCOS SHALE

The Hopi Sandy Member was first referred to by Repenning and Page (1956) as a prominent sandstone zone midway up the Mancos Shale slope. Subsequently, Peterson and Kirk (1977) referred to it as the middle sandy unit. The widespread and easily recognized nature of this interval was the basis for raising this unit to a formal member of the Mancos Shale (Kirkland, 1991).

The Hopi Sandy Member ranges from 12 to 22 m in thickness across Black Mesa, generally thickening from the southwest to the northeast (Fig. 3). It is 15.1 m thick at Blue Point, 15.84 m thick at Coal Chute, and 21.11 m thick at Lohali Point (Kirkland, 1990, 1991). The base of the member is placed where thin, fine-grained sandstones become common (every 10 to 20 cm) just above the highest calcareous shale. The upper contact is placed where thin sandstones rapidly disappear, generally just above the most prominent sandstone in the member (Fig. 3).

Sandstones within this member are fine- to very fine-grained, subfeldspathic to feldspathic, yellowish-gray (5Y7/2) arenites. The grains are angular, with calcite replacing much of the feldspar. Fine grains of mica and plant debris are often abundant along bedding planes.

Sedimentary structures associated with the individual sandstone units have a distinct vertical sequence. The bases are sharp and typically scoured with prominent flute casts, tool marks, gutter casts, and washed-out burrows. Shell material is often concentrated above this surface. Internally, very low angle to planar bedding and/or small-scale hummocky cross-bedding is found toward the base and ripple stratification at the top of the sandstone beds. Overlying the sandstone beds, finely interbedded silty shale, shale, and very fine sandstone may be draped over the ripples. Burrows penetrate each unit from the upper surface to varying degrees.

The abundance and thickness of individual sandstones increase upward through the member. At the type section and at most other exposures in the southwest there are two overall coarsening upward sequences, which form a two-tiered bluff in the Mancos Shale slope. To the north and northeast, where the Mancos Shale slope is not broken by the Hopi Sandy Member, one overall coarsening-upward sequence can be distinguished. The abundance and thickness of sandstone units also increase to the southwest and are most strongly developed at Blue Point.

To the north and northeast, where no break in slope can be distinguished, the member is most readily recognized by the presence of thin sandstone slabs that litter the slope. Also characteristic in this area are large (as much as a meter across) septarian concretions and cone-in-cone horizons paralleling individual sandstone units.

The Hopi Sandy Member is interpreted to represent a shelf environment within the reach of storm wave-base. This is indicated by repeated scoured surfaces followed by a sequence of sedimentary structures reflecting decreasing energy. Proximity trends, as discussed by Aigner (1985), indicate the shoreline was to the southwest. In addition, the feldspathic nature of the sediments indicates a southern source area.

The widespread nature of the Hopi Sandy Member indicates a significant offshore component to sediment transport. This may be an artifact of a sea-level still-stand allowing for repeated winnowing and reworking of sand seaward into equilibrium with storm wave-base. An alternative explanation could be that much of the seaward transport of fine sand was by way of turbid sediment plumes being discharged from distributary channels along the coast during storms. The large amount of plant debris found in the member supports a sediment plume mechanism for transporting these sediments. This in turn was followed by reworking by storm-induced geostrophic currents.

As with the underlying member, faunal diversity decreases to the north and east in the Hopi Sandy Member, ranging from an average of 10 taxa at Blue Point to an average of 3 taxa per sample at Lohali Point. The ammonite *Collignoniceras woollgari* is the dominant fossil in this member. Inoceramids are also present, particularly in the southwest. Infaunal suspension feeders (*Corbula, Turritella*) and deposit feeders (*Nucula, Levicerithium, Tellina*) are the most common benthic groups in the southwest and are uncommon in the north and east.

Bioturbated sediments and a diverse infauna reflect a well-oxygenated seafloor in the southwest. However, the lack of significant bioturbation and a low-diversity fauna at Lohali Point indicate depleted oxygen levels in deeper water offshore and the presence of an appreciable slope to the seafloor.

UPPER SHALE MEMBER OF THE MANCOS SHALE

The upper shale member of the Mancos Shale at Black Mesa extends from the top of the highest sandstone of the Hopi Sandy Member to the first cliff-forming sandstone of the Toreva Formation (Fig. 2). This interval thickens considerably from the southwest, where it is 33.86 m thick at Blue Point (including the Blue Point Tongue of the Toreva Formation), to the northeast, where it is 85.13 m thick at Lohali Point. The member is 73.71 m thick at the intervening section at Coal Chute (Kirkland, 1990, 1991).

In the southwest, noncalcareous silty shale and siltstone dominate the member, and soft, bioturbated, argillaceous sandstone is an important component at Blue Point. Silt content is lowest a short distance above the top of the Hopi Sandy Member. Sand content is highest in the transition zone, with the Blue Point Tongue and in the interval between the Blue Point Tongue and the main body of the Toreva Formation.

Renewed subsidence at the end of deposition of the Hopi Sandy Member is reflected by a return to shale deposition. At Blue Point, renewed progradation of the shoreline is indicated by the influx of siltstone and fine sand shortly above the base of the member and their increasing dominance up section into the base of the Blue Point Tongue of the Toreva Formation. Well-oxygenated substrate conditions are indicated by the degree of bioturbation found in these sediments.

To the north and east, olive-black (5Y2/1), noncalcareous, virtually structureless claystone, stained by limonite and jarosite, dominates the member, indicating a dominance of longshore sediment transport rather than offshore transport. These claystones are remarkably similar to those found in the Blue Hill Shale Member of the Carlile Shale in the central part of the seaway (Hattin, 1962; Glenister and Kauffman, 1985), to which they correlate at least in part. Siltstone horizons are present for a few meters above the top of the Hopi Sandy Member but are rarely associated with the remarkably pure claystones that dominate the member up to the transition zone with the Toreva Formation. Rare scattered septarian concretions and calcareous lenses displaying cone-in-cone structure are typical of this lithology.

Twelve bentonites are scattered through the member in the north. However, no bentonites have been recognized in the silty shales in the southwest (Fig. 3). The virtual absence of fossils within this interval requires that petrographic or chemical fingerprinting techniques must be used to test these correlations.

The upper shale member is largely barren of invertebrate macrofauna. Immediately above the top of the Hopi Sandy Member a fauna similar to that found in the underlying member is encountered. At Blue Point, sparse infaunal suspension feeders and detritivores are encountered. To the north virtually no taxa are found in the dark claystones with the exception of the brachiopod *Lingula* and very rare large inoceramids and small ammonites, indicating that conditions on the seafloor were particularly hostile. *Lingula* is often found as the sole element of many faunas (West, 1976). However, a similarly depauperate fauna in the Blue Hill Shale at Pueblo, Colorado, has been interpreted to be a result of preservational bias of the macrofauna, as a moderately diverse fauna of arenaceous foraminiferans is present (Eicher, 1966; Glenister and Kauffman, 1985). A somewhat similar arenaceous foraminiferan fauna is likewise found in the dark claystones of the upper shale member (Hazenbush, 1972, 1973; Leckie and others, 1991). Thus, preservational bias cannot be discounted. The presence of abundant limonite and jarosite suggests that bottom conditions were, at the very least, unusual in the deeper parts of the basin. Poor circulation within the central seaway, due to progradation of the shoreline well out into the seaway at this time in central New Mexico (Cobban and Hook, 1984) and in central Wyoming (Merewether and Cobban, 1986), may have been sufficient to promote these unusual bottom conditions. Fossils are not commonly encountered again until the transition zone with the Toreva Formation.

BLUE POINT TONGUE OF THE TOREVA FORMATION

The prominent tongue of the Toreva Formation reported at Blue Point by Repenning and Page (1956) and referred to as the sandstone tongue of the Toreva Formation by Peterson and Kirk (1977) and Franczyk (1988) has been designated the Blue Point Tongue (Kirkland, 1991). At the type section, the Blue Point Tongue is a cliff-forming sandstone 5.42 m thick; locally, however, it thins and thickens from 2.5 m or less to more than 8 m laterally over distances of 100 m or less. The lower contact is gradational through 10 m of interbedded mudstone and soft argillaceous sandstone. Locally, the lower contact is characterized by ball- and pillow-structures up to 2 m thick. It is separated from the main body of the Toreva Formation by 6.7 m of nonresistant sandy shale and argillaceous sandstone, which thins to 2 m, 0.8 km to the south at the erosional edge of Blue Point and thickens to over 10 m with increasing shale content to the north. Within 5 km to the north at Beautiful Mountain, the Blue Point Tongue splits into several thin sandstones, and 25 km to the north at Howell Mesa there is no evidence at all of the Blue Point Tongue in the upper shale member of the Mancos Shale.

Overall, the Blue Point Tongue is yellowish-gray (5Y 7/2) in color, capped by a medium-to-dark-brown (5YR 6/4-4/4) fossil-rich interval. Lithologically, it is a fine- to medium-grained subfeldspathic to feldspathic arenite. Calcite has replaced much of the feldspar, which is dominated by untwinned orthoclase and plagioclase, with minor coarsely twinned microcline. Stratification consists of low- to medium-angle, tabular cross-bedding, with the top 30 to 40 cm consisting of planar to rippled beds 5 to 15 cm thick. Commonly the upper third contains oblate sandstone concretions 20 to 30 cm across and unusual, horizontally-directed spiral concretions.

The limited areal extent of the Blue Point Tongue as compared to the widely distributed Hopi Sandy Member indicates that the dominant agent of sediment transport was directed along shore rather than offshore. In a wave-dominated coastline, sediment is transported progressively along shore, with offshore bars and spits developing where deflections in the coast direct sediment offshore. The feldspathic nature of the sands indicates transport was from the south (Franczyk, 1988).

The Blue Point Tongue contains abundant, diverse, and often extremely well preserved fossils. At present more than 50 taxa have been recognized (Kirkland, 1990). Fossils occur in lenses toward the top of the main part of the unit and are distributed in laterally more continuous shell beds throughout the slabby caprock. Shallow infaunal (*Veniella, Pleuriocardia, Corbula, Turritella, Pinna*) and epifaunal (*Oxytoma, Syncyclonema*, oysters) suspension feeders dominate the fauna, but detritivores (*Anchura*) and carnivorous gastropods (naticids, volutids, fascularids) are also common. Deep infaunal suspension feeders are least abundant as body fossils.

The complete lack of ammonites and inoceramids within the cross-bedded sandstone of the Blue Point Tongue, along with the great abundance and diversity of neogastropod species, indicates that these sandstones were deposited on the landward side of a sand shoal of some sort. Norm Sohl (1981, personal communication) has observed that similar recent gastropod faunas are restricted to normal marine waters protected by sand shoals, whereas inoceramids and ammonites were ubiquitous in open marine environments during the Cretaceous (e.g., Kauffman, 1969). This, in addition to the great diversity of the fauna, indicates that although the site was in direct communication with the sea, it was protected by a sand bar or spit. Abundant ammonites in the slabby fossiliferous sandstones at the top of the Blue Point Tongue represent the destruction of this bar or spit and a return to a fully open marine setting with renewed subsidence and/or sea level rise.

NATURE OF THE MANCOS-TOREVA CONTACT

The main body of the Toreva Formation gradationally overlies the Mancos Shale. The contact is diachronous and intertonguing, ranging from the upper *Collignoniceras woollgari* Zone in the southwest to the overlying *Prionocyclus hyatti* Zone in the north and east (Kirkland, 1990, 1991).

The transition zone between the Mancos Shale and the Toreva Formation is usually 5 to 20 m thick. It grades from dark shale interbedded with siltstone, mudstone, and thin beds of very fine-grained sandstone to mudstone and soft, bioturbated, argillaceous sandstone interbedded with very fine sandstone, siltstone, and dark shale. Fine plant debris is commonly concentrated along bedding planes. The sandstones are subfeldspathic to feldspathic with sharp lower contacts, laminar to low-angle cross-bedded (rarely hummocky), and often rippled at the top. These sandstone beds are laterally fairly continuous at most sections but locally may be lenticular on a scale of a few meters toward the top of the transition zone. Franczyk (1988) reports ball-and-pillow structures as much as 5 m thick in the area of northeastern Black Mesa.

Fossils are fairly common locally in the transition zone of the uppermost Mancos Shale. Suspension feeders dominate, tiered at a variety of levels with nearly equal numbers of deep (*Cymbophora*), shallow (*Pleuriocardia*), and epifaunal suspension feeders (*Inoceramus, Lopha*). Shallow infaunal deposit feeders are represented by *Tellina*. The carnivorous gastropod *Gyroides* is also present at most localities where fossils are present.

The contact of the Mancos Shale with the Toreva Formation is placed at the base of the first cliff-forming sandstone of the lower sandstone member of the Toreva Formation (Repenning and Page, 1956; Franczyk, 1988). This member ranges from 15 to 25 m in thickness and is composed of fine- to medium-grained, yellowish-gray (5Y7/2) subfeldspathic to feldspathic arenites, with sheet-like geometries inclined overall to the north-northeast. The lower sandstone member displays planar and low-angle cross-bedding in the lower part, medium-scale trough cross-bedding in the middle, and planar bedding at the top.

Locally, as at the Lohali Point section, this characteristic sequence is underlain by a sequence of lenticular scour-based units filled by beds of medium-grained sandstone that are conformable to the scoured base. These units are from 1-to-3-m thick by 5-to-10-m across with convex bases and fairly flat tops, except where truncated by an overlying bed. Large-scale load structures are developed in some of these units. Up section the sandstone beds thin to less than 1 m and become laterally more continuous until they merge with a sequence typical of the lower sandstone member. The underlying transition zone at this section is unusual in being rich in leaves and branches and completely devoid of macroinvertebrate fossils.

Over most of Black Mesa the lower sandstone member is overlain conformably by carbonaceous sediments of the middle carbonaceous member of the Toreva Formation, but as reported by Franczyk (1988), medium- to coarse-grained, arkosic, lenticular sandstones of the middle carbonaceous member may locally cut out much of the lower sandstone member. One such coarse-grained unit appears (Franczyk, 1988) to have cut out the entire lower sandstone member a few kilometers north of the Lohali Point section.

In the area of northeastern Black Mesa, Franczyk (1988) has interpreted the transition of the Mancos Shale up into the lower sandstone member of the Toreva Formation as representing the progradation of a wave-dominated delta system across the area during the *Prionocyclus hyatti* Zone. Two distinct delta-front deposits represent the autocyclic construction and destruction of the delta front with switching of the distributary channel. Sediment deposited at the distributary mouths is reworked along the coast into the shoreface and into coastal sand bodies. Locally, on scales of tens of kilometers, distributary channels a few kilometers across cut down from the overlying middle carbonaceous member through the lower sandstone member. These distributary channels fed subsequent delta systems farther to the west, providing solid evidence of sea-level fall (Wiemer, 1983).

The transition from marine to terrestrial deposition recorded at the Lohali Point section supports these conclusions. The replacement of marine invertebrates by terrestrial plant material in the transition zone indicates the close proximity of a significant distributary channel. The lenticular sand bodies at the base of the Toreva are interpreted as representing the effect of flood discharge below fair-weather base, with a gradual transition into a typical shoreface sequence as fair-weather processes came to dominate the preserved record. An open marine, shallow water, macroinvertebrate fauna has been found in the transition zone, both to the north and to the south of the Lohali Point section.

The lower sandstone member at both the Blue Point and Coal Chute sections represents the north-northwestward progradation of a wave-dominated shoreline. The position and nature of the deltas supplying sediment to these shorelines are unknown but are assumed to have been similar to those described by Franczyk (1988). The bar or spit represented by the Blue Point Tongue is likewise assumed to have been sourced in a similar manner.

Fossils are rare within the lower sandstone member of the Toreva Formation. In large part, this is because of early dissolution of the shell material by acidic fresh groundwater draining into the sand from overlying coastal swamps prior to lithification of the sandstone. However, the local depositional setting may also play a part. Fossils have been found in abundance at Blue Point as internal-external molds within large sandstone concretions. This fauna is similar to that of the underlying transition zone with the Mancos Shale but is of greater diversity (20 to 30 taxa), has a greater relative abundance of infaunal taxa, and includes common examples of the gastropod *Pyktes* (= *Pugnellus*) as a common element, indicating a shallow open marine environment. Finally, a lenticular (0.5 m by 20 m), monotypic shell bed of large (20 cm long) *Crassostrea soleniscus* was observed in the basal few meters of the Toreva on the southern end of Black Mountain southwest of Lohali Point, represents a brackish-water setting and perhaps represents the deposits near the mouth of a small estuary.

SYSTEMATICS

Introduction

The following systematics section follows a standard format suggested by Erle Kauffman (1986, personal communication). Identifications were made by reference to published taxonomic studies and by discussions with acknowledged experts on the specific taxonomic groups under consideration; particularly Dr. Erle G. Kauffman and Dr. William P. Elder with regard to the bivalves, Dr. William A. Cobban with regard to the ammonites, and Dr. Norman F. Sohl with regard to the gastropods.

For each taxon, only synonymies for major references studied by the author are given. Thus, no attempt to provide complete synonymies was made, although references providing complete synonymies are noted. The distribution and relative abundance of each species at specific sample levels is given in Kirkland (1990).

Paleoecologic data are provided for each taxonomic group, with specific inferences for individual species provided where warranted. A preliminary discussion of the paleoecologic units defined at Black Mesa by these taxa is provided in Kirkland (1990).

Locality information is summarized in Figure 1 and Table 1.

Repositories

MNA: Museum of Northern Arizona, Flagstaff, Arizona.

UMMP: University of Michigan Paleontological Museum, Ann Arbor, Michigan

USNM: Smithsonian Institution Museum of Natural History, Washington, D.C.

KINGDOM MONERA
DIVISION CYANOPHYTA

Plate 1, Figure D

Discussion — The only evidence of bluegreen algae at Black Mesa is the presence of endolithic algae in some oysters from shale facies, upper sandstone member of the Dakota Formation. The borings consist of dense fine tubules much less than a mm across and generally less than one cm long. Borings of this type are characteristic of the lower intertidal zone where light is intense and grazing pressure is high (Ekdale and others, 1984).

These are the only remains directly indicating the presence of benthic algae at Black Mesa. A systematic examination of shell material for endolithic algae throughout the section might provide a means of tracking the extent of the photic zone.

Illustrated material — MNA N3766 from MNA loc. #265, shale facies, upper sandstone member, Dakota Formation.

KINGDOM PROTISTA
DIVISION PYRROPHYTA
CLASS DINOPHYCEAE

Discussion — The dinoflagellates and acritarchs from Black Mesa have been reported on by Jones (1976), who recognized 46 species of dinoflagellate cysts and 24 species of acritarchs. Further discussion of distribution of these taxa is found in Kirkland (1990).

DIVISION COCCOLITHOPHORIDA

Discussion — The distribution of coccoliths across the Cenomanian-Turonian boundary at Blue Point has been discussed briefly by Bralower (1988). Primarily he used his data to construct a revised biozonation of this interval based on coccoliths and to dispute marker bed and invertebrate biozone correlations presented by Elder (1985, 1987) and Kirkland (1990, 1991). The distribution of coccoliths throughout the section is under study by C. Fisher at the University of Colorado. Coccoliths are an important part of the biota at Black Mesa, both as being an important part of the base of the food chain and as the primary source of carbonate in the sediment.

Coccoliths are abundant in all the fine calcareous sediments at Black Mesa. Examination of a few samples of the calcisilts from Black Mesa by SEM has revealed that coccoliths are also very diverse (Kirkland, 1990). Preservation appears to be enhanced when protected by the organic sheath of copepod fecal pellets.

PHYLUM SARCODINA
CLASS RADIOLARIA

Discussion — The radiolarian *Dictyomitra* has been recognized at Black Mesa by Olesen (1986), who reports it to be rare and limited to the basal 2 m of the Mancos Shale at Blue Point.

CLASS FORAMINIFERA

Discussion — The distribution and significance of Foraminifera at Black Mesa has been reported on by Hazenbush (1972, 1973), Olesen (1986, 1991), and Leckie and others (1991). Foraminifera are commonly used for paleoenvironmental interpretations based on the types and ratios of planktonic, calcareous benthic, and arenaceous benthic taxa (e.g., Eicher and Worstell, 1970; Frush and Eicher, 1975; Eicher and Diner, 1985).

KINGDOM PLANTA
Terrestrial Plant Material

Discussion — Identifiable terrestrial plant material has been reported from the middle carbonaceous member of the Dakota Formation and from the middle carbonaceous member of the Toreva Formation by Repenning and Page (1956). Pollen has been described from these units by Agassie (1967) and Romans (1975). In addition, intact material has been identified locally from the top of the shale facies of the upper sandstone member of the Dakota Formation along the north side of Coal Mine Mesa and in the upper 10 m of the Mancos Shale at the Lohali Point section.

Fossil logs have been found scattered throughout the study interval and served as a substrate for wood boring bivalves.

Fragmentary plant debris was found in each interval sampled during the course of this study. Fine disseminated plant debris is common to abundant in the middle shale and Hopi Sandy Members. The significance of this material is that it indicates the proximity to shoreline and provided a potential food resource for deposit-feeding organisms and suggests a dominance of terrestrial over marine organic carbon in the system. However, no analysis has been made of the organic carbon at Black Mesa.

KINGDOM ANIMALIA
PHYLUM PORIFERA
CLASS DEMOSPONGIA
Genus *Cliona* Grant, 1826
Cliona spp.
Plate 1, Figure A; Plate 5, Figure H

Description — Externally, borings expressed as cross-cutting rows of holes, primarily on shells of various species of oysters. These shells are uncommonly bored to such an extent that only remnants of shell exposing the internal galleries are preserved. The diameter of the irregular branching galleries range from 0.2–1.4 mm to 2–4 mm in individual specimens.

Discussion — Borings of the sponge *Cliona* are referred to the ichnogenus *Entobia*, but as the taxonomy of the trace fossils encountered in the Greenhorn cyclothem are beyond the scope of the present study, only a few trace fossils are discussed under the heading of the taxa most likely to have produced them.

Size differences in the external perforations and the internal galleries produced by clionid sponges at different levels at Black Mesa suggest that a number of species are present. However, different species of *Cliona* can only be distinguished by differences in their spicules.

Occurrence — Clionid sponges producing delicate, small diameter galleries (average 0.2–1.4 mm in diameter) are restricted to the shale facies of the upper sandstone member of the Dakota Formation, middle Cenomanian *Metoicoceras mosbyensis* Zone. Clionid sponges producing robust, large diameter galleries (average of 2–4 mm in diameter) are found in the sandstone facies of the upper sandstone member of the Dakota Formation and in *Pycnodonte* biostromes in the lower part of the lower shale member, Mancos Shale, upper Cenomanian *Metoicoceras mosbyensis* Zone through *Neocardioceras juddii* Zone and these are much less commonly recognized in the Blue Point Tongue and lower sandstone member of the Toreva Formation, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone and *Prionocyclus hyatti* Zone.

Illustrated material — MNA N3765 from MNA loc. #265, shale facies, upper sandstone member, Dakota Formation; MNA N5068 from MNA loc. #296, sandstone facies, upper sandstone member, Dakota Formation.

Paleoecology — Clionid sponges bore in both living and dead shells, as well as in other carbonate substrates. Boring may continue until the shell has been completely destroyed by the sponge; clionid sponges are an important source of bioerosion. The degree of boring is related to the time the substrate is exposed at the sediment-water interface and to the density of settling of the sponges.

Clionids range from brackish to open marine in their distribution. Lawrence (1969) found that the borings produced by clionids in brackish water have fine perforations and thin internal galleries (0.2–1.4 mm in diameter) and in open marine waters have large perforations and robust galleries (averaging (2–4 mm in diameter). A similar distribution is recognized at Black Mesa, indicating the potential utility of clionid borings in recognizing variations in salinity within marginal marine settings in the Western Interior.

PHYLUM COELENTERATA
CLASS ANTHROZOA
ORDER SCLERATINIA

Discussion — Identifications of the corals from Black Mesa were provided by J. W. Wells (1980, personal communication) of Cornell University.

Family Caryophyliidae
Genus *Trochocyathus* Milne Edward and Haime, 1848
Subgenus *Platycyathus* de Fromentel, 1863
Trochocyathus (*Platycyathus*) sp.
Plate 19, Figure E

Diagnosis — Solitary, small (average up to 1 cm across), thin and discoidal; nonepithicate; pali in distinct crowns; columella spongy; simple laminar septa (estimate) in four cycles with smooth upper margins and laterally finely granulated; free living.

Discussion — This is one of the few taxa found both above and below the Cenomanian-Turonian stage boundary and is the only coral at Black Mesa present in the Turonian.

Occurrence — Scattered in the lower shale member of the Mancos Shale from the upper Cenomanian *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone through the lower Turonian *Watinoceras coloradoense* Zone at all Black Mesa sections (Kirkland, 1990) and in southern Utah.

Illustrated material — MNA N1069 from MNA loc. #262, lag at base of *Neocardioceras juddii* Zone, unit 21.

Paleoecology — Free-living, ahermatypic coral; recent forms are found in depths from 350–550 meters (Vaughan and Wells, 1943).

Genus *Parasimilia* Milne Edwards and Haime, 1848
Parasimilia spp.
Plate 15, Figures A–C

Diagnosis — Solitary, fairly small (up to 2.6 cm high), stout trochiform, wall septothecal, deep endotheca; columnella spongy; simple laminar septa in four cycles; fixed by small base.

Discussion — Whereas living species of this genus are restricted to deep water, the presence of specimens at the top of the Dakota Formation in the *Sciponoceras gracile* Zone at Blue Point indicates that during the Cretaceous species of the genus dwelt in water at least as shallow as storm wave-base.

Occurrence — Widespread but rare, throughout the *Sciponoceras gracile* Zone, most common in the southwestern part of Black Mesa (Kirkland, 1990).

Illustrated material — MNA N942 from MNA loc. #271, BM10; MNA N5358, MNA N5359 from MNA loc. #262, BM8.

Paleoecology — Epifaunal, a hermatypic coral in which living species are distributed in water depths from 310 to 370 m (Vaughn and Wells, 1943).

Family Guyniidae

Genus *Stylotrochus* de Fromentel, 1861

Stylotrochus sp.

Plate 15, Figure D

Diagnosis — Solitary, very small (up to 0.6 cm high), high thin trochiform; wall with low costae, no mural pores; columella styliform; septa of three cycles; no pali; free living.

Discussion — This genus is known from one species from the Turonian of France. Vaughn and Wells (1943) placed it provisionally in the Guyniidae on the basis of overall form although lacking mural pores.

Occurrence — Known from a few specimens from BM8, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone on the western end of Coal Mine Mesa, southwestern Black Mesa, MNA loc. #813.

Illustrated material — MNA N1222 from MNA loc. #813, BM8.

Paleoecology — Members of this family are deep water ahermatypic forms. This genus appears to be a free-living epifaunal form as an adult.

Family Oculinidae

Genus *Archohelia* Vaughn, 1919

Archohelia dartoni Wells

Plate 19, Figure A–D, F

Archohelia dartoni Wells, 1933; p. 141, pl. 12, figs, 11, 12; pl. 14, figs. 31–35.
Archohelia dartoni Wells; Coates and Kauffman, 1973, p. 966, pl. 1, figs. 1–6.
Archohelia dartoni Wells; Cobban, Hook, and Kennedy, 1989, p. 15, fig. 14.

Description — Colonial coral, encrusting to dendritic; branches oval in cross-section, greatest width often over 1 cm; coralites small (average of 0.2–0.3 cm across); corallites bud from axial corallite and form a spiral pattern on branch; corallites with three cycles of septa and well developed papillose columnella; corallites raised with radial costae extending away from rim; beyond costae-bounding coralites, the extensive peritheca is smooth.

Discussion — Coates and Kauffman (1973) have described the nature of the type locality from the middle Turonian of northwestern New Mexico in considerable detail. This was the first report of a coral thicket in the Western Interior. A repeated succession of coral thickets is preserved in a resistant carbonate unit.

Another coral thicket has been reported from the late Cenomanian in the Big Burro Mountains of southwestern New Mexico by Cobban and others (1989). These thickets are preserved in sandy limestone concretions.

The specimens of *Archohelia dartoni* from Black Mesa are found weathered out of calcareous shales and have not been observed in situ. The local abundance of the material suggests that thickets were developed. The substrate on which these thickets developed is well documented as being a *Pycnodonte newberryi* biostrome. A number of specimens were observed encrusting *Pycnodonte newberryi* as well as on a quartzite pebble (Plate 19, Figure A) and the broken surface of a plesiosaur vertebra (Plate 19, Figure B).

Occurrence — The types came from the middle Turonian Blue Hill Shale Member of the Carlile Shale, *Prionocyclus hyatti* Zone near Lamy, New Mexico. At Black Mesa common at Blue Point (MNA loc. #262) at the base of the upper Cenomanian *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone between BM10 and BM11 and is not known from any other locality at Black Mesa. Also reported from the upper Cenomanian *Sciponoceras gracile* Zone in southwestern New Mexico.

Illustrated material — MNA N1072, N1084, N1091, N5364, N5365, from MNA loc. #262 in lag at base of *Neocardioceras juddii* Zone, unit 21.

Paleoecology — Colonial ahermatypic coral which colonizes firm substrates in cool, well oxygenated, deep water (Coates and Kauffman, 1973). The association of warm water taxa (vascoceratid ammonites) immediately above the occurrence at Black Mesa suggests relatively warm water at this site, and other data suggest that the site was within the reach of storm wave base.

PHYLUM BRYOZOA

Discussion — Identifications of bryozoans recovered from Black Mesa were provided by A. Cheetham (1980, personal communication) who also provided paleoecologic data.

Paleoecology — All bryozoans recovered in this study represent encrusting forms, which lived as sessile, colonial filter feeders.

CLASS GYMNOLAEMATA

ORDER CHEILOSTOMATA

Family Membraniporidae

Genus *Membranipora* Blainville, 1830

cf. *Membranipora* sp.

Plate 1, Figure B; Plate 2, Figure A

Diagnosis — Encrusting form, with subrectangular, close-packed apertures with thin mural wall; forms thin sheets encrusting shells.

Discussion — As the simple anascans are difficult to identify, the specimens described here are only provisionally referred to *Membranipora*. It is also possible these specimens represent *Conopeum*.

Occurrence — Modern species are worldwide in distribution, and whereas the Family Membraniporidae has its origins in the Cretaceous, the genus *Membranipora* has not been positively identified from the Cretaceous. At Black Mesa this form is commonly found encrusting *Flemingostrea prudentia* in the shelly shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #264, #265, #308, #540).

Illustrated material — MNA 4493 from MNA loc. #540, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — Modern species of this general morphology are among the few bryozoans characteristic of brackish water environments (A. Cheetham, 1980, personal communication).

Family Calloporidae

Genus *Rhamphonotus* Norman, 1894

cf. *Ramphonotus* sp.

Plate 15, Figures, E, I

Diagnosis — Encrusting bryozoan, with moderately-closely packed zooecia forming radial pattern from central point of growth; well developed mural walls with few spines.

Discussion — All specimens found are small (average 1 cm across colony) and isolated from site of encrustation. Due to the state of preservation, these forms may also represent a species of *Amphiblestrum* Gray, 1948.

Occurrence — Essentially worldwide, Cretaceous to Recent. At Black Mesa, rare in the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone, MNA loc. #303, BM8 (Kirkland, 1990).

Illustrated material — MNA N1199, N1200 from MNA loc. #303, BM8.

Paleoecology — Anascans of this type are characteristic of open marine conditions today.

Genus *Solenophragma*

***Solenophragma* sp.**

Plate 15, Figure H

Description — Thin round branch of erect portion of encrusting bryozoan; aperture of zooecia round and tightly packed together with thick mural rim without spines.

Discussion — Only one specimen of this bryozoan has been recovered at Black Mesa.

Occurrence — Cretaceous of the Gulf Coast, Wyoming?, and Germany. At Black Mesa one small specimen was recovered from an ant hill resting on the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone at Balakai Point (MNA 306) in the southeast.

Paleoecology — Extinct genus associated with typical marine faunas in the Gulf Coast region.

PHYLUM BRACHIOPODA

CLASS INARTICULATA

ORDER LINGULIDA

Family Lingulidae

Genus *Lingula* Bruguiere, 1797

***Lingula subspatula* Hall and Meek ?, 1855**

Plate 49, Figures A, B

Lingula subspatula Hall and Meek ?; Stephenson, 1952, p. 54, pl. 10, figs. 1–3.

Diagnosis — Phosphatic shell thin, elongate-spatulate; lateral margins subparallel, with ornament of fine growth lines. Long axis of shell averages 4 mm, largest observed shell 10 mm long.

Discussion — *Lingula subspatula* has been broadly applied to diverse lingulids from the Cretaceous of North America. Until a detailed study of the material from North America and overseas is made these identifications are regarded as tentative. The material described here compares well with that illustrated by Stephenson (1952).

Occurrence — The holotype is from the Pierre Shale near Red Cloud Island, South Dakota. Reported from the Cenomanian to Maestrichtian of the Western Interior and Gulf Coast. At Black Mesa, rare in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #264, #265, #308, #540) and widely scattered (locally common) in the upper shale member of the Mancos Shale, middle Turonian *Prionocyclus hyatti* Zone on the north and east sides of the mesa (Kirkland, 1990). Locally common at some horizons.

Illustrated material — MNA N5295 from MNA loc. #989, from seven meters above BM77; MNA N5335 from MNA loc. #989, from six meters above BM77.

Paleoecology — Lingulids live in burrows formed by their long fleshy pedicle in fine sediment. *Lingula* is commonly found as the sole taxon at many fossil sites and may be abundant in subsaline environments (West, 1976).

ORDER ACROTRETIDA

Family Discinidae

Genus *Discinisca* Dall, 1871

***Discinisca* sp.**

Plate 26, Figure A

Diagnosis — Small (3–5 mm) phosphatic, cap-shaped brachial valve with ornament of fine growth lines and fine ribs radiating from the apex of cap. Valves found isolated or randomly attached to inoceramid shells.

Occurrence — Widely scattered throughout the lower shale member of the Mancos Shale across Black Mesa (Kirkland, 1990).

Illustrated material — MNA N5297 from MNA loc. #813, from one meter below BM15.

Paleoecology — Disciniscids are filter feeders that live firmly attached to hard substrates by means of a short pedicle projecting from their flat pedicle valve.

PHYLUM MOLLUSCA

CLASS BIVALVIA

SUBCLASS PALAEOTAXODONTA

ORDER NUCULOIDA

Superfamily Nuculacea

Family Nuculidae

Genus *Nucula* Lamarck, 1799

Paleoecology — *Nucula* is a shallow infaunal deposit feeder, preferring soft fine-grained, subtidal, organic-rich substrates. Its large foot permits this robust genus to burrow moderately fast, but once below the sediment surface it remains semi-sessile or moves slowly and intermittently in search of food for significant time intervals (Kauffman, 1969b; Stanley, 1970).

***Nucula coloradoensis* Stanton, 1893**

Plate 36, Figures L–O

Nucula coloradoensis Stanton, 1893; p. 94, pl. XXI, fig. 9.
Nucula coloradoensis Stanton; Kauffman, 1961, Ph. D, p. 197, pl. 14, fig. 26.

Description — Shell small (up to 1.5 cm long), moderately biconvex, subtriangular, ventral margin broadly rounded, crenate; taxodont dentition typical for genus;

surface ornament of dense fine radiating costae and fine growth lines.

Discussion — The specimens from Black Mesa compare very closely with the holotype illustrated by Stanton (1893) and Kauffman (1961) and are considered to be conspecific.

Occurrence — Holotype from the middle Cenomanian, *Calycoceras tarrantense* Zone, in concretions equivalent to the Thatcher Limestone Member of the Graneros Shale, Huerfano County, Colorado. At Black Mesa, fairly common at Blue Point and rare at Lohali Point, in the middle Turonian, middle shale member, Hopi Sandy Member, and rarely, upper shale member, Mancos Shale.

Illustrated material — MNA N5195 from MNA loc. #262, one meter below base of Hopi Sandy Member, middle shale member; MNA N5197 from MNA loc. #262, 5 m below base of Hopi Sandy Member, middle shale member; MNA N5200 from MNA loc. #262, one meter above BM66, middle shale member; MNA N5202 from MNA loc. #989, 7 m above BM77, upper shale member; all from Mancos Shale.

Paleoecology — The distribution of this species at Black Mesa suggests that it was restricted to normal marine waters of normal salinity in soft substrates.

Nucula sp.

Plate 3, Figure C

Diagnosis — Small (1 cm long) *Nucula* with triangular, biconvex shell; beak slightly anterior of midline, known from rare internal molds.

Occurrence — Rare in the upper Cenomanian *Metoicoceras mosbyensis* Zone in the shale facies of the upper sandstone member of the Dakota Formation (MNA loc. #264).

Paleoecology — The distribution of this form indicates a preference for brackish water (Fursich and Kirkland, 1986).

Illustrated material — MNA N4504 from MNA loc. #264, shale facies, upper sandstone member, Dakota Formation.

Superfamily Nuculanacea
Family Nuculanidae
Genus *Nuculana* Link, 1807

Paleoecology — Ecology as in *Nucula*, but thinner, more elongate shell indicates that *Nuculana* burrows more rapidly (Stanley, 1970).

Nuculana mutuata Stephenson, 1952

Plate 3, Figures A, B

Nuculana? mutuata Stephenson, 1952; p. 57, pl. 10, figs. 10–12.
Nuculana mutuata Stephenson; Fursich and Kirkland, 1986, p. 549, fig. 5, i.

Description — Shell small (1 cm long), elongate-subovate, slightly inequilateral, equivalve, with beaks subcentral and dorsal margins diverging at broadly obtuse angle. Ventral margin broadly curved; with posterior margin narrowly rounded and anterior margin broadly rounded; dentition taxodont. Surface smooth with very fine, obscure growth lines.

Occurrence — The types are from the middle Cenomanian Lewisville Member of the Woodbine Formation of central Texas. At Black Mesa, restricted to the upper Cenomanian *Metoicoceras mosbyensis* Zone in the shale facies of the upper sandstone member of the Dakota Formation (MNA loc. #264, #265, #540, #963).

Illustrated material — MNA N4506, N4505, from loc. #540, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — The distribution of *Nuculana mutuata* in Texas and Arizona seems to indicate that this species is restricted to brackish water environments (Fursich and Kirkland, 1986).

Nuculana sp.

Plate 43, Figure A

Discussion — *Nuculana* known from internal molds and shell fragments. These specimens are similar in size and shape to *Nuculana mutuata*, but as the preservation is poor, no attempt has been made to assign them to species.

Occurrence — Common, restricted to the middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone in the Blue Point Tongue of the Toreva Formation at Blue Point (MNA loc. #1150).

Illustrated material — MNA N5061 from MNA loc. #1150, top of Blue Point Sandstone Tongue, Toreva Formation.

SUBCLASS CRYPTODONTA
ORDER SOLEMYOIDA
Superfamily Solemyacea
Family Solemyidae
Genus *Solemya* Lamarck, 1818

Paleoecology — *Solemya* is a suspension-feeding and perhaps a partially detrital-feeding bivalve, which lives in an open Y-shaped burrow formed in mud substrates in which it is highly mobile. It feeds by pumping water through its burrow and perhaps on bacteria growing in the lower closed portion of the burrow (Stanley, 1970). At least some living species are chemosymbiotic with sulphur oxidizing bacteria (Cavanaugh, 1983).

Solemya obscura Stanton, 1893

Plate 13, Figure B; Plate 36, Figures Q, R

Solemya? obscura Stanton, 1893; p. 95, pl. XXI, fig. 8.

Description — Shell small (to 1.5 cm long), thin and elongate, dorsal and ventral margins nearly parallel; beak small near posterior margin which angles downward from beak and is narrowly rounded; anterior margin broadly rounded; surface with faint growth lines and radiating costae, best developed on posterior flank.

Discussion — With the exception of one possible specimen from the upper Cenomanian, all specimens are from the middle Turonian and compare well with the species as described by Stanton (1893). The one specimen from the upper Cenomanian compares well in size and overall shape, but does not display the radial costae typical of this species, although this may simply reflect preservation. In ornament the specimen compares well with *Solemya* n. sp., which is common at this level, it differs enough in size and form to be provisionally grouped with *Solemya obscura*.

Occurrence — The type specimen was from the middle Turonian, *Prionocyclus hyatti* Zone in the Codell Sandstone Member of the Carlile Shale, in Huerfano Park southern Colorado. At Black Mesa in the middle Turonian *Collignoniceras woollgari* Zone from near the top of the lower shale member up section through the Hopi Sandy Member, being most common in the southwest at Blue Point. Also possibly represented by one specimen from a concretion from between BM8 and BM10 in the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone at Blue Point (Kirkland, 1990).

Illustrated material — MNA N5166 from MNA loc. #262, concretion between BM8 and BM10 (unit 17), lower part, lower shale member, Mancos Shale; MNA N5189, just above BM54; MNA N5191, above BM68; both from MNA loc. #262, middle shale member, Mancos Shale.

Solemya n. sp.

Plate 13, Figure A

Diagnosis — Shell similar to *Solemya obscura* but smaller (< 1 cm long), radial ornament apparently lacking; beak even less protruding and more posterior than in *Solemya obscura* with more evenly curved posterior margin.

Occurrence — At Black Mesa, common in the lower shale member of the Mancos Shale from the *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through the *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone across Black Mesa (Kirkland, 1990), as well as at this level in southern Utah and west-central New Mexico.

Illustrated material — MNA N5064 from MNA loc. #306, BM10, lower part, lower shale member, Mancos Shale.

SUBCLASS PTERIOMORPHIA

ORDER ARCOIDA

Superfamily Arcacea

Family Arcidae

Genus *Arca* Linne, 1758

Paleoecology — This epifaunal to crevice-dwelling, suspension-feeding bivalve nestles in shell beds, where it is attached mid-ventrally by byssal threads. The anterior sulcus funnels currents increasing feeding effciency (Kauffman, 1969b). This genus is apparently not as vagrant as are some closely related genera, such as *Barbatia*.

Arca n. sp.

Plate 6, Figure H

Description — Medium sized (3–4 cm), elongated, subtrapezoidal shell; hinge line long and straight with numerous transverse subequal teeth; interarea broad with duplivinicular ligament scars, beak recurved, protruding above interarea around 25% of length from anterior margin, posterior margin narrowly rounded from hinge and then regularly curved to ventral margin, anterior margin slightly concave extending at slightly acute angle from hinge where it is sharply curved into ventral margin which is slightly concave at mid-point, overall ventral margin is parallel to hinge. Sulcae extend from just anterior to beak to anterior margin and from umbo to mid-line of ventral margin separated by strong umbonal ridge. Surface ornamented by fine growth lines and costae separated by costellae.

Discussion — Well preserved specimens of this arcid are common in the Twowells Sandstone Tongue of the Dakota Formation in east-central Arizona from which this species should be described. Rare specimens recovered from the sandstone facies of the upper sandstone member of the Dakota Formation on the north side of Coal Mine Mesa appear to be conspecific.

Occurrence — At Black Mesa rare from the sandstone facies of the upper sandstone member of the Dakota Formation on the north side of Coal Mine Mesa, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #265). Also represented at this level by extremely well preserved specimens in the Twowells Sandstone Tongue of the Dakota Formation in east-central Arizona.

Illustrated material — MNA N1058, from MNA loc. #265, sandstone facies, upper sandstone member, Dakota Formation.

Genus *Barbatia* Gray, 1842

Paleoecology — *Barbatia* is an epifaunal nestler like *Arca*, but is much more vagrant in its habits.

Barbatia tramitensis (Cragin, 1893)

Plate 3, Figures D, F

Barbatia micronema (Meek); Stanton, 1893, p. 89, pl. XXI, figs. 3, 4, (in part, not figs, 1, 2).
Protarca? *tramitensis* (Cragin); Stephenson, 1952, p. 59, pl. 11, figs. 17–22.
Barbatia micronema (Meek); Fursich and Kirkland, 1986, p. 549, fig. 5, f.

Description — Shell large (> 6 cm long), thick, moderately elongated, subtrapezoidal shell; hinge line long and straight with teeth transverse below beak, becoming larger and strongly inclined laterally; interarea narrow with duplivinicular ligament scars; beak recurved, protruding above interarea around 20% of length from anterior margin, both anterior and posterior margins narrowly rounded from hinge and then regularly curved, ventral margin slightly concave at mid-point, overall ventral margin gently curved; greatest height of shell toward anterior margin; weak sulcus extends from umbo to mid-line of ventral margin; moderately developed umbonal ridge. Surface ornamented by relatively strong growth lines and dense costae. Shell becomes less elongate during ontogeny, with teeth below beak becoming progressively lost through expansion of the interarea.

Discussion — Stanton (1893) synonymized this species with Meek's (1873) *Barbatia micronema*. Meek's specimens come from the Albian Bear River Formation and as illustrated by Stanton (1893) and noted by Stephenson (1952) are more elongate, with parallel dorsal and ventral margins. Stephenson (1952) assigned this species provisionally to *Protarca*, but the species appears best assigned to *Barbatia*.

Occurrence — The type was found with many other specimens in the middle Cenomanian Lewisville Member of the Woodbine Formation. At Black Mesa restricted to the upper Cenomanian *Metoicoceras mosbyensis* Zone in the shale facies of the upper sandstone member of the Dakota Formation where it is widespread. It is also present in the same facies of the Dakota Formation in southern Utah.

Illustrated material — MNA N4513 from MNA #265; MNA N4514 from MNA loc. #540; both from shale facies, upper sandstone member, Dakota Formation.

Paleoecology — The distribution of this taxon indicates it prefers exposed shell beds in brackish water, where shells are sometimes found in life position (Fursich and Kirkland, 1986).

Family Parallelodontidae
Genus *Nemodon* Conrad, 1869

Paleoecology — Because of the shell form of this genus it is thought to have been a byssally attached, epifaunal nestler (Kauffman, 1969b).

***Nemodon* n. sp.**
Plate 10, Figure Q

Nemodon sulcatinus (Evans and Shumard)?; Stanton, 1893, p. 91, pl. XXI, fig. 5.

Description — Small (@ 0.5 cm), moderately elongate, subtrapezoidal shell; hinge line long and straight, hinge teeth not visible in specimens examined, but parallel hinge in genus; interarea relatively narrow; beak recurved, protruding above interarea around 30% of length from anterior margin, anterior margin sharply rounded from hinge and then regularly curved, posterior margin slightly concave extending at slightly acute angle from hinge where it is sharply curved into ventral margin which is slightly concave at mid-point, overall ventral margin is parallel to hinge. Sulcae extend from just anterior to beak to anterior margin and from umbo to mid-line of ventral margin separated by strong umbonal ridge. Surface ornamented by fine growth lines and costae.

Discussion — The type of *Nemodon sulcatinus* is from the Maestrichtian Fox Hills Sandstone. Specimens of this species illustrated by Speden (1970, pl. 7, figs. 7–13; pl. 8, figs. 1–10) are more coarsely ornamented and somewhat more elongate than the specimens of *Nemodon* from Black Mesa. The material questionably referred to *Nemodon sulcatinus* by Stanton (1893, pl. XXI, fig. 5) compares well with the Black Mesa material. These come from the the same stratigraphic level in southern Utah and are with little question conspecific with the Black Mesa material. The Cenomanian material from Black Mesa, although representing an undescribed species, is too poorly preserved to warrant a formal description of the taxon.

Occurrence — At Black Mesa, uncommon to rare in the lower part of the lower shale member of the Mancos Shale throughout the upper Cenomanian *Sciponoceras gracile* Zone through *Neocardioceras juddii* Zones. Elsewhere, at this level in southern Utah and central Texas.

Illustrated material — MNA N5184 from MNA loc. #992, below BM4, lower part, lower shale member, Mancos Shale.

Family Cucullaeidae
Genus *Idonearca* Conrad, 1862
***Idonearca depressa* White, 1877**
Plate 6, Figure G

Idonearca depressa White, 1877; p. 183, pl. 18, figs. 13a, b.
Trigonarca depressa (White); Stanton, 1893, p. 93, pl. XIX, fig. 2.
Idonearca depressa White; Cobban, 1977, p. 13, pl. 16, figs. 20–24, pl. 19, figs. 10–12.

Description — Thick, medium to large (up to 6 cm long) shell, very inflated; outline subtrapezoidal to subquadrate; hinge line straight and much shorter than ventral margin, horizontal lateral hinge teeth, strong umbonal ridge, surface covered by fine raised growth lines and radiating costae, which cover the entire shell.

Discussion — The specimens described by Stanton (1893) were nearly 3 cm long and more than 2 cm high; they are comparable to most specimens from Black Mesa. Cobban (1977) has noted that most specimens from the Twowells Sandstone Tongue of the Dakota Formation in west-central New Mexico were as much as 6 cm long, but otherwise compare closely with Stanton's material. One specimen from Black Mesa compares in size with the specimens from the Twowells Sandstone.

Occurrence — At Black Mesa known only from the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #265). Also common near the base of the Cretaceous sequence on the east side of of the Deer Creek Coal Field, south of the San Carlos Reservoir east of Phoenix, Arizona and in the Twowells Sandstone Tongue of the Dakota Formation in west-central New Mexico.

Illustrated material — MNA N1057 from MNA loc. #265, sandstone facies, upper sandstone member, Dakota Formation.

Paleoecology — By analog, using the shell form (Kauffman, 1969; Stanley, 1970), this arcid is interpreted to be a shallow infaunal taxon, byssally attached to particles in the substrate with the commissure exposed at or just above the sediment-water interface. All specimens of this species known to the author are from fine-grained shelf sandstones, indicating a preference for fine sand substrates.

Family Noetiidae
Genus *Breviarca* Conrad 1872
***Breviarca*? sp.**
Plate 49, Figure F

Description — Small (0.5 cm), subrectangular to subquadrate, with straight hinge and diverging transverse hinge teeth; anterior, posterior, and ventral margins broadly curved; inflated with well developed umbonal ridge; ornamented by fine growth lines and radiating costae.

Discussion — The one specimen referred to *Breviarca* from Black Mesa consists of a composite internal mold. It is most closely comparable to *Breviarca minor* Stephenson (1952), but the specimen from Black Mesa is not well enough preserved to determine whether it is truly conspecific with that species.

Occurrence — The type specimen of this species is from the middle Cenomanian, Templeton Member of the Woodbine Formation in central Texas. At Black Mesa one specimen was recovered from a bioturbated sandstone interval 11 m above BM77 in the upper shale member of the Mancos Shale, middle Turonian *Prionocyclus hyatti* Zone, at the Lohali Point section (MNA loc. #989).

Illustrated material — MNA N5192 from MNA loc. #989, 11 m above BM77, upper shale member, Mancos Shale.

Paleoecology — The inflated, subrectangular to subquadrate form of species of this genus indicates that these taxa were shallow infaunal forms.

ORDER MYTILOIDA
Superfamily Mytilacea
Family Mytilidae

Paleoecology — Stanley (1970) provided a model for interpreting whether an extinct species of mytilid bivalve is epifaunal or semi-infaunal based on its shell form. This model is based on the study of the many diverse living mytilids. He found that as a rule of thumb, shells that are widest toward the ventral margin are epifaunal, whereas, shells that are widest near the mid-line or toward the dorsal margin are infaunal to semi-infaunal. Stanley's model is used to interpret the life habits of mytilids recovered at Black Mesa.

Genus *Mytilus* Linne, 1758
"Mytilus" ? spp. ?

Plate 11, Figure E; Plate 36, Figure T

Description — Medium sized (1–3 cm long), compacted shells with narrow anterior margin; shell roughly triangular, curving away from dorsal margin; umbonal ridge below midline of shell; surface smooth but for fine growth lines.

Discussion — Two rather poor specimens are questionably referred to the genus *Mytilus* on the basis of overall shell form. No internal features are visible so it cannot be determined whether these specimens would best be referred to another genus. It cannot be determined from these specimens if they represent the same species or two different species.

Occurrence — One specimen (Plate 11, Figure E) from the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone at Blue Point. The second specimen (Plate 36, Figure T) from about one meter above BM61, lower part of the middle shale member of the Mancos Shale, middle Turonian *Collignoniceras woollgari woollgari-Mytiloides hercynicus* subzone of the *Collignoniceras woollgari* Zone at the Lohali Point section.

Illustrated material — MNA N1245 from MNA loc. #344, sandstone facies, upper sandstone member, Dakota Formation; MNA N5193 from MNA loc. #989, one meter above BM61, middle shale member, Mancos Shale.

Paleoecology — From the shell form these specimens are interpreted to represent byssally attached epifaunal suspension-feeders.

Genus *Brachidontes* Swainson, 1840
Brachidontes filisculptus (Cragin, 1893)

Plate 1, Figure E; Plate 3, Figures G, H

Modiolus filisculptus Cragin; Adkins, 1928, p. 137.
Brachidontes filisculptus (Cragin); Stephenson, 1952, p. 83, pl. 20, figs. 19–21.
Brachidontes filisculptus microcostae Stephenson, 1952, p. 84, pl. 20, figs. 16–18.
Brachidontes fulpensis Stephenson, 1952, p. 84, pl. 20, figs. 10–13.
Brachidontes arlingtonanus Stephenson, 1952, p. 85, pl. 20, figs. 14, 15.
Brachidontes arlingtonanus Stephenson; Hattin, 1967, p. 572, 573, fig. 4 (6).
Brachidontes filisculptus microcostae Stephenson; Hattin, 1967, p. 573, fig. 6 (11).
Brachidontes filisculptus (Cragin); Fursich and Kirkland, 1986, p. 549, figs. 5E, 6B.

Description — Thin shell up to 4.5 cm long; elongate, subtriangular, beaks small, umbonal ridge situated just below mid-line of shell; sulcus extends from above beak toward anterior margin before disappearing, second sulcus extends from beak to ventral margin, ornament of radiating fine costellae, which bifurcate toward margin of shell.

Discussion — Collections of this species from Black Mesa display a great deal of variation in size and costellae density, as well as minor variations in the shape of the shell. These variations are interpreted to represent the ecophenotypic effects of differences in salinity, suspended material, and substrate conditions. In addition, the effects of crowding may have affected shell form. The many stratigraphically overlapping species described by Stephenson (1952) in the middle Cenomanian, Woodbine Formation of central Texas most likely represent examples of ecophenotypic variation within one species.

Brachidontes multilingera Meek (1873) is similar to *Brachidontes filisculptus*. The type of *Brachidontes multilingera* is from the Albian near Coalville, Utah and has been reported by Stanton (1893) to range from the Albian to the Santonian in the type area. If all of this material does indeed represent *Brachidontes multilingera* then it is probable that *Brachidontes filisculptus* is a junior synonym. Only a careful morphometric analysis of populations from numerous sites would resolve this question.

Occurrence — Abundant at Black Mesa, restricted to the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone, where it is present at all localities where fossils have been found. Elsewhere, ranging from at a minimum the middle through upper Cenomanian of Texas, Utah, Kansas, and Nebraska.

Illustrated material — MNA N892, N984, N4535 from MNA loc. #265, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — Shell form indicates that this is a byssally attached epifaunal mytilid. Dense shell beds consisting of exclusively *Brachidontes* suggesting that they formed mussel beds like those formed by many modern epifaunal mytilids (Fursich and Kirkland,1986). Their distribution at Black Mesa indicates brackish water facies, comparable with living species of the genus.

Genus *Modiolus* Lamarck, 1799

Paleoecology — Shell form indicates of the species of this genus from Black Mesa are shallow infaunal to semi-infaunal, byssally attached to particles within the substrate.

Modiolus cf. *M. attenuatus* (Meek and Hayden)

Plate 11, Figure H b; Plate 43, Figure C

Description — Thin shells to 5 cm long, very elongate; beak small and subterminal; dorsal and ventral margins nearly parallel expanding slightly away from the beak; shell nearly circular in cross-section, near beaks becoming laterally flattened toward anterior margin. Shell with only fine growth lines.

Discussion — Specimens of *Modiolus attenuatus* (Meek and Hayden), as illustrated by Meek (1876) and Speden (1970) from the Maastrichtian Fox Hills Sandstone closely resemble the specimens from Black Mesa. Internal features are not known for these specimens. The extreme elongation of these shells, as compared to any well documented species of *Modiolus*, suggests that they may be referable to an undescribed genus, but this can only be ascertained with examination of the internal features.

Occurrence — At Black Mesa fairly common in the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone, at Blue Point. In addition, a slightly smaller but otherwise comparable specimen was recovered from the top of the Blue Point Tongue of Toreva Formation, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone, at Blue Point.

Illustrated material — MNA N1239 from MNA loc. #344, shale facies, upper sandstone member, Dakota Formation. MNA N5398 from MNA 1150, top of Blue Point Sandstone Tongue, Toreva Formation.

Modiolus coloradoensis n. sp.

Plate 43, Figure B; Plate 48, Figure B

Volsella coloradoensis Kauffman, 1961, Ph. D.; pl. 13, figs. 28–31.

Etymology — Named for the type locality in Huerfano Park, south central Colorado.

Diagnosis — Thin shell fairly small (up to 2.5 cm long), rounded subrectangular to wedge-shaped outline; inflated, subcylindrical, beak broad and about 10% of length from anterior margin, strong umbonal ridge at about 23° to hingeline extending to ventral anterior margin, ventral margin inclined at about 14° to hinge line, shell smooth except for fine growth lines.

Description — Measurements of the types from Kauffman (1961) indicate the holotype (UMMP 37995) is 8.9 mm high, 15.8 mm long, and 3.4 mm wide, and the largest paratype (UMMP 37994) is 11.5 mm high, 26.3 mm long, and 4.6 mm wide.

Discussion — Close to *Modiolus* n. sp., but differs primarily in dorsal and ventral margins diverging away from the beak; giving the species more of a wedge shape. In addition, the beak is not as close to the anterior end of the shell as in *Modiolus* n. sp. Apparently close to *Modiolus modesta* (Stephenson, 1952), but the ventral and dorsal margins do not diverge at such a large angle and the beak not as anterior. It differs from *Modiolus alveolana* (Stephenson, 1952) in lacking strong, evenly spaced concentric growthlines. Of the described taxa, with which the author is familiar, *Modiolus coloradoensis* n. sp. appears to be closest to *Modiolus tarrantana* (Stephenson, 1952) from the middle Cenomanian of central Texas from which it differs in its smaller size and greater divergence between its dorsal and ventral margins.

Occurrence — The types are from the Codell Sandstone Member of the Carlile Shale, middle Turonian *Prionocyclus hyatti* Zone in Huerfano Park, Colorado. At Black Mesa, present in the Blue Point Tongue and lower sandstone member of the Toreva Formation, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone at Blue Point.

Type specimens — Holotype, UMMP 37995 nearly complete pair of coattached valves with portion of posterior margin broken off; paratypes, UMMP 37994, 37996, 37997; all from Codell Sandstone Member of Carlile Shale, Huerfano Park, Colorado.

Illustrated material — MNA N5054 from MNA loc. #1150, top of Blue Point Sandstone Tongue, Toreva Formation; MNA N5350 from MNA loc. #342, lower sandstone member, Toreva Formation.

Modiolus perryi n. sp.

Plate 11, Figures D, V, W

Etymology — Named for Michael Perry first executive director of the Dinamation International Society in recognition of his support of paleontology research on the Colorado Plateau.

Diagnosis — This species differs in its nearly rectangular shape, particularly in its nearly parallel ventral and dorsal margins in combination with its fine growthline.

Description — Thin shell fairly small (up to 2 cm), rounded subrectangular outline; inflated, cylindrical; beak broad and nearly terminal; strong umbonal ridge extending to ventral anterior margin, anterior and posterior margins of nearly equal height with dorsal and ventral margins nearly parallel, shell ornamented by fine growth lines.

Discussion — Specimens of *Modiolus* from the upper Cenomanian of the Colorado Plateau have been referred to *Modiolus silentiensis* McLearn (1926) (Koch, 1975; Kirkland, 1983). McLearn's type of *Modiolus silentiensis* has a shorter anterior margin, and the ventral margin is inclined to the hinge at about 48°. *Modiolus perryi* would seem to be closest in form to *Lithophaga ripleyana* Gabb (Wade, 1926), but differs in lacking strong growth lines.

Occurrence — At Black Mesa present in the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone, as well as at this level across southern Utah.

Type specimens — Holotype, MNA N5066 from MNA loc. #306; paratype, MNA N1061 from MNA loc. #271, both from BM10, lower part, lower shale member, Mancos Shale; paratype, MNA N1079, from MNA loc. #344, top of Dakota equivalent, basal Mancos Shale (Kirkland 1991).

Genus *Botula* Morch, 1853

"*Botula*"? sp.

Plate 36, Figure W

Description — Shell small (1.0 cm long), ovate and subcylindrical, beak near terminal.

Discussion — The one specimen provisionally assigned to this genus consists of an internal mold and further study of more material may necessitate assignment to a different genus.

Occurrence — One specimen from about 10 m above base of upper shale member of the Mancos Shale, middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone at Blue Point (MNA loc. #262).

Illustrated material — MNA N5194 from MNA loc. #262, 10 m above base of upper shale member, Mancos Shale.

Paleoecology — *Botula* is a boring bivalve (Abbott, 1968). No hard substrates thick enough for these shells to bore into were observed with the Black Mesa specimen. A few borings (< 1 cm deep by 0.4 cm wide) in large specimens of *Exogyra* (*Costagyra*) *olisiponensis* from the upper sandstone member of the Dakota Formation may have been made by *Botula*.

Superfamily Pinnacea

Family Pinnidae

Genus *Pinna* Linne, 1758

Discussion — *Pinna* may be confused with the similar and closely related wedge-shaped genus *Atrina*. *Pinna* is readily distinguished by the presence of an internal ridge (produced by fracturing of the shell during growth) running along the midline of the shell, which internally divides the inner nacreous layer.

Paleoecology — Semi-infaunal, suspension-feeder that has broad anterior margin exposed at sediment-water interface. Byssally attached to particles in the sediment by a very extensive rope like byssus.

Pinna petrina White, 1874

Pinna petrina White, 1874; p. 182, pl. 13, figs. 7a, b.
Pinna petrina White; Stanton, 1893, p. 88, pl. XIX, fig. 4, pl. XX, fig. 1.
Pinna petrina White; Cobban, 1977, p. 13, pl. 1, figs. 2, 4, pl. 3, fig. 8, pl. 15, fig. 21.

Diagnosis — Large shell (to 16 cm long), triangular shaped with terminal beaks; dorsal and ventral margins diverge at an angle of up to 35°; 8–10 strong radial ribs on dorsal half of shell with an equal number or weaker radial ribs on the ventral half of shell, irregular; strong growth lines interrupt ribs; the radial ribbing fades on the adult shell.

Discussion — Specimens of *Pinna petrina* are generally fairly poorly preserved and difficult to extract from the sandstone matrix in which they are found. The material observed does compare well with specimens collected by the author from the Twowells Sandstone Tongue of the Dakota Formation and with those illustrated by other authors.

Occurrence — The type is from the middle Cenomanian, Paguate Sandstone Tongue of the Dakota Formation south of Paguate, New Mexico. Cobban (1977) reported the species in sandstones from the middle through upper Cenomanian in west-central New Mexico. At Black Mesa in the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone, rarely along the north side of Coal Mine Mesa (MNA loc. #265) and more commonly at the Coal Chute section (MNA loc. #963). Also encountered at this level in southern and central Utah. The species has also been noted in the uppermost Cenomanian *Neocardioceras juddii* Zone in the Cretaceous undifferentiated along the Mogollon Rim in central Arizona.

Pinna kauffmani n. sp.

Plate 43, Figures D, E

Pinna petrina White; Kauffman, 1961, Ph. D., p. 288, pl. 24, fig. 9.
Pinna lakesi? White; Kauffman, 1961, Ph. D., p. 290, pl. 24, figs. 6–8.

Etymology — Named in recognition of Dr. Erle G. Kauffman's early collection and illustration of this species.

Diagnosis — *Pinna kauffmani* n. sp. is readily distinguished from *Pinna petrina* in its more lancelate outline and ornament, which persists to the adult stage.

Description — Large shell (to 19 cm long), triangular shaped with terminal beaks; dorsal and ventral margins diverge at an average angle of 25°, 6–8 strong radial ribs on posterior half of shell with about a nearly equal number of weaker radial ribs on the dorsal half of shell; weak concentric rugae may extend a short distance from the dorsal margin of shell; strong irregular growth lines interrupt ribbing.

Discussion — Species described by Kauffman (1961) from the Codell Sandstone Member of the Carlile Shale at Huerfano are probably conspecific with the new species described above.

Occurrence — At Black Mesa common in the Blue Point Tongue, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone at Blue Point (MNA loc. #1150). Also in the Codell Sandstone Member of the Carlile Shale at Huerfano Park, Colorado, middle Turonian *Prionocyclus hyatti* Zone.

Type specimens — Holotype MNA N5095; paratype N5498 from MNA loc. #1150, top of Blue Point Sandstone Tongue, Toreva Formation.

Genus *Plesiopinna* Amano, 1956

Plesiopinna ? sp.

? *Plesiopinna* sp. Cobban, 1977; p. 14, pl. 1, figs. 1, 3.

Description — Large shell fragments crossed by radial ribs and fine rugae.

Discussion — Shell fragments from Black Mesa are similar to more complete material from the same level in northwestern New Mexico near Four-Corners. The New Mexico material compares rather well with specimens illustrated by Cobban (1977) from somewhat older strata in the area of west-central New Mexico.

Occurrence — At Black Mesa known only by a few shell fragments in the basal lower shale member of the Mancos Shale, upper Cenomanian *Vascoceras diartianum* subzone of the *Sciponoceras gracile* south of Yale Point (below BM4, MNA loc. #296). Also known from better material at this level at Red Wash in northwestern New Mexico near the Four Corners. Cobban (1977) illustrated similar but better preserved material from the upper part of the Oak Canyon Member of the Dakota Formation, middle Cenomanian of west-central New Mexico.

Paleoecology — The shell form of this genus, which overall is much like that of the species of *Phelopteria* described below, suggests that this was a byssally attached epifaunal suspension-feeder.

ORDER PTERIOIDA

Superfamily Pteriacea

Family Bakevelliidae

Genus *Gervillia* DeFrance, 1820

Gervillia navajovus n. sp.

Plate 11, Figures T, U

Etymology — Named for the Navajo Tribe on whose lands the type specimens were found.

Diagnosis — This species is distinctive in its small size and highly elongate shell.

Description — Thin shell, medium-sized (small for genus, up to 5 cm long); elongate (length to width ratio about 5:1), curved ensiform outline; long axis of shell 20–25° from hinge line; hinge line straight with well developed obtuse posterior auricle and very small obscure anterior auricle; irregularly spaced rugae best developed toward dorsal margin.

Occurrence — Present in concretion horizons BM8 and BM10 in the lower part of the lower shale member of the Mancos Shale, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone on the eastern side of Black Mesa (MNA loc. #306, #989, #992). Also present in BM8 in southern Utah.

Type specimens — Holotype, MNA N5072 displaced pair of valves; paratype MNA N5073, from MNA loc. #306, BM10, lower part, lower shale member, Mancos Shale.

Paleoecology — Shell form indicates that this genus was a byssally attached (often hanging pendant from objects above the substrate), epifaunal form which would be oriented by currents to bring posterior margin into the down current direction.

Genus *Phelopteria* Stephenson, 1952

Discussion — From the author's experience, species of the genus *Phelopteria* can be divided into two major species groups that may on further study prove to separable at either the genus or subgenus level. The first group, the *Phelopteria dalli* group, is composed of large species that apparently become greatly thickened on maturity and are most common in shallow water settings. The second group, the *Phelopteria minuta* group, is composed of small to medium sized species that are typical of more offshore environments. Immature specimens of species belonging to the *Phelopteria dalli* group are very difficult to distinguish from adults of the *Phelopteria minuta* group. A complete revision of the group by W. P. Elder of the U. S. Geological Survey is in progress.

Paleoecology — The shell form of *Phelopteria* indicates that species were byssally attached, epifaunal forms which would be oriented by currents to bring the posterior margin into the down current direction (Kauffman, 1969).

Phelopteria dalli species group

Discussion — As used herein, the *Phelopteria dalli* species group includes *Phelopteria dalli* (type species of the genus) and *Phelopteria gastrodes* discussed below, as well as *Phelopteria aguilerae* (Böse, 1918) from the lower Turonian of northern Mexico.

Paleoecology — All specimens of this group from Black Mesa are from shallow marine sandstones. The large, thick shell of these forms would seem to be an adaptation to high energy conditions. The presence of deep pedal retractor muscle scars indicates that the group was able to pull down tight against the site of attachment during storm events.

Phelopteria dalli (Stephenson, 1936)
Plate 6, Figure B a

Pteria? dalli Stephenson, 1936; p. 389, pl. 3, figs. 3, 4.
Phelopteria dalli (Stephenson); Stephenson, 1952, p. 68, pl. 14, figs. 4–14.

Description — Large shell (hinge length of up to 9 cm), pteriaform, moderately inequivalve; hinge straight, umbo inflated with beak situated about 30% of length from anterior margin; anterior auricle triangular and well differentiated from disk, posterior auricle larger and only subtly separated from disk; shell nearly erect to well inclined; ventral margin broadly curved; surface smooth.

Discussion — Internal features are not visible on any of the specimens from Black Mesa, and in terms of external features the range of variation observed of *Phelopteria dalli* seems to completely overlap the range in variation observed in specimens of *Phelopteria gastrodes*. Material illustrated by Stephenson (1952) seems to indicate that the principal difference is that *Phelopteria dalli* has a thicker shell and is more inclined.

Occurrence — The type specimen was dredged up from Cenomanian strata off Nova Scotia. At Black Mesa present in the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #265, #963), as well as at this level in southern Utah. The species is also widespread in the middle Cenomanian Woodbine Formation of central Texas.

Illustrated material — MNA N227 from MNA loc. #265, sandstone facies, upper sandstone member, Dakota Formation.

Phelopteria gastrodes (Meek, 1873)
Plate 44, Figures A–D

Avicula gastrodes Meek; Stanton, 1893, p. 72, pl. IX, figs. 7–10.

Diagnosis — Like *Phelopteria dalli*, but thicker shelled.

Description — Internal features are visible on a number of specimens. Preliminary observations indicate the presence of several ligament pits on the thickened hinge and several deep pedal retractor muscle scars beneath umbonal ridge. In addition, juvenile shells appear more inclined than adults, suggesting that through ontogeny the shell becomes more erect.

Occurrence — The type came from the "second ridge", middle Turonian near Coalville, Utah. Other specimens were illustrated by Stanton from the Codell Sandstone Member of the Carlile Shale, middle Turonian *Prionocyclus hyatti* Zone in Huerfano Park, Colorado. At Black Mesa known only from the Blue Point Tongue, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone at Blue Point (MNA loc. #1150).

Illustrated material — MNA N5381, N5382, from main body and MNA N5094, N5536 from top of Blue Point Sandstone Tongue, Toreva Formation, MNA loc. #1150.

Phelopteria minuta species group

Discussion — A great diversity of small, thin shelled *Phelopteria* included in the *Phelopteria minuta* species group is present within the lower shale member of the Mancos Shale at Black Mesa. At present this material is under study by W. P. Elder of the U. S. Geological Survey at Menlo Park, California. Within this member the distributions of the various species were controlled as much by the local environment as by evolutionary turnover (Elder, personal commun., 1989). The following descriptions of potential species in this group are tentative awaiting the results of Elder's study.

Paleoecology — Small pterioids of this type are common in offshore Cretaceous settings (Kauffman, 1967) and were probably byssally attached to objects projecting into or even floating in the water column as is predicted by their small size and presence in environments with reduced oxygen levels near the sediment-water interface.

Phelopteria minuta Kauffman and Powell, 1977
Plate 11, Figure M; Plate 25, Figure D
Plate 27, Figure C, ?E

Phelopteria minuta Kauffman and Powell, 1977; p. 50, pl. 8, figs. 4, 6.

Description — Thin shell, small (<2 cm hinge length), pteriaform, slightly inclined, slightly inequivalve with left valve more inflated than right; beak inflated and barely projecting above weakly beaded hinge; beading along hinge may be the external expression of ligament pits; anterior auricle triangular, separated from disk, distinct sulcus running nearly at right angles to hinge; posterior auricle slightly projecting, only weakly differentiated from disk; ventral margin evenly curved; shell ornamented by fine rugae.

Discussion — Elder (1989, personal commun.) reports that *Phelopteria minuta* seems to be most abundant in offshore calcareous facies.

Occurrence — The type is from the upper Cenomanian Hartland Shale Member of the Greenhorn Limestone in Cimarron County, northwestern Oklahoma where it ranges through both the Lincoln and Hartland Members of the Greenhorn Limestone. At Black Mesa ranging from the upper Cenomanian *Sciponoceras gracile* Zone to the basal middle Turonian.

Illustrated material — MNA N1214 from MNA loc. #303, BM8; MNA N3601 from MNA loc. #989, below BM12; both from lower part, lower shale member; MNA N3607 from MNA loc. #262, BM18, middle part, lower shale member, Mancos Shale.

Phelopteria sp. A
Plate 11, Figure R; Plate 27, Figure H

Diagnosis — Like *Phelopteria minuta* but somewhat more inclined, with a larger anterior auricle.

Occurrence — At Black Mesa upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through the *Neocardioceras juddii* Zone.

Illustrated material — MNA N3619 from MNA loc. #989, below BM12; MNA N3605 from MNA loc. #306, BM10; both from lower part, lower shale member, Dakota Formation.

Phelopteria sp. B

Plate 19, Figure H

Description — Thin shell, medium-sized (to 4.5 cm maximum length); rhombohedral outline with dorsal and ventral margins subparallel and anterior and posterior margins subparallel; shell inflated; anterior auricle relatively small and well differentiated from disk; posterior auricle only weakly differentiated from disk, surface ornamented by irregular weak rugae and fine growth lines.

Discussion — This species is rather large for a member of the *Phelopteria minuta* species group and appears closest to *Phelopteria* sp. F, but has weaker more irregular rugae.

Occurrence — At Black Mesa restricted to the upper Cenomanian *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* in the area of southwestern Black Mesa (MNA loc, 814).

Illustrated material — MNA 3535 from MNA Loc. #814, BM11.

Phelopteria sp. C

Plate 27, Figures B b, D

Diagnosis — Small, thin-shelled like *Phelopteria minuta*, but much more inclined, with a narrow inflated disk and narrow posterior auricle, not extended and nearly continuous with disk.

Occurrence — At Black Mesa common in the *Watinoceras coloradoense* Zone.

Illustrated material — MNA N3609, N3618 from MNA loc. #262, BM18, middle part, lower shale member, Mancos Shale.

Phelopteria sp. D

Plate 27, Figure F

Phelopteria quadrate species aff. *P. minuta* Kauffman and Powell, 1977; p. 52, pl. 8, figs. 7, 8.

Description — Small, thin-shelled, quadrate, inflated; hinge line shorter than ventral margin; anterior auricle large, rounded, and well differentiated from disk by narrow sulcus; posterior auricle relatively short for genus and poorly differentiated from disk; shell ornamented by dense fine rugae.

Discussion — This species compares rather well with the quadrate form described by Kauffman and Powell (1977) from the upper Cenomanian of Oklahoma. The species is clearly distinct from any other at Black Mesa in its inflated quadrate form and nonprojecting auricles.

Occurrence — At Black Mesa, one right valve was recovered from below BM17, lower Turonian *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone at the Lohali Point section. Also from the upper Cenomanian Hartland Shale Member of the Greenhorn Limestone in Cimarron County, northwestern Oklahoma.

Illustrated material — MNA N3614 from MNA loc. #989, below BM17, top of lower part, lower shale member, Mancos Shale.

Phelopteria sp. E

Plate 27, Figure G

Diagnosis — Species of *Phelopteria* much like *Phelopteria* sp. D, but is readily distinguished by its extremely long hinge and more strongly projecting auricles.

Occurrence — One pair of compacted valves from above BM30, lower Turonian *Mammites nodosoides* Zone at Blue Point (MNA loc #262).

Illustrated material — MNA N5454 from MNA 262, above BM30, middle shale member, Mancos Shale.

Phelopteria sp. F

Plate 27, Figures I–M

Diagnosis — Thin shell, medium-sized (3.5 cm long hinge); like *Phelopteria* sp. B, but more erect with rather dense folds on auricles; disk with distinct even rugae and beaded hinge reflecting underlying ligament pits.

Occurrence — At Black Mesa, rather common in the *Mammites nodosoides* Zone.

Illustrated material — MNA N3621, BM28; N3622, 2 m above BM32; N3624, below BM34; all from MNA loc. #989; MNA N3620. from MNA loc. #262; all specimens from middle part, lower shale member, Mancos Shale.

Genus *Pseudoptera* Meek, 1873

Paleoecology — Like *Phelopteria*, a byssally attached epifaunal suspension-feeder.

Pseudoptera propleura Meek, 1873

Plate 44, Figure G

Gervillia propleura (Meek); Stanton, 1893, p. 74, pl. X, figs. 1–3.

Description — Shell of fairly large size (up to 9 cm long); subtriangular; beak sharp, shell strongly inclined posteriorly, with very small anterior auricle and large posterior auricle extending for most of length of shell, separated from main part of shell by low radial dorsal ridge; strong subangular umbonal ridge separates anterior-ventral portion from main part of shell, shell flattened between dorsal and umbonal ridges; hinge line long and straight with multiple ligament pits, antero-ventral margin oblique, very gently rounded, posteroventral margin subrounded to subtruncated.

Discussion — The shell of this species is larger and thicker than other species of *Pseudopteria*. Stanton (1893) reported weak radial ornament on the anterior-ventral portion of shell and folds on the posterior auricle. This ornament was not observed on the few poorly preserved specimens from Black Mesa.

Occurrence — Types from middle Turonian at Coalville, Utah. At Black Mesa, rare in the Blue Point Sandstone Tongue (MNA loc. #1150), middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone. Also from Codell Sandstone, middle Turonian *Prionocyclus hyatti* Zone at Huerfano Park, Colorado.

Illustrated material — MNA N5097 from MNA loc. #1150, top of Blue Point Sandstone Tongue, Toreva Formation.

Pseudoptera sp. cf. *P. serrata* Stephenson, 1952

Plate 11, Figures G, N

Pseudoptera serrata Stephenson, 1952; p. 71, pl. 13, fig. 6.

Description — Thin shell of medium size (3.5 cm long); subtriangular; beak sharp; shell strongly inclined posteriorly, with very small anterior auricle and large posterior auricle extending for most of length of shell, separated from main part of shell by low radial ridge; strong subangular umbonal ridge separates anterior-ventral portion from main part of shell; hinge line long and straight; anterior-ventral margin oblique very gently rounded; posteroventral margin subrounded to subtruncated. Surface ornament consists of numerous widely spaced, radial costellae, which are serrated where they intersect growth lines.

Discussion — The specimens from Black Mesa are more inclined and more completely covered by radial ornament that those illustrated by Stephenson (1952), but are closer to this form than any other described species.

Occurrence — Restricted to the *Sciponoceras gracile* Zone at Black Mesa, most common in marker bed BM8, also found at this level in southern Utah.

Illustrated material — MNA N3545 from MNA loc. #344, top of sandstone facies, upper sandstone member, Dakota Formation; MNA N5178 from MNA loc. #989, BM8, lower part, lower shale member, Mancos Shale.

Family Inoceramidae

Discussion — Inoceramids are one of the most common and biostratigraphically useful fossil groups present in the Cretaceous of the Western Interior Basin. The group has an evolutionary turnover rate comparable or exceeding that of most other taxonomic groups used in biostratigraphy (Kauffman, 1970, 1972, 1975, 1978). A broad tolerance of different marine environments among adult inoceramids and a planktonic larval stage of long duration, permits the rapid colonization of a broad range of substrates intercontinentally with each evolutionary innovation (Kauffman, 1975, 1976a, 1976b, 1977d). In addition, the shell construction of prismatic calcite underlain by nacreous aragonite found in this group permits preservation of these common fossils under a variety of diagenetic regimes. However, confusion regarding the systematics of the inoceramids has limited their application to high resolution biostratigraphic analysis (Kauffman and Powell, 1977).

As Kauffman and Powell (1977) have reported, generic concepts have been used inconsistently and are largely based on external characters as can be seen in Cox and others (1969). This has led to unnatural groupings of species as it does not take into account the widespread homeomorphy in shell form and ornament observed in the inoceramids. The importance of internal features, which document fundamental biologic differences, has received little attention. Kauffman (1969, personal communication) has nearly completed a total revision of generic and subgeneric classification of the inoceramids based on the generally conservative internal features, such as the nature of the hinge plate, ligament pits, musculature, and byssal apparatus among other features. Until this revision appears, the classification of Cox and others (1969) is followed, as fortunately the few genera of inoceramid present in the Greenhorn cyclothem at Black Mesa are based on taxa present in the study area.

In addition, concepts at the species and subspecies level have been complicated by over-splitting, based on small differences in morphology without regard to variation, and lumping of similar species into broadly based species, which have greatly reduced utility. Poor illustrations and the scattering of type specimens in museums around the world has hindered the direct comparison of species concepts in different regions, limiting the ability of researchers to document synonyms (Kauffman, 1977d). Another problem has resulted in poor documentation or misunderstandings regarding the stratigraphic position of type specimens. It is only with the detailed analysis of individual lineages based on large populations in close stratigraphic succession that many of these historic problems can be resolved, as has been demonstrated by Kauffman (1970; Kauffman and Powell, 1977).

The following section takes a conservative approach to the systematics of the inoceramids from Black Mesa. The material collected during the course of this study was extensive, but the kind of morphometric approach required to refine the systematic of this group beyond what is presented here is beyond the scope of this study.

Genus *Inoceramus* Sowerby, 1814

Inoceramus apicalis Woods, 1911

Plate 37, Figure P

Inoceramus lamarcki var. *apicalis* Woods, 1911; p. 319, pl. 53, figs. 4–6.
Inoceramus apicalis Woods; Cobban, 1983, p. 5, pl. 2, figs. 1–6, 9, 10; pl. 8, fig. 10.

Description — Thin shell, small (1 cm high); outline round early in ontogeny becoming elongate toward reaching maturity; inflated, moderately inequivalve; hinge long, beak near terminal, slightly prosogyrus; erect early in ontogeny becoming more inclined (around 60°), large posterior auricle separated from main part of shell by break in slope or shallow sulcus; ornamented by crowded regular raised growth lines, with scattered rugae.

Discussion — All specimens from Black Mesa that have been assigned to *Inoceramus apicalis* appear to be juveniles and compare well with the early growth stages of the specimens illustrated by Cobban (1983) from about the same level in northeastern Nebraska and eastern South Dakota.

Occurrence — The types came from the upper Turonian of southern England. Also recognized in Germany. At Black Mesa uncommon in the Hopi Sandy Member of the Mancos Shale, middle Turonian basal *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5520 from MNA loc. #989, 3 m above base of Hopi Sandy Member, Mancos Shale.

Paleoecology — Kauffman (1967, 1969a) proposes that inoceramids of this type were byssally attached to objects on the seafloor in nearshore high-energy environments.

Inoceramus cuvierii Sowerby, 1814

Plate 31, Figures F, G, I, J; Plate 44, Figure F;
Plate 48, Figures A, C; Figure 49, Figure H?

Inoceramus lamarcki var. *cuvieri* Sowerby; Woods, 1911, p. 317, pl. LIII, figs. 4–6, text-figs. 73–84.
Inoceramus cuvieri Sowerby; Hattin, 1962, p. 54, pl. 15, figs A, B, D.
Inoceramus cuvieri Sowerby; Kauffman, 1976b, pl. 4, figs. 1, 8, 10.
Inoceramus cuvieri Sowerby; Keller, 1982, p. 89, pl. 4, fig. 3; pl. 5, fig. 3.

Description — Moderately thin shell with greatly thickened hinge; large (up to 25 cm high); subrectangular; beak terminal, little enrolled, and slightly projecting; umbo moderately inflated; moderately inequivalve; hinge relatively short with auricle differentiated from disk by break in slope; erect (inclination of 65 to 80°); anterior margin steep and straight to concave; shell ornamented by fine lamellae and even concentric rugae of unequal strength, which tend to be very weak on stratigraphically older forms and strong on stratigraphically late forms.

Discussion — *Inoceramus cuvieri* is widespread nearly worldwide and occurs through much of the middle Turonian. Kauffman (1975, 1976a, 1976b, 1977b, 1977d) has informally divided the species into two subspecies based primarily on the increased strength of rugae through time. This trend is generally observed at Black Mesa, but rare non-rugate specimens have been observed near the top of its range with rugate forms.

Occurrence — The type is from the lower part of the middle Turonian of southern England, where it occurs through most of the middle Turonian. At Black Mesa, fairly common through the *Collignoniceras woollgari* Zone from the base of the middle Turonian above BM35 upward into the upper shale member of the Mancos Shale to the northeast and into the lower sandstone member of the Toreva Formation in the southwest at Blue Point. One specimen that may represent this species was recovered near the top of a sandstone interval in the upper shale member 20 m below the base of the Toreva Formation, middle Turonian *Prionocyclus hyatti* Zone at the Lohali Point section (Kirkland, 1990). Elsewhere nearly worldwide through the middle Turonian.

Illustrated material — MNA N5236, below BM54, upper part, lower shale member; MNA N5451, one meter below BM66, middle shale member; MNA N5047, one meter above BM68, middle shale member; MNA N5260, 3 m above base of Hopi Sandy Member; all from MNA loc. #262, Mancos Shale; MNA N3581 from MNA loc. #989, siderite concretions 19 m below base of Toreva Formation, upper shale member, Mancos Shale; MNA N5259 from MNA loc. #1150, top of Blue Point Sandstone Tongue Toreva Formation; MNA N5250, N5588 from MNA loc. #342, lower sandstone member, Toreva Formation.

Paleoecology — The large shell of this species may be an adaptation for reclining on the left valve on soft substrates as there is no evidence of a strong byssal attachment (Kauffman, 1967, 1969a). While the shell remained small (< 10 cm long) it may have been byssally attached, becoming free living as it became fully mature.

Inoceramus sp. cf. *I. dimidius* White, 1974

Plate 50, Figures J, K

Inoceramus dimidius White; White, 1976, p. 181, pl. 16, fig. 2a–d.
Inoceramus dimidius White; Stanton, 1893, p. 78, pl. X, figs. 5, 6.
Inoceramus? dimidius dimidius White; Kauffman, 1977b, pl. 8, figs. 7, 12, 13.
Inoceramus dimidius White; Hook and Cobban, 1979, p. 44, fig. 5.

Description — Thin shell, relatively small (up to 4 cm high), fairly erect with an inclination of 60–70°; dramatic change in overall form at a marked geniculation, early stage extending from 1–2 cm from beak, subrounded, low convexity, with long hinge and closely spaced, strong, even rugae; mature stage marked by rapid increase in the convexity of shell with a marked relative increase in height relative to length, ornament greatly reduced but for a few widely spaced rugae.

Discussion — These inoceramids compare closely with *Inoceramus dimidius* and their presence at the base of the Toreva Formation at the Coal Chute section led Repenning and Page to conclude that this indicated the upper Turonian *Prionocyclus macombi* Zone. This interpretation is not compatible with the other fossils found at this site, which indicate the *Prionocyclus hyatti* Zone.

The occurrence of these specimens at Black Mesa represents one of the oldest known occurrences of inoceramids of the *Inoceramus dimidius* species group. Previously, Kauffman (1968) has noted the occurrence of this group in the late middle Turonian.

Occurrence — The type is from the upper Turonian *Prionocyclus macombi* Zone in northern New Mexico. At Black Mesa, uncommon in the transition zone between the Mancos Shale and Toreva Formation on the north and east sides of the basin (MNA loc #878, #988), middle Turonian *Prionocyclus hyatti* Zone. Elsewhere it is widespread across the Western Interior in the lower half of the upper Turonian.

Illustrated material — MNA N3571, N3577 from MNA loc. #988, base of lower sandstone member, Toreva Formation.

Paleoecology — Kauffman (1967, 1969a) proposed that inoceramids of this type were byssally attached to the seafloor in nearshore high-energy environments.

Inoceramus flavus Sornay, 1972

Plate 12, Figures C, D

Inoceramus flavus Sornay, 1972; p. 4, pl. A, fig. 1, 2, text-fig. 2.

Description — Thin shell, medium-sized (to 6 cm high); subtriangular; beak terminal and projecting, umbo moderately inflated and moderately to highly enrolled, strongly prosogyrus; moderately inequivalve; hinge relatively short with auricle well differentiated from disk by break in slope to weak posterior sulcus; shell sub-erect (inclination of 60 to 70°); prominent umbonal ridge; anterior margin steep and slightly concave; shell ornamented by rather weak irregularly spaced concentric rugae of unequal strength, and fine raised growth lines.

Discussion — *Inoceramus flavus* is readily distinguished from *Inoceramus pictus* and *Inoceramus nodai* by its short posterior auricle, rapidly expanding shell, and strongly prosogyrus beak.

Occurrence — The type specimen is from the upper Cenomanian of Madagascar. Present at Black Mesa through the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone, being most common at the base of the zone. Widespread in the Western Interior.

Illustrated material — MNA N3565 from MNA loc. #992, BM8, lower part, lower shale member, Mancos Shale.

Paleoecology — The inflated shell, byssal slit, and thickened hinge of this taxon suggest that it may have been byssally attached, resting on the more inflated left valve and drawn up against the anterior margin. A tolerance of higher energy conditions is indicated by the common occurrence of this taxon at the top of the Dakota Formation at Blue Point.

Inoceramus n. sp. aff. *I. heinzi* Sornay, 1972

Plate 19, Figure N; Plate 20, Figures B, C

compare with *Inoceramus heinzi* Sornay, 1972; p. 7, pl. B, fig. 4, text-fig. 3.
compare with *Inoceramus heinzi* Sornay; Matsumoto and Noda, 1986, p. 415, pl. 83, figs. 4a–d; pl. 85, figs. 2–3b.

Description — Thin shell, large (up to 10 cm high); subquadrate to subrectangular; beak terminal and projecting, shell moderately inflated; prosogyrus, moderately inequivalve; hinge long with auricle poorly differentiated from disk; distinct sulcus posterior to broad umbonal ridge;

shell moderately inclined (inclination of 50 to 70°); anterior margin steep, straight; shell ornamented by weak, evenly spaced concentric rugae of unequal strength and fine raised growth lines.

Discussion — This species is unlike any inoceramid found at Black Mesa and seems closest to *Inoceramus heinzi* as illustrated by Sornay (1972). The specimens from the middle Cenomanian of Japan illustrated by Matsumoto and Noda (1986) are more elongate with more projecting beaks. The specimens from Black Mesa differ from the type specimen mostly in having a distinct postero-ventral sulcus. As this is a significant feature it is felt these specimens represent an undescribed species.

Occurrence — At Black Mesa restricted to the *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone and most common in the area of extreme southwestern Black Mesa (MNA loc. #814).

Illustrated material — MNA N3525, N3526, N3527 from MNA 814, BM11, lower part, lower shale member, Mancos Shale.

Paleoecology — The internal features of this inoceramid are unknown, but based on the large size and inflated shell this taxon is thought to have been byssally attached to shells on the substrate early in ontogeny and to have rested freely on the larger left valve upon reaching maturity.

Inoceramus howelli White, 1876
Plate 50, Figures B–E

Inoceramus howelli White, 1876; p. 284, pl. 4, figs. 1a–c.
Inoceramus fragilis Hall and Meek; Stanton, 1893, (in part), p. 76, pl. XI, figs. 3–5.
Inoceramus howelli White; Cobban, 1983, p. 6, pl. 2, figs. 13–16.

Description — Thin shell, medium-sized (up to 5 cm high); subrectangular; beaks terminal and projecting, umbo moderately inflated and enrolled; prosogyrus; inequivalve, hinge short with auricle well differentiated from disk by sharp break in posterior slope of disk; sulcus posterior to distinct umbonal ridge separated from auricle by a fold; inclination 50–60°; anterior margin steep, straight to concave; ornamented by weak, irregularly spaced concentric rugae of unequal strength, and by fine raised growth lines, which fade on posterior auricle.

Discussion — This inoceramid is an important guide fossil for the top of the middle Turonian in the Western Interior.

Occurrence — The types from Utah are from the middle Turonian *Prionocyclus hyatti*, as are the specimens from Black Mesa, known only from the transition zone between the Mancos Shale and Toreva Formation on the north and east sides of the basin (MNA #878, #988). Elsewhere it is widespread across the Western Interior.

Illustrated material — MNA N3570, N3578, N5440 from MNA #988, Mancos Shale-Toreva Formation transition zone.

Paleoecology — Kauffman (1967, 1969a) proposed that inoceramids of this type were byssally attached to the seafloor in nearshore, relatively high-energy environments. The flat anterior face of this species may indicate that it could have been held tight to the substrate when unpredictable high energy events (storms) occurred.

Inoceramus nodai Matsumoto and Tanaka, 1988
Plate 12, Figure A; Plate 19, Figure K;
Plate 20, Figures A, D

Inoceramus tenuistriatus Nagao and Matsumoto; Pergament, 1966, p. 47, pl. 13, figs. 2–4, pl. 14, figs. 2–4.
Inoceramus tenuistriatus ? Nagao and Matsumoto; Kauffman and Powell, 1977, p. 67, pl. 2, fig. 5; pl. 3, figs. 7, 9, 10.
Inoceramus tenuistriatus Nagao and Matsumoto; Keller, 1982, p. 62, pl. 1, figs. 3a, b.
Inoceramus nodai Matsumoto and Tanaka, 1988; p. 571, figs. 1–3, 5–13.

Description — Moderately thin shell, medium to large (to 10 cm high); broad, subquadrate to subcircular outline; beak terminal, little enrolled, and barely projecting; umbo moderately inflated; subequivalve; hingeline long with auricle poorly differentiated from disk; moderately inclined during early growth (around 50°) becoming more erect during later ontogeny (65°); anterior margin steep and straight to concave; shell ornamented by even concentric rugae and fine raised growth lines.

Discussion — *Inoceramus nodai* is superficially similar to *Inoceramus tenuistriatus* Nageo and Matsumoto (1939) from the upper Turonian of Japan. *Inoceramus tenuistriatus* has recently been the subject of an extensive review by Noda (1988), who demonstrated that this species lacks the even rugae and large size of specimens referred to the species from the upper Cenomanian. Matsumoto and Tanaka (1988), in their study of the upper Cenomanian Inoceramidae from Japan, defined the species *Inoceramus nodai* and recognized this species in the upper Cenomanian of North America and Europe had been previously referred to *Inoceramus tenuistriatus*.

Occurrence — The type specimens are from Japan with the species reported to occur throughout the upper Cenomanian. At Black Mesa in the lower part of the lower shale member of the Mancos Shale the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone upward through the *Neocardioceras juddii* Zone. In the central Western Interior extends downward into at least the *Metoicoceras mosbyensis* Zone. Present nearly worldwide.

Illustrated material — MNA N3568 from MNA loc. #324, BM10; MNA N1228, from MNA loc. #304, BM11; N3524, N3530 from MNA loc. #814, BM11; all from lower part, lower shale member, Mancos Shale.

Paleoecology — The large broad shell found in adult examples indicates that this species may have been free lying on the substrate. Juveniles may have been byssally attached.

Inoceramus sp. cf *I. nodai* Matsumoto and Tanaka, 1988
Plate 28, Figure K

Description — Moderately thin shell, medium-sized (5 cm high), broad, subcircular outline; beak terminal and barely projecting; umbo moderately inflated; hingeline moderately long with auricle poorly differentiated from disk;shell moderately erect (inclination of 65°); anterior margin steep and straight, forming slightly obtuse angle with hinge; mature shell ornamented by even concentric rugae and fine raised growth lines.

Discussion — *Inoceramus* is rare in the lower Turonian of the Western Interior. Most specimens from the central Western Interior that the author has seen, seem comparable to *Inoceramus pictus*.

One specimen referable to the genus *Inoceramus* has been collected from the lower Turonian at Black Mesa. It is compared to *Inoceramus nodai* on the basis of its relatively broad shell, but as the specimen is badly crushed and poorly preserved it is possible that it may be closer to another species of *Inoceramus*.

Occurrence — One specimen from MNA loc. #262, middle part of the lower shale member of the Mancos Shale two meters below BM21, lower Turonian *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone.

Illustrated material — MNA N5254 from MNA loc. #262, 2 m below BM21, middle part, lower shale member, Mancos Shale.

Paleoecology — Like *Inoceramus nodai* this form may have been a free-lying species as an adult.

Inoceramus pictus Sowerby, 1829
Plate 12, Figures B, E–J; Plate 25, B, C

Inoceramus pictus Sowerby, 1829; Woods, 1911, (in part), p. 279, fig. 36, non pl. 49, figs. 5, 6.
Inoceramus pictus pictus Sowerby, 1829; Kauffman and Powell, 1977, p. 55, pl. 1, fig. 1.
Inoceramus pictus gracilistriatus Kauffman and Powell, 1977; p. 56, pl. 1, fig. 2.

Description — Thin shell, medium to large (to 10 cm high); subrectangular; beak terminal, little enrolled, and variably projecting; umbo moderately inflated; moderately inequivalve; hinge moderately long with auricle differentiated from disk by break in slope by weak posterior sulcus; shell moderately erect (inclination of 65 to 70°); anterior margin steep and straight to concave; shell ornamented by evenly spaced concentric rugae of unequal strength, and fine irregular raised growth lines.

Discussion — Kauffman and Powell (1977) documented that members of the *Inoceramus pictus* lineage are the most common inoceramids in the upper Cenomanian of the Western Interior. They erected the subspecies *Inoceramus pictus gracilistriatus* as in the Western Interior many, if not most, differ from the type concept of *Inoceramus pictus* from England in being less inflated, having a smaller posterior auricle, having finer more irregular growth lines and weaker rugae. The specimens, while variable in the strength of the growth lines, compare well with Kauffman and Powell's (1977) *Inoceramus pictus gracilistriatus*.

Occurrence — The type is from the upper Cenomanian of southern England and ranges from the upper middle through uppermost Cenomanian. At Black Mesa, ranges from very rare specimens at the top of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone and becomes common up section ranging through to the top of the Cenomanian and possible basal Turonian above BM13. Elsewhere, various subspecies occur nearly worldwide.

Illustrated material — MNA N232 from MNA loc #271, BM10; MNA N3566, N3567 from MNA loc. #989, BM8; MNA N3563 from MNA loc. #254, BM10, MNA N5518 from MNA loc. #306, BM10; MNA N9120 from MNA loc. #236, BM8; MNA N232, N3564 from MNA loc. #305, concretions associated with BM12 and BM13; all from lower part, lower shale member, Mancos Shale.

Paleoecology — Kauffman (1967, 1969a) interpreted this species to have been a byssally attached form. However, Kauffman and Powell (1977) have reinterpreted this species to be free lying to weakly attached by a byssus.

Genus *Mytiloides* Brongniart, 1822

Discussion — Seitz (1934) documented that the prevailing concept of *Mytiloides labiatus* (the type species) was incorrect and that historically *Mytiloides mytiloides* had been thought to represent the concept of *Mytiloides labiatus*. In addition, he documented that *Mytiloides labiatus* was part of a rapidly evolving lineage in which he recognized numerous varieties.

Employing careful morphometric analysis of successive populations, Kauffman (1970) has documented a series of biostratigraphically useful species and subspecies. Some of the preliminary results of this work have been reported in Kauffman (1975) and Kauffman and Powell (1977). Stanley (1979) reported this work as recording one of the best examples of gradualism he knows of, although Kauffman (1987, personal communication) now recognizes a series of small scale punctuated events in the evolution of the lineage as well. The complex evolution of this lineage has made recognition of species moderately difficult.

Matsumoto and Noda (1975) and Badillet and Sornay (1980) have recognized the overlap of quite different species types from the *Mytiloides labiatus* lineage and have questioned the ability to subdivide the lineage into meaningful species. The author has recognized the same changes in morphology from the beginnings of the lineage to near the end of the lineage at Black Mesa that Kauffman (1970, 1975, 1976a, 1976b; Kauffman and Powell, 1977) has recognized in the central Western Interior and overseas. Thus this basic classification is used herein.

A vertical classification is used here, as opposed to a horizontal classification. This is done for ease as much as anything else. A great deal more work needs to be done to establish the amount of gene flow between different morphologic types at successive stratigraphic levels, although at levels the different morphologies do appear to maintain their distinctive morphologies quite well. Kauffman (1987, personal communication) is building on a data base that should answer these questions and it is not within the scope of the present work to provide a final classification of this important group.

Paleoecology — Inoceramids of the genus *Mytiloides* have no pedalbyssal muscle scars or byssal slit and have been interpreted as free-lying on the seafloor or possibly semi-infaunal (Kauffman, 1967, 1969a; Kauffman and Powell, 1977). The thin shell of these species was not well suited to high energy conditions.

Mytiloides sp. cf. *M. teraokai* (Matsumota and Noda)
Plate 49, Figures I–K; Plate 50, Figures A, F

Inoceramus codellanus Kauffman, 1961, Ph. D.; p. 58, pl. 3, figs. 6–9, 11, ?10.
Inoceramus teraokai Matsumota and Noda, 1968; p. 319, pl. 32, figs. 1–5, text-fig. 2.
Inoceramus teraokai Matsumota and Noda; Noda, 1975, p. 248, pl. 32, figs. 1–5, 9, text-fig. 15A.
Mytiloides teraokai (Matsumota and Noda); Matsumoto, Noda, and Kozai, 1982, p. 64, pl. 9, figs. 4, 5.
Mytiloides teraokai (Matsumota and Noda); Elder, 1992, p. 31, fig. 15.1.

Description — Thin shell, moderately large (up to 12 cm high), outline during early growth nearly circular, becoming elongate on maturity; prosogyrus; blunt beak little projecting, situated 10–20% of length from anterior margin; shell moderately inclined (50–60°); moderately inflated, slightly inequivalve; posterior auricle short, narrow and differentiated from main part of shell by break in slope, anterior margin extended laterally to form a small rounded anterior auricle; shell ornament of regularly spaced concentric rugae, which tend to be strongest on posterior slope.

Discussion — Kauffman (1961) described this form from the middle Turonian Codell Sandstone Member of the Carlile Shale. Overall the Black Mesa specimens compare very well with this material. One illustrated specimen (Kauffman, 1961, pl. 3, fig. 10) displays a much larger anterior auricle than has been observed on any of the Black Mesa specimens.

Elder (1992, personal communication) has pointed out to the author the similarities between "Inoceramus codellana" (Kauffman, 1961) and *Mytiloides teraokai* (Matsumoto and Noda, 1968) in both form and age. Until a detailed comparison is made it is thought that it is best to compare this material to *Mytiloides teraokai*.

Occurrence — *Mytiloides teraokai* occurs in the middle Turonian of Japan and the middle-upper Turonian of Alaska (Elder, 1992). Kauffman's (1961) specimens are from the Codell Sandstone Member of the Carlile Shale, middle Turonian *Prionocyclus hyatti* Zone. The specimens from Black Mesa are slightly older and are known from one locality near the top of a sandstone interval in the upper shale member 20 m below the base of the Toreva Formation, middle Turonian *Prionocyclus hyatti* Zone at the Lohali Point section (MNA loc. #989).

Illustrated material — MNA N3550, N5434, N5435, N5437, N5463 from MNA loc. #989, siderite concretions 19 m below base of Toreva Formation, upper shale member, Mancos Shale.

Mytiloides columbianus (Heinz, 1935)

Plate 26, Figure G; Plate 29, Figures A–E, J

Orpheoceramus columbianus Heinz, 1935; p. 304.
Mytiloides sp. transitional between *M. opalensis* (Böse) and *M. mytiloides* (Mantell) Kauffman and Powell, 1977, p. 78, pl. 6, fig. 4; pl. 7, fig. 3.
Mytiloides columbianus (Heinz); Kennedy, Wright, and Hancock, 1987, p. 64, text-fig. 12A–C.

Description — Thin shell, medium-sized (to 7.5 cm high); outline curved oval; prosogyrus; blunt beak little or not projecting, situated 5–10% of length from anterior margin; shell moderately inclined (average of 50°); moderately inflated, slightly inequivalve; posterior auricle triangular and differentiated from disk by break in slope; shell ornament of regularly spaced concentric rugae which become separated by several raised growth lines at 2–4 cm from beak along growth axis.

Discussion — *Mytiloides columbianus* is close to *Mytiloides mytiloides* and differs only in maintaining evenly spaced concentric rugae without intervening raised growth lines to a significantly later stage in ontogeny. As this early ornament is like that found in *Mytiloides elongata* (usage herein), immature specimens of *Mytiloides columbianus* may be confused with *Mytiloides elongata*.

Mytiloides columbianus provides a transitional form between *Mytiloides elongata* and *Mytiloides mytiloides* in its progressive acquisition of crowded raised growth lines at earlier and earlier stages of development. *Mytiloides columbianus* overlaps with the range of *Mytiloides elongata* in the lower part of its range and overlaps completely the range of *Mytiloides mytiloides* at the top of its range. In addition, *Mytiloides columbianus* may have given rise to *Mytiloides subhercynicus* by becoming broader in its shell form. Its range overlaps with that of *Mytiloides subhercynicus* at the top of its range.

Occurrence — The type was described from the lower Turonian of Columbia. At Black Mesa, common in the middle part of the lower shale member of the Mancos Shale from about BM15 *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone to about BM30 middle *Mammites nodosoides* Zone (Kirkland, 1990).

Illustrated material — MNA N5471, N5244, from MNA loc. #262, BM18; MNA N5458 from MNA loc. #262, below BM15; MNA N5215, from MNA loc. #262, BM20; MNA N5246 from MNA loc. #262, BM23-24; MNA N5251 from MNA loc. #989, 3 m above BM26; MNA N5592 from MNA loc. #989, below BM17; all from lower shale member, Mancos Shale.

Mytiloides duplicostatus (Anderson, 1958)

Inoceramus duplicostatus Anderson, 1958; p. 100, pl. 17, figs. 3, 4.
Mytiloides sp. aff. *M. duplicostatus* (Anderson); Kauffman and Powell, 1977, p. 100, pl. 7, figs. 2, 6.

Diagnosis — *Mytiloides duplicostatus* is much like *Mytiloides elongata* and differs primarily in having paired rugae, which are evenly spaced.

Discussion — As *Mytiloides duplicostatus* is so similar to *Mytiloides elongata* and completely overlaps its range at Black Mesa, it is very possible that it represents simply a distinct variation of *Mytiloides elongata*. *Mytiloides duplicostatus* is much more uncommon relative to *Mytiloides elongata* at Black Mesa.

Occurrence — The type is from the lower Turonian of California. Uncommon at Black Mesa from the middle part of the lower shale member of the Mancos Shale in the lower Turonian a short distance above the Cenomanian-Turonian stage boundary below BM14 *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone to about the top of the *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone. Widespread in the Western Interior at this level.

Illustrated material — MNA N5051 from MNA loc. #813, below BM15, lower part; MNA N5547 from MNA loc. #989, BM28, middle part, lower shale member, Mancos Shale.

Mytiloides elongata (Seitz, 1934)

Plate 28, Figures B–E, G

non *Inoceramus opalensis* Böse, 1923, p. 184, pl. 13, figs. 1–3.
Inoceramus labiatus var. *opalensis*, Böse; Seitz, 1934 p. 340, pl. 39, fig. 1a, b; text-figs. 14a–c, 15a–c.
Inoceramus labiatus var. *opalensis*, n. f. *elongata*, Seitz, 1934 p. 340, pl. 38, figs, 4–6; pl. 39, fig. 2–4; text-figs. 14a–c, 15a–c.
Mytiloides opalensis (Böse); Kauffman and Powell, 1977, p. 79, pl. 6, figs. 3, 6.
Inoceramus goppelnensis Badillet and Sornay, 1980; p. 323.
? non *Orpheoceramus columbianus* Heinz, 1935; p. 304.

Description — Thin shell, medium-sized (up to 6 cm high); outline subcircular to oval; prosogyrus; blunt beak little or not projecting, situated 10–20% of length from anterior margin; shell moderately inclined (45–60°); little inflated, slightly inequivalve; posterior auricle triangular and differentiated from main part of shell by break in slope; shell ornament of regularly spaced concentric rugae, which tend to be strongest on posterior slope.

Discussion — *Mytiloides elongata* is a particularly important species of inoceramid in that it generally is the first common species of inoceramid above the Cenomanian-Turonian stage boundary globally. Unfortunately, there has been considerable dispute as to its nomenclature.

The nomenclatural problems arise from Seitz's (1934) mistaken assumption that Böse's (1923) species *Inoceramus opalensis* was the same form as his *Inoceramus labiatus* var. *opalensis* from the basal Turonian. Research by Cobban has indicated that Böse's specimens came from high in the lower Turonian or even in the middle Turonian (Matsumoto and Noda, 1986; Kennedy and others, 1987). This mistake in identity has been propagated for some time (e.g., Kauffman, 1975, 1977b, 1977d; Troger, 1981; Birkelund and others, 1984). In recent years several names have erected to include Seitz's concept of *Mytiloides opalensis*.

Badillet and Sornay (1980) erected the species *Inoceramus goppelnensis*, based on the material illustrated by Seitz as *Inoceramus labiatus* var. *opalensis* from Goppeln, Germany, to include the species *Mytiloides opalensis sensu* Seitz and *Mytiloides subhercynicus*. Several subsequent authors have agreed (Keller, 1982; Matsumoto and Noda, 1986). However, *Mytiloides subhercynicus* is a distinct species. Badillet and Sornay (1980) did not use the name *Inoceramus elongata* as the name had been previously used by Etheridge (1872). As *Mytiloides elongata* is a species of the genus *Mytiloides*, Etheridge's (1872) use of *Inoceramus elongata* should pose no problem.

Cobban and others (1987), suggested that *Orpheoceramus columbianus* of Heinz (1935) is synonymous with *Mytiloides opalensis sensu* Seitz. The specimens illustrated by Kennedy and others (1987), display raised growth lines between the rugae and appear to represent a form transitional between typical *Mytiloides opalensis sensu* Seitz and *Mytiloides mytiloides*. This name is used herein (see above) for such forms. Heinz (1935) did not illustrate his species, and if it is truly synonymous with *Mytiloides opalensis sensu* Seitz, then it would still be a junior synonym of *Mytiloides elongata*.

For the time being the author feels the term *Mytiloides elongata* has priority for this species. Etheridge (1872) described *Inoceramus elongata* from Queensland, Australia, but the species appears to be a true species of *Inoceramus*, thus the term "elongata" would be available for a species of *Mytiloides*.

Further study of little known species that were described earlier may change this view. It is important that international agreement be made soon on this significant taxon. It is somewhat unfortunate that this name must be used for this species, because compared to several other species of the genus, *Mytiloides elongata* is not very elongate.

Occurrence — Common at Black Mesa, from in the middle part of the lower shale member of the Mancos Shale in the lower Turonian a short distance above the Cenomanian-Turonian stage boundary below BM14 *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone to about the top of the *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone (Kirkland, 1990). Elsewhere nearly worldwide at this level.

Illustrated material — MNA N5249, above BM15; MNA N5546, one meter above BM15; MNA N5522, one meter above BM16; all from MNA loc. #262; MNA N5258, below BM16; MNA N5252, above BM14; both from MNA loc. #989; all from lower part, lower shale member, Mancos Shale.

Mytiloides hattini Elder, 1991

Plate 28, Figure A

Inoceramus sp. Hattin, 1975a, p. 44, pl. 5, fig. T.
Mytiloides n. sp. Elder and Kirkland, 1985, p.133.
Mytiloides n. sp. A Elder, 1989b, figs.5–9.
Mytiloides hattini Elder, 1991; p. 235–240, fig. 3.1–19 (with synonmy).

Description — Thin shell, medium-sized (up to 7.5 cm high); outline curved oval; prosogyrus; blunt beak little or not projecting and 5–10% of length from anterior margin; shell moderately inclined (average of 55°), slightly inflated, slightly inequivalve; posterior auricle triangular and differentiated from main part of shell by break in slope; shell ornament of closely spaced concentric raised growth lines, with weak rugae present on some specimens.

Discussion — *Mytiloides hattini* is readily distinguished from all other lower Turonian species of *Mytiloides* in its ornament of dense, evenly spaced raised growth lines. This species of *Mytiloides*, which is currently under study by Elder (1990, mauscript submitted), is of particular importance in biostratigraphy in that it is the most widespread occurring fossil above the Cenomanian-Turonian stage boundary, among all lower Turonian fossil groups in the Western Interior. *Mytiloides elongata*, which is also characteristic of the basal lower Turonian usually occurs a short distance above the first occurrence of *Mytiloides hattini*.

Occurrence — At Black Mesa, first appears at the Cenomanian-Turonian stage boundary between BM13 and BM15, *Pseudaspidoceras flexuosum* through to BM20, *Vascoceras birchbyi* subzones of the *Watinoceras coloradoense* Zone (Kirkland, 1990). It is most abundant at the base of its range. It occurs throughout the Western Interior at this level.

Illustrated material — MNA N5458 from MNA loc. #989, below BM14, lower part, lower shale member, Mancos Shale.

Mytiloides hercynicus (Petrascheck, 1903)

Plate 31, Figures D, H

Inoceramus labiatus Schlotheim; Hattin, 1962, p. 54, pl. 14, fig. B, ? D, ? non pl. 14, figs. F, G.
Mytiloides hercynicus (Petrascheck); Kauffman, 1976b, pl. 3, fig. 7.
Mytiloides hercynicus (Petrascheck); Keller, 1982, pl. 4, fig. 1, text-fig. 59.

Description — Thin shell, moderately large (to 15 cm high); outline subcircular; prosogyrus; blunt beak slightly projecting and 10–15% of length from anterior margin; shell moderately inclined (50–60°); little inflated, slightly inequivalve; posterior auricle small poorly defined, weakly ornamented; shell ornament of dense regularly spaced narrow rugae, which range from nearly circular to subquadrate in trend and become more widely separated and interspersed with strong raised growth lines with increasing size.

Discussion — This distinct species is the highest common species of *Mytiloides* found at Black Mesa and provides a useful basis on which to divide the *Collignoniceras woollgari* Zone, as it is present only in the lower part of the zone.

Occurrence — At Black Mesa, in the upper most lower shale member of the Mancos Shale, above BM32, lower Turonian *Mammites nodosoides* Zone through the middle Turonian *Collignoniceras woollgari woollgari-Mytiloides hercynicus* subzone of the *Collignoniceras woollgari* Zone, about a meter above BM62 in the middle shale member and is most common in the upper half of its range (Kirkland, 1990). Elsewhere nearly worldwide.

Illustrated material — MNA N3549, N5233 from MNA loc. #262, above BM54, base of middle shale member, Mancos Shale.

Mytiloides latus (Sowerby, 1828) *sensu* Hattin, 1962

Plate 37, Figures O, Q

non *Inoceramus labiatus* var. *latus* Sowerby; Woods, 1911, p. 284, text-figs. 38–40.
Inoceramus latus Sowerby; Hattin, 1962, p. 54, pl. 14, figs. A, C, E.
Inoceramus latus Sowerby; Hattin, 1975b, p. 201, pl. 2, fig. 5.
non *Inoceramus latus* Mantell; Keller, 1982, p. 85, pl. 6, fig. 4.

Description — Thin shell, rather small (2.5 cm high); outline subcircular; slightly prosogyrus; blunt beak not projecting and about 25% of length from anterior margin; shell moderately inclined (average of 60°); little inflated, slightly inequivalve; posterior auricle poorly differentiated from main part of shell; anterior margin of shell greatly expanded, fine ornament of regularly spaced concentric rugae and dense raised growth lines.

Discussion — The type of *Inoceramus labiatus* var. *latus* is from the upper Turonian of southern England. It differs in having a nearly terminal beak, being more inclined, and being more inflated (compare with Woods, 1911). *Mytiloides latus sensu* Hattin on the other hand is from the middle Turonian and has beaks that are close to the midline of the shell because of the extensive anterior expansion of the shell, a much more erect shell, and a little inflated shell. Kauffman (1990, personal communication) has suggested that the North American species may be related to *Sergipia*.

Occurrence — At Black Mesa present from just below the Hopi Sandy Member upward to about the top of the unit, middle Turonian uppermost *Collignoniceras woollgari woollgari* subzone into basal *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990). Elsewhere widespread in the Western Interior. Hattin (1962) reports it from the upper part of the Fairport Chalky Shale Member of the Carlile Shale in central Kansas.

Illustrated material — MNA N5517 from MNA loc. #989, MNA N5240 from MNA loc. #298, both from just below top of Hopi Sandy Member, Mancos Shale.

Mytiloides sp. cf. *M. latus* (Sowerby)

Plate 28, Figures H, I

Description — Thin shell, rather small (3 cm high), outline subcircular; slightly prosogyrus; blunt beak little projecting and nearly terminal; shell moderately inclined (average of 55°), little inflated, slightly inequivalve; posterior auricle set off from main part of shell by slight break in slope; anterior margin of shell expanded; fine shell ornament of regularly spaced concentric rugae and dense raised growth lines after geniculation rugae strengthen.

Discussion — This inoceramid is similar to *Mytiloides latus sensu* Hattin (1962, 1975b) in overall form but is more inclined and has nearly terminal beaks. In this it is more similar to *Mytiloides latus sensu stricto*.

Its relationships to *Mytiloides latus sensu* Hattin is unknown, as no intermediate forms have been found between its occurrence in the lowest Turonian and that of *Mytiloides latus sensu* Hattin in the middle Turonian.

Occurrence — Present at Black Mesa, in the lower Turonian from below BM14, *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone to below BM27, lower *Mammites nodosoides* Zone (Appendix C). Elder (1987, personal communication) reports that this inoceramid is widespread throughout the Western Interior.

Illustrated material — MNA N5237 from MNA loc. #306, just above Cenomanian-Turonian boundary, 3 m above BM13, MNA N5238 from MNA loc. #989, 2 m above BM16, both from lower part, lower shale member, Mancos Shale.

Mytiloides labiatus (Schlotheim, 1813)

Plate 30, Figure E; Plate 31, Figure A

Inoceramus labiatus Schlotheim; Seitz, 1934, p. 450, pl. 38, figs. 1–3.
Mytiloides labiatus labiatus (Schlotheim); Kauffman, 1976b, pl. 4, fig. 9; pl. 5, figs. 8, 14.
Mytiloides labiatus (Schlotheim) n. subsp., Kauffman, 1976b; pl. 2, fig. 6; pl. 3, fig. 4, 5; pl. 5, figs. 17, 18.
Mytiloides labiatus (Schlotheim); Kauffman and Powell, 1977, p. 72, pl. 7, fig. 5.

Description — Thin shell, large (to 15 cm high); shape curved, elongate; blunt, prosogyrus, beak little to well projecting and 5–10% of length from anterior margin; shell moderately inclined (average of 40°); typically with inflated erect umbo; whereas most Black Mesa specimens only moderately inflated; moderately inequivalve; posterior auricle triangular and well differentiated from main part of shell by break in slope; shell ornament of irregular rugae.

Discussion — Specimens of *Mytiloides labiatus* are rare at Black Mesa, and those that do occur are mostly what appears to be an early form that is not as inflated as the type concept of Seitz (1934). Those rather rare specimens that appear to have an inflated umbo are badly distorted by compaction. Typical specimens of *Mytiloides labiatus* are much more common and apparently appear earlier to the north in Montana and Canada (Elder, 1987, personal communication).

Kauffman (e.g., 1976b, 1977b) has recognized a new late subspecies of *Mytiloides labiatus*, which has crowded, concentric raised growth lines during early growth and following a geniculation becomes inflated with typical ornament of *Mytiloides labiatus*. Specimens of this form have been observed in the basal middle Turonian of in the upper part of the Bridge Creek Limestone Member of the Greenhorn Limestone in central Colorado (Elder and Kirkland, 1985). Poorly preserved specimens like these have been observed in the upper part of lower shale member of the Mancos Shale at Black Mesa, ranging higher than typical *Mytiloides labiatus*.

Occurrence — The type is from the highest lower Turonian or basal middle Turonian of Germany. At Black Mesa uncommon in the upper lower shale member of the Mancos Shale from about BM27, lower Turonian *Mammites nodosoides* Zone to about BM40, basal middle Turonian *Collignoniceras woollgari woollgari-Mytiloides hercynicus* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990). Elsewhere nearly worldwide.

Illustrated material — MNA N5523 from MNA loc. #989, below BM27; MNA N5241 from MNA loc. #262, below BM38; both from lower shale member, Mancos Shale.

Mytiloides mytiloides (Mantell, 1822)

Plate 29, Figures F–I; Plate 30, Figure A

Inoceramus labiatus Schlotheim; Stanton, 1893, p. 77, pl. X, fig. 4; pl. XIV, fig. 2.
Inoceramus labiatus Schlotheim; Woods, 1910, p. 281, fig. 37?, pl. 50, 1–4.
Inoceramus labiatus var. *mytiloides* Mantell; Seitz, 1934, p. 340, pl. 36, figs. 1–4, text-fig. 2a–f.
Mytiloides mytiloides (Mantell); Kauffman and Powell, 1977, p. 74, pl. 6, figs. 11–16; (with synonymy).
Mytiloides mytiloides (Mantell) s.l.; Cobban, 1983, p. 6, pl. 1, fig. 1; pl. 8, figs. 8, 9.

Description — Thin shell, medium-sized (up to 7.5 cm high); outline curved oval; blunt, prosogyrus beak slightly or not projecting and 5–10% of length from anterior margin; shell moderately inclined (average of 50°); moderately inflated, slightly inequivalve; posterior auricle triangular and differentiated from main part of shell by break in slope; ornament of regularly spaced concentric rugae, which become separated by several raised growth lines 1–1.5 cm ventral of beak.

Discussion — This is the *Inoceramus labiatus* of most authors (Kauffman and Powell, 1977). It is readily distinguished from *Mytiloides labiatus* by having a less inflated umbo and regular, even ornament.

This species is close to *Mytiloides columbianus* from which it differs primarily in the occurrence of fine raised growth lines early in ontogeny. Its gradual replacement of *Mytiloides columbianus* as the dominant species of *Mytiloides* suggests the gradational evolution of *Mytiloides mytiloides* out of *Mytiloides columbianus*. *Mytiloides mytiloides* in turn gives rise to *Mytiloides labiatus*.

Occurrence — At Black Mesa, common in the middle part of the lower shale member of the Mancos Shale from BM17 to BM30, lower Turonian *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone into the upper *Mammites nodosoides* Zone (Kirkland, 1990). Elsewhere nearly worldwide.

Illustrated material — MNA N5053, BM28; MNA N5243, BM30; both from MNA loc. #989; rest from MNA loc. #262, MNA N5248, BM18; MNA N5235, below BM26; MNA N5255, one meter BM28; all from middle part, lower shale member, Mancos Shale.

Mytiloides mytiloides arcuata (Seitz, 1934)

Plate 30, Figures B–D, F

Inoceramus labiatus var. *mytiloides* n. f. *arcuata* Seitz, 1934, p. 340, pl.37, figs. 4, 5, text-figs. 3d–f.
Mytiloides mytiloides arcuata (Seitz); Kauffman, 1977b, pl. 6, fig. 9.

Diagnosis — Large (to 15 cm high); ornament and convexity like typical *Mytiloides mytiloides*; but more elongate, curved, and inclined (average of 35°) like *Mytiloides labiatus*.

Discussion — This variety of *Mytiloides mytiloides* provides a transition from *Mytiloides mytiloides* into *Mytiloides labiatus*.

Occurrence — At Black Mesa, middle part of lower shale member of the Mancos Shale, BM27 to about three meters above BM32, lower Turonian *Mammites nodosoides* Zone (Kirkland, 1990). Elsewhere nearly worldwide.

Illustrated material — MNA N5048, above BM30; MNA N5236, N5049, BM30; All from MNA loc. #989; MNA N5257 from MNA loc. #262, below BM28; all from middle part, lower shale member, Mancos Shale.

Mytiloides subhercynicus (Seitz, 1934)

Plate 31, Figures B, C

?? *Mytiloides opalensis* Böse, 1923; p. 184, pl. 13, figs. 1–3.
Inoceramus labiatus var. *subhercynicus* Seitz, 1934, p. 340, pl. 40, figs. 1, 2, 5, text-fig. 13a–f.
Inoceramus labiatus var. *subhercynicus* n. f. *transiens* Seitz, 1934; p. 340, pl. 40, figs. 3, 4.
Mytiloides subhercynicus transiens (Seitz); Kauffman, 1976b, pl. 1, fig. 6; pl. 2, figs. 2, 7.
Mytiloides subhercynicus (Seitz); Kauffman, 1976b, pl. 3, fig. 3.
Inoceramus goppelnensis transiens Badillet and Sornay, 1980; p. 323.
Mytiloides transiens (Seitz); Keller, 1982, p. 133, pl. 3, fig. 5.

Description — Thin shell, moderately large (to 9 cm high); outline subcircular; blunt, prosogyrus beak only slightly projecting and 10–15% of length from anterior margin; shell moderately inclined (50–60°), little inflated, slightly inequivalve; posterior auricle narrow poorly defined; shell ornament of regularly spaced concentric rugae, which become separated by several raised growth lines 2–3 cm away from beak along growth axis.

Discussion — *Mytiloides subhercynicus transiens* is distinguished in being somewhat more elongate and in having rugae becoming subparallel to hinge line in mature specimens. Both forms are present at Black Mesa.

Badillet and Sornay (1980), in disputing the utility of inoceramids of the *Mytiloides labiatus* lineage, synonymized *Mytiloides opalensis sensu* Seitz and *Mytiloides subhercynicus* and created the term *Inoceramus goppelnensis* for these forms. As discussed above under *Mytiloides elongata*, these forms should not be synonymized, as *Mytiloides opalensis sensu* Seitz is not as large or broad. They do recognize Seitz's *Inoceramus labiatus* var. *subhercynicus* n. f. *transiens* as a separate group under *Inoceramus goppelnensis transiens*.

In addition, they described the new subspecies *Mytiloides goppelnensis tourtenayensis*, which is distinguished by having the earliest few centimeters characterized by dense concentric rugae separated from a mature ornament like that of typical *Mytiloides subhercynicus* by a sharp change in ornament. Specimens of *Mytiloides* in the basal middle Turonian Pfiefer Member of the Greenhorn Limestone, that compare well with *Mytiloides goppelnensis tourtenayensis*, occur with *Mytiloides subhercynicus* and *Mytiloides hercynicus*. Badillet and Sornay (1980) use the co-occurrence of these taxa in France to dispute the utility of these inoceramids in biostratigraphy.

Mytiloides goppelnensis tourtenayensis provides an interesting clue to the origin of *Mytiloides hercynicus*. It suggests that *Mytiloides hercynicus* developed from *Mytiloides subhercynicus* through *Mytiloides goppelnensis tourtenayensis* by neoteny.

Mytiloides goppelnensis tourtenayensis has not been identified at Black Mesa, but the interval in which it should occur is characterized by poor preservation and it is possible that specimens of this taxa could have been mistaken for *Mytiloides subhercynicus* or *Mytiloides hercynicus*.

Mytiloides subhercynicus may have had its origins in *Mytiloides columbianus* by simply increasing the breadth of the shell. Although somewhat more erect, there would appear to be a remote possibility that *Mytiloides opalensis* is a senior synonym of *Mytiloides subhercynicus*, as Böse's type compares rather well and is from the high lower Turonian to low middle Turonian (Kennedy and others, 1987).

Occurrence — At Black Mesa, in the upper half of the lower shale member of the Mancos Shale, BM28 to about BM50, lower Turonian *Mammites nodosoides* Zone into the middle Turonian *Collignoniceras woollgari woollgari-Mytiloides hercynicus* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990). Elsewhere nearly worldwide.

Illustrated material — MNA N3548, below BM28; MNA N5255, one meter below BM28; both from middle part, lower shale member, Mancos Shale.

Mytiloides submytiloides (Seitz, 1934)

Plate 12, Figure K; Plate 19, Figures L, M

Inoceramus labiatus var *submytiloides* Seitz, 1934; p. 444, pl. 37, figs. 1–3, text-figs. 6–8.
Mytiloides sp. cf. *M. submytiloides* (Seitz); Kauffman and Powell, 1977, p. 82, pl. 6, figs. 7, 10.

Description — Thin shell, medium-sized (5.5 cm high); outline subrectangular and slightly curved; blunt, prosogyrus beak somewhat projecting and terminal; shell moderately inclined (40 to 52°); moderately inflated, slightly inequivalve; posterior auricle poorly defined separated from main part of valve by shallow sulcus; umbonal ridge broad but well developed; shell ornament of irregularly spaced concentric rugae of variable strength which fade out on auricle.

Discussion — An anterior sulcus is present on some of Seitz's (1984) types (Kauffman and Powell, 1977). This feature has not been recognized on the specimens from Black Mesa. There seems to be a be an evolutionary trend within the species of weakly rugate forms in the *Sciponoceras gracile* Zone to increasingly more strongly rugate forms upward through the *Neocardioceras juddii* Zone.

Occurrence — The type is from near the Cenomanian-Turonian boundary in Germany, widespread at this level in the Western Interior. At Black Mesa, in the lower shale member of the Mancos from BM8 to a short distance above BM13, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone (mostly eastern Black Mesa) through *Neocardioceras juddii* Zone (Kirkland, 1990).

Illustrated material — MNA N6397 from MNA loc #236, BM8; MNA N3532 from MNA loc. #814, BM11; MNA N5257 from MNA loc. #262; all from lower part, lower shale member, Mancos Shale.

***Mytiloides*? n. sp.**

Plate 50, Figures G–I

Description — Thin shell, medium-sized (4.5 cm high); outline subtriangular; prosogyrus beak projecting and terminal; shell very inclined (average of 40°); inflated, slightly inequivalve; posterior auricle narrow and moderately well separated from main part of shell; umbonal ridge broad but well developed; shell ornament of regularly spaced concentric rugae which fade out on auricle.

Discussion — This species does not compare well with any described species of inoceramid. It is provisionally placed in the genus *Mytiloides* on the basis of its inclination, but it may well prove to be better assigned to another genus.

Occurrence — Present on the northern and eastern sides of Black Mesa in the uppermost Mancos Shale and basal Toreva Formation, middle Turonian *Prionocyclus hyatti* Zone (MNA loc. #878, #988).

Illustrated material — MNA N3575, N3576, N3579 from MNA loc. #988, lower sandstone member, Toreva Formation.

Paleoecology — In contrast to other species assigned to *Mytiloides*, this species has only been found in shallow water settings, suggesting a tolerance to higher energy conditions. This may be expressed in its great convexity in both valves.

Genus *Sergipia* Maury, 1925

***Sergipia hartti*? Hessel, 1988**

Plate 31, Figure E

Sergipia hartti Hessel, 1988; p. 23, text-figs. 32D–F, 33, 34.

Description — Thin shell, rather small (2.5 cm high), shell round and erect, little inflated; beak blunt and subcentral; posterior auricle long, not distinctly differentiated from disk; small anterior auricle present; shell ornamented by closely spaced evenly curved rugae.

Discussion — One compacted right valve from near the top of the lower Turonian seems to have a small anterior auricle and thus is assignable to the genus *Sergipia*. It would seem to be closest to *Sergipia hartti* Hessel (1988).

Sergipia is mainly characteristic of the southern hemisphere. Its presence in the Western Interior demonstrates the dispersal potential of the pelagic larvae of inoceramids (Kauffman, 1975).

Occurrence — The type is from high in the lower Turonian in the Sergipe Basin of Brazil, also recognized in west Africa. At Black Mesa, one specimen from the middle part of the lower shale member of the Mancos Shale from above BM32, lower Turonian *Mammites nodosoides* Zone (MNA loc. #262).

Illustrated material — MNA N5050 from MNA loc. #262, above BM32, middle part, lower shale member, Mancos Shale.

Paleoecology — Although Hessel (1988) interpreted *Sergipia* to be a byssally attached infaunal to semi-infaunal suspension-feeder, the shell form of this genus suggests that it was an epifaunal recumbent form (Kauffman, 1969).

Superfamily Pectinacea

Family Oxytomidae

Genus *Oxytoma* Meek, 1864

Paleoecology — These small pteriform bivalves probably were byssally attached to the substrate, reclining on the larger ornate left valve.

***Oxytoma*? sp.**

Plate 27, Figure A

Description — Very small (up to 0.8 cm high); thin-shelled pteriaform bivalves; hinge long and straight; anterior auricle broadly connected to disk along convex anterior margin; posterior auricle similar although nearly twice as long; shell ornamented by radial costae, which are best developed on posterior half of shell.

Discussion — The several available specimens of this taxon are very compacted. Assignment to *Oxytoma* is tentative as these may represent an undescribed species of *Phelopteria* with radial ornament.

Occurrence — Several specimens from the middle part of the lower shale member of the Mancos Shale below BM21, lower Turonian *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone at Blue Point (MNA loc. #262).

Illustrated material — MNA N4806 from MNA loc. #262, below BM21, middle part, lower shale member, Mancos Shale.

***Oxytoma* (*Hypoxytoma*) *arizonensis* n. sp.**

Plate 43, Figures L–N, O(a), P

Etymology — Named for the state of Arizona, where the types and only known specimens have been found.

Diagnosis — Closest to *Oxytoma nebrascana* from which it differs in having finer intercalated costellae on the left valve and no radial ornament on the right valve.

Description — Small (up to 1.5 cm); thin, pteriaform, bivalve, with highly dissimilar valves. Left valve inflated, with beak projecting above long straight hinge, beak located about 30% of distance from anterior margin; shell inclined about 70°; anterior auricle triangular with anterior margin forming continuous curve with ventral margin of disk and separated from disk by a break in slope; posterior auricle long, broad, and slightly projecting, with broadly concave posterior margin continuous with ventral margin; shell ornamented by evenly spaced narrow radial costae that are each separated by a single intercalated costella, that are crossed by raised growth lines to give radial ornament a beaded appearance. Right valve less inflated and slightly smaller; anterior ear separated from disk by byssal notch; long ligament groove extends length of hinge; shell unornamented but for fine growth lines.

Discussion — *Oxytoma* (*Hypoxytoma*) n. sp. is superficially similar to specimens of *Oxytoma* (*Hypoxytoma*) *nebrascana* (Evans and Shumard) illustrated by Speden (1970) from the Maestrichtian Fox Hills Formation of South Dakota. The Black Mesa species differs primarily in having finer intercalated costellae between the costae on the left valve and in having no ornament developed on the right valve.

Occurrence — Common at Black Mesa in the Blue Point Tongue of the Toreva Formation, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* at Blue Point (MNA loc. #1150).

Type specimens — Holotype, MNA N5055 left valve from capping sandstone; paratypes, MNA 5060 right valve from capping sandstone, MNA N5550, N5060, left valves from main body of the Blue point Sandstone Tongue, Toreva Formation, from MNA loc. #1150.

Family Entoliidae
Genus *Entolium* Meek, 1865
Entolium gregarium Kauffman and Powell, 1977

Plate 26, Figures K, L

Entolium (Entolium) gregarium Kauffman and Powell, 1977; p. 87, pl. 4, fig. 2; pl. 5, fig. 4; pl. 6, figs. 8, 9; pl. 8, figs. 1, 2.

Diagnosis — Very thin, small (to 0.6 cm high) shell; outline subcircular with relatively very small equal sized auricles, bilaterally symmetrical; triangular resiliifer; shell slightly inflated, ornament of fine faint growth lines.

Discussion — The compacted specimens at Black Mesa compare rather well with Kauffman and Powell's (1977) description of the species and the material from Black Mesa adds nothing to their description.

Occurrence — The type specimens are from the upper Cenomanian Hartland Shale Member of the Greenhorn Limestone of extreme northwestern Oklahoma. At Black Mesa, in the lower shale member of the Mancos Shale from BM15 to BM32, lower Turonian *Watinoceras coloradoense* Zone, to *Mammites nodosoides* Zone (Appendix C), locally abundant in the lower part of its range.

Illustrated material — MNA N4813, one meter above BM12; MNA N4815, below BM32; both from MNA loc. #989, middle part, lower shale member, Mancos Shale.

Paleoecology — The thin smooth shell, low convexity, and bilateral symmetry indicate that species of this genus were well adapted to free-lying on soupy substrates and were swimming to avoid predation (Kauffman, 1969b; Stanley, 1970). The great numbers of specimens commonly found together, often to the exclusion of other taxa, suggests that this a gregarious and possibly an opportunistic species (Kauffman and Powell, 1977).

Family Pectinidae
Genus *Syncyclonema* Meek, 1864

Discussion — Cox and others (1969) include *Syncyclonema* in the family Entoliidae. A careful analysis of the type species by Speden (1967) supports its inclusion in the Pectinidae. This is based on the less circular shape, deep byssal notch, ornamented auricles, and tooth-like structures on each side of the resilifer in *Syncyclonema*.

Syncyclonema spp.

Plate 43, Figures F–I; Plate 44, Figure P (d)

Description — Thin, small (to 1.0 cm high, but usually less) shell; subcircular to ovate, moderately inflated, nearly bilaterally symmetrical; auricles blunt and subequal in size on left valve; anterior auricle larger with underlying byssal notch on right valve; posterior auricle truncate; shell ornamented by fine ribs on auricles with a smooth disk except for fine growth lines and rarely very weak rugae.

Discussion — Specimens of *Syncyclonema* have been collected from a number of levels at Black Mesa. At the present time it has not been determined whether these specimens represent one species or several species.

Occurrence — At Black Mesa, present in concretions in the lower part of the lower shale member of the Mancos Shale, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone, common in the Blue Point Tongue, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone at Blue Point, one specimen from the upper shale member of the Mancos Shale associated with a sandstone interval 20 m below base of Toreva Formation, *Prionocyclus hyatti* Zone Lohali Point.

Illustrated material — MNA N5096, N5552, N5530 from main body and MNA N5063 from top of Blue Point Sandstone Tongue, Toreva Formation, MNA loc. #1150.

Paleoecology — These pectinids were byssally attached to the sea floor, but could swim well enough to escape predation. The occurrence of species of this genus in shell rich units suggests that they preferred to be byssally attached to objects on the substrate and nestled within the shell beds.

Genus *Camptonectes* (Agassiz MS) Meek, 1864

Paleoecology — Species of this genus were epifaunal and byssally attached much of the time, but were able to release the byssus and swim.

Camptonectes platessa White, 1874

Plate 6, Figures D, E

Camptonectes platessa White; White 1877, p. 176, pl. 17, fig. 5a.
Camptonectes platessa White; Stanton, 1893, p. 72, pl. IX, fig. 6.
? *Camptonectes* ex. gr. *C. virgatus* (Nilsson); Cobban, 1977, p. 16, pl. 19, fig. 7.

Description — Thin, medium-sized (to 4.5 cm high) shell; outline subcircular, slightly inflated, nearly bilaterally symmetrical; auricles triangular, differentiated from disk by narrow sulcae; anterior auricles longer than posterior auricles, anterior right auricle set off by byssal notch; auricles give dorsal side of shell a quadrate appearance; posterior margin broadly rounded; shell ornamented by dense, flattened radial costae that diverge near the midline of shell, interspaces narrower than costae; costae interrupted by periodic strong raised growth-lines.

Discussion — Stephenson (1952) has commented on the conservative nature of the genus *Camptonectes* in the Cretaceous and both his *Camptonectes moodyi* and *Camptonectes ellsworthensis* from the middle Cenomanian Woodbine Formation of Texas are close to *Camptonectes platessa.*

Occurrence — The type is from the upper Cenomanian 5 miles west of Mineral Springs, northern Arizona. At Black Mesa, present in the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #265, #963). Also present at this level in the uppermost Dakota Formation of Utah and across central Arizona and central New Mexico.

Illustrated material — MNA N1056 from MNA loc. #265; MNA N5077 from MNA loc. #963; both from sandstone facies, upper sandstone member, Dakota Formation.

Paleoecology — The distribution of this species indicates a preference for sand substrates under fairly high energy regimes.

Camptonectes sp. A

Plate 11, Figures S, X; Plate 26, Figure M

Diagnosis — Like *Camptonectes platessa* but smaller (to 1.5 cm high) and with denser, finer, divergent radial costae.

Discussion — It is possible that specimens assigned to this group represent more than one species as there is some variation in the length/height ratio. It is also possible that some of these specimens might represent dwarf forms of *Camptonectes platessa* restricted in size by unfavorable conditions offshore.

Occurrence — At Black Mesa sporadically present through much of the lower shale member of the Mancos Shale from the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone upward into the basal middle Turonian *Collignoniceras woollgari woollgari-Mytiloides hercynicus* subzone of the *Collignoniceras woollgari* Zone. Most common in the *Sciponoceras gracile* Zone.

Illustrated material — MNA N4816 from MNA loc. #306, BM10; MNA N4825 from MNA loc. #262, BM8; both from lower part; MNA N4820 from MNA loc. #262, below BM32, middle part, lower shale member, Mancos Shale.

Paleoecology — The distribution of these forms indicates a preference for offshore more quiet water environments.

Camptonectes sp. B
Plate 11, Figure Y

Diagnosis — Like *Camptonectes platessa*, but much smaller (1.0 cm), relatively more inflated, and has coarser radial costae.

Discussion — This form appears to represent a new species readily distinguished from those referred to *Camptonectes* sp. A.

Occurrence — At Black Mesa present in concretions of the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone. Also recognized at this level in southern Utah.

Illustrated material — MNA N4824 from MNA loc. #989, BM8, lower part, lower shale member, Mancos Shale.

Paleoecology — This species is interpreted to favor offshore setting with abundant shell debris.

Family Plicatulidae
Genus *Plicatula* Lamarck, 1801

Paleoecology — Most living species of *Plicatula* are cemented epifaunal bivalves. The species from Black Mesa have not been found cemented to other objects and tend to have small attachment areas. This suggests that these species were cemented early in ontogeny and then became free-lying on the substrate resting on their plicae and/or propped up on spines. As these species are found in both sandstone and open marine shale facies during transgression, it is suggested that they require low net sedimentation rates.

Plicatula hydrotheca White, 1876
Plate 6, Figures C, B (b); Plate 11, Figure P

Plicatula hydrotheca White; Stanton, 1893, p. 69, pl. IX, figs. 1, 2.

Description — Shell of medium thickness, small (average of 2 cm high); subtriangular to ovate, higher than long, moderately inflated; beak angle acute with rather straight dorso-posterior and dorso-anterior sides; ventral margin smoothly curved; shell ornamented by rounded, crenulated to noded, radial plicae, wider than interspaces, plicae bifurcating and intercalated (14–18), periodic raised growth lines interrupt plicae.

Discussion — The elongate subtriangular form and rounded plicae of the specimens from Black Mesa compare well with the specimens of *Plicatula hydrotheca* illustrated by Stanton (1893) from about the same stratigraphic level and facies.

Occurrence — The type specimens are from the top of the Dakota Formation, upper Cenomanian at the head of Water-pocket Canyon in southern Utah. At Black Mesa common in the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyense* Zone and scattered in the lower Cenomanian up to about a meter above BM13, upper Cenomanian *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone.

Illustrated material — MNA N227, N1042 from MNA loc. #265, sandstone facies, upper sandstone member Dakota Formation; MNA N1159 from MNA loc. #262, BM8, lower part, lower shale member, Mancos Shale.

Paleoecology — *Plicatula hydrotheca* is commonly the only taxon recovered from the basal 5 meters of the Mancos Shale in the area of northeastern Black Mesa, suggesting a tolerance of reduced oxygen levels at the sediment-water interface.

Plicatula cf. *P. ferryi* Coquand, 1862
Plate 6, Figure F; Plate 11, Figure O;
Plate 25, Figure E

Plicatula cf. *P. ferryi* Coquand; Cobban, 1972, p. 16, pl. 9, fig. 9; pl. 16, figs. 6–12; pl. 19, figs. 5, 6.
Plicatula cf. *P. ferryi* Coquand; Cobban and Hook, 1989, p. 250, fig. ^E–G.

Description — Shell of medium thickness, small to medium size (1–4.5 cm long), round to ovate, longer than high, slightly to moderately inflated; beak slightly obtuse with rather rounded dorso-posterior and dorso-anterior sides; ventral margin smoothly curved, ornamented by variably developed rounded radial costae sometimes plicate toward margin, bearing spines which tend to be most strongly developed near the posterior and anterior margins, wider than interspaces; costae bifurcating and intercalated (average of around 40 on large specimens, 5 cm long), regular, widely spaced raised growth lines interrupt plicae.

Discussion — This species is distinguished from *Plicatula hydrotheca* largely in being longer than high and in bearing spines. In this the species appears to be closest to *Plicatula ferry* Coquand (Cobban, 1977). Most specimens recognized from the top of the Dakota Formation are as much as 4.5 cm across, while specimens from the lower Mancos Shale are no more than 1.5 cm across. This suggests that the Mancos Shale specimens might represent dwarf specimens of *Plicatula* n. sp. ? or perhaps represent a distinct species.

Occurrence — Large specimens present in the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone. Rare in the lower part of the lower shale member of the Mancos Shale upper Cenomanian from BM8, *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone to just above BM13, *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone.

Illustrated material — MNA N3558 from MNA loc. #963, sandstone facies, upper sandstone member, Dakota Formation; MNA N5154, BM8; MNA N5489, one meter above BM13; both from MNA loc. #989, lower part, lower shale member, Mancos Shale.

Superfamily Anomiacea
Family Anomiidae
Genus *Anomia* Linne, 1758

Paleoecology — Species of this epifaunal genus are immobile, byssally attached to hard substrates to which the shell is tightly pressed and often displays xenomorphic growth.

Anomia ponticulana Stephenson, 1952

Plate 3, Figures I–L

Anomia ponticulana Stephenson, 1952; p. 81, pl. 20, figs. 1–4.
Anomia ponticulana Stephenson, Fursich and Kirkland, 1986, p. 549, fig. 5c, d.

Description — Upper valve thin, small (average of 1 cm across), round to ovate (higher than long), inflated cap-shaped; beak small set well above dorsal margin; shell-ornamented by fine concentric growth lines and sparce weak concentric rugae. Aragonitic lower valves have not been observed. Fibrous, calcified byssus has been observed attached to shells of *Flemingostrea prudentia*.

Discussion — Stephenson (1952) reported fine radial riblets on a number of specimens, but noted that the majority of specimens show no sign of this feature. Radial riblets were not observed on any of the Black Mesa specimens.

Occurrence — The type is from the Lewisville Member of the Woodbine Formation, middle Cenomanian of central Texas. At Black Mesa common in and restricted to the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #264, #265, #540).

Illustrated material — MNA N4496 from MNA loc. #265, MNA N4537, N4497, N4495 from MNA loc. #540; all from shale facies, upper sandstone member, Dakota Formation.

Paleoecology — The distribution of this species indicates that it preferred brackish water environments (Fursich and Kirkland, 1986).

Anomia sp. A

Plate 26, Figure F

Description — Upper valve very thin, very small (average of 0.5 cm across), subcircular, cap-shaped; beak blunt and subcentral; shell ornamented by fine concentric growth lines. Lower valve very thin, smaller, subcircular, flat; beak blunt and located near dorsal margin, byssal sinus not recognized.

Discussion — At Black Mesa. specimens low in the sequence tend to be subcircular, while those higher in the sequence are more elongate and they are divided into a lower Turonian subcircular form, *Anomia* sp. A and a lower middle Turonian elongate form, *Anomia* sp. B.

Hasenmueller and Hattin (1990) have recognized two species from the Greenhorn Limestone of Kansas; these compare well with *Anomia* sp. A, but at present it is not possible to determine which of these species (*Anomia cobbani* or *Anomia pfeiferensis*) is closest to being conspecific with *Anomia* sp. A without detailed morphometric analysis.

Occurrence — At Black Mesa scattered throughout the middle part of the lower shale member of the Mancos Shale, lower Turonian, *Watinoceras coloradoense* Zone and *Mammites nodosoides* Zone.

Illustrated material — MNA N5207 from MNA loc. #989, below BM27, middle part, lower shale member, Mancos Shale.

Anomia sp. B

Plate 36, Figures U, V

Description — Upper valve very thin, very small (up to 1 cm long), subovate, longer than high, variably inflated; beak very blunt, close to dorsal margin; shell ornamented by fine growth lines, glossy and occasionally with weak concentric rugae. Lower valve unknown.

Discussion — This species is from the middle Turonian stratigraphically higher than *Anomia cobbani, Anomia pfeiferensis*, and *Anomia* sp. A. from which it differs in being longer than high.

Occurrence — At Black Mesa uncommon and scattered in the middle Turonian *Collignoniceras woollgari* Zone through the middle shale member of the Mancos Shale from just above BM54, from the *Collignoniceras woollgari woollgari-Mytiloides hercynicus* subzone into the *Collignoniceras woollgari woollgari* subzone.

Illustrated material — MNA N5205, 3 m above BM54; MNA N5204, 10 m above BM54; both from middle shale member, Mancos Shale.

Superfamily Limacea

Family Limidae

Genus *Lima* Bruguiere, 1797

Paleoecology — This is a byssally attached epifaunal taxon, which prefers to nestle among objects on the seafloor. The genus has refined chemosensory and tactile sensory tentacles and is highly mobile, being able to swim by rapid closing motions of the valves together.

Lima utahensis Stanton, 1893

Plate 11, Figure AA

Lima utahensis Stanton, 1893; p. 71, pl. IX, fig. 5.

Description — Thin shell, small (to 1.5 cm high), subcircular to subovate, inflated; hinge straight and approximately half the length of shell; auricles small and subequal in size, separated from disk by strong breaks in slope; shell slightly oblique (average inclination of 75°), ornamented by finely crenulate, radial costae nearly equal in size to interspaces.

Discussion — This species is generally uncommon at Black Mesa The species was most common in BM8 on the east side of Black Mesa associated with serpulid biostromes.

Occurrence — The type specimen is from the upper Cenomanian of southern Utah. At Black Mesa generally uncommon in the *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone.

Illustrated material — MNA N5151 from MNA loc. #306, BM10, lower part, lower shale member, Mancos Shale.

Lima sp. cf. *Lima utahensis* Stanton, 1893

Plate 43, Figure Q

Description — Thin shell, small (1.5 cm high), subovate, inflated; hinge straight and approximately one-third the length of shell; auricles small and subequal in size, separated from disk by strong breaks in slope; oblique (inclination of about 75°); shell ornamented by finely crenulate, radial costae nearly equal to interspaces.

Discussion — This species is close to *Lima utahensis* but differs in having smaller auricles and somewhat coarser costae. Larger samples of both species are required to determine whether these features are variable and whether this is indeed a distinct species.

Occurrence — At Black Mesa, rare in the Blue Point Tongue, middle Turonian *Collignoniceras woollgari regulare* subzone, *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5394 from MNA loc. #1150, top of Blue Point Sandstone Tongue, Toreva Formation.

Lima sp.
Plate 11, Figure F

Diagnosis — Small species of *Lima* differing from *Lima utahensis* in is larger auricles, round outline, and coarser ornament.

Occurrence — One specimen from the top of the Dakota Formation, upper Cenomanian, *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone at Blue Point (MNA loc. #344).

Illustrated material — MNA N1245 from MNA loc. #344, sandstone facies, upper sandstone member, Dakota Formation.

Genus *Limatula* Wood, 1839
Limatula kochi n. sp.
Plate 11, Figure Z

Etymology — Named for Dr. Karl Koch, who first collected a specimen of this taxon.

Diagnosis — Thin shell, small (0.8 cm); ovate (approximately twice as high as long), moderately inflated; hinge slightly convex and approximately one half the length of shell; posterior auricle much larger than anterior auricle and bearing prominent radial ridge; separated from disk by strong break in slope; slightly oblique (inclination of about 70°), ornamented by finely radial costae nearly equal to interspaces on anterior two thirds of shell; posterior flank smooth.

Discussion — This species is conspecific with *Lima* n. sp. illustrated by Koch (1977) from the upper Cenomanian *Sciponoceras gracile* Zone of southern Utah. The only example of another species of *Limatula* from the Cretaceous of the United States with which the author is familiar is *Limatula acutilineata* (Conrad) (Stephenson, 1941) from which it differs in its smaller size, the narrowness of the shell and in its weaker, less dense ribbing.

Occurrence — Rare in BM8 on east side of Black Mesa,*Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone, also rare in southern Utah.

Holotype — MNA N5155 from MNA loc. #306, BM10, lower part, lower shale member, Mancos Shale.

Paleoecology — Like *Lima*, species of this genus have highly developed sensory tentacles and were highly mobile, but preferred to be nestled among debris on the seafloor.

Superfamily Ostreacea
Family Gryphaeidae
Genus *Pycnodonte* Fischer de Waldheim, 1835
"Gryphaeoid Pycnodonts"

Paleoecology — Sessile, as adults free-living recliners on firm substrates as determined by their small attachment areas and enrolled, bowl-shape form (Hallam, 1968; Stanley, 1970; Stenzel, 1971; LaBarbara, 1981). Kauffman (1967, 1969) reports an offshore distribution for these forms. At Black Mesa, the primary control on distribution appears to be net sedimentation rate and the development of firm substrates, as concentrations of these forms are restricted to apparent sediment bypass horizons developed during the transgressive hemicyclothem and have not been observed in the regressive hemicyclothem. Depth also plays a role as *Pycnodonte* are not found in the shallowest open marine settings.

Pycnodonte sp. aff. *P. kellumi* (Jones, 1938)
Plate 5, Figures H, J, K

Ostrea (Gryphaea ?) patina Meek and Hayden; Reagan, 1927, p. 119, text-figs. 15–26.
Gryphaea washitaensis var. *kellumi* Jones, 1938; p. 107, pl. 3, figs. 3–5.
Pycnodonte aff. *P. kellumi* (Jones); Cobban, 1977, p. 17, pl. 20, figs. 1–15.
Pycnodonte aff. *P. kellumi* (Jones); Hook and Cobban, 1977, p. 51, figs. 5A–H.
Pycnodonte aff. *P. kellumi* (Jones); Cobban and Hook, 1989, p. 252, figs. 6I, J.

Description — Moderately thick shell, large (to 6 cm long) for genus; quadrate to subrounded, highly inequivalve. Lower left valve inflated, moderately enrolled, beak low and broad usually with small attachment area; low poorly defined umbonal ridge, a broad shallow sulcus separates a moderately inflated posterior auricle from the main part of valve, resilifer extends from beak; chomata line the dorsal margin and extend more internally along outside edge of pallial line on lateral sides of shell before fading out; ornamented by irregular concentric growth lamellae and irregular broad rugae. Right valve flat and ornamented by irregular concentric growth lamellae.

Discussion — The evolution of the gryphaeoid pycnodonts during the middle and upper Cenomanian has been discussed in considerable detail (Cobban, 1977; Hook and Cobban, 1977). Jones (1938) described the subspecies *Gryphaea washitaensis* var. *kellumi* from Coahuila, Mexico in strata ranging from Albian through Turonian in age. Cobban (1977) studied this material and found that all the material (including co-occurring specimens assigned to *Gryphaea washitaensis*) could be referred to *Pycnodonte kellumi*.

Pycnodonts from the middle Cenomanian of western New Mexico compare rather well with *Pycnodonte kellumi* (Cobban, 1977; Hook and Cobban, 1977). These specimens differ most from the *Pycnodonte* sp. aff. *P. kellumi* in having a smooth shell and having a much weaker posterior sulcus. As the New Mexican material is larger than the the Mexican material, Cobban (1977) only provisionally relates the material to Jones' (1938) taxon, as *Pycnodonte* sp. sf. *P. kellumi*.

Pycnodonte sp. aff. *P. kellumi* represents a distinct transitional form between *Pycnodonte* sp. cf. *P. kellumi* and *Pycnodonte newberryi* and could as readily have been referred to *Pycnodonte* sp. aff. *P. newberryi* (Cobban, 1977; Hook and Cobban, 1977). This taxon is a distinctive index fossil for the upper Cenomanian *Metoicoceras mosbyensis* Zone. This form should be described as a distinct species.

Occurrence — At Black Mesa, generally common to abundant at the top of the Dakota Formation and/or base of the Mancos, upper Cenomanian *Metoicoceras mosbyensis* Zone, from Star Mountain in the northeastern Hopi Buttes east and north along the entire eastern side of the mesa to the north side of the mesa; MNA loc. #254, #296, #306, #338, #387, #989, #992. Also found at this level in east-central Arizona, across western New Mexico, western Colorado, Utah, Wyoming, and Montana.

Illustrated material — MNA N5064, N5068, N5070, from MNA loc. #296, from base of Mancos Shale.

Pycnodonte newberryi newberryi (Stanton, 1893)
Plate 11, Figure C; Plate 19, Figure I

Gryphaea newberryi Stanton, 1893; p. 60, pl. V, figs. 1–5.
Pycnodonte newberryi Stanton; Hook and Cobban, 1977, p. 51, fig. 4A–N.
Pycnodonte newberryi Stanton; Cobban and Hook, 1989, p. 252, figs. 7E–G.

Description — Moderately thick shell, medium-sized (2–3 cm high, up to 4.5 cm high), subovate to subtriangular, highly inequivalve. Lower left valve inflated, enrolled; beak low and broad usually with small attachment area, moderately well developed umbonal ridge; a prominent sulcus separates a moderately inflated posterior auricle from the main part of valve; resilifer extends from beak to hinge; chomata line the dorsal margin and extend more internally along outside edge of pallial line on lateral sides of shell before fading out; ornamented irregular concentric growth lamellae and irregular broad rugae. Right valve flat and ornamented by irregular concentric growth lamellae.

Discussion — *Pycnodonte newberryi* is a widely distributed and distinctive index fossil of the uppermost Cenomanian *Sciponoceras gracile* and *Neocardioceras juddii* Zones (Hook and Cobban, 1977). It is readily distinguished from *Pycnodonte* sp. aff. *P. kellumi* in being proportionaly shorter and more enrolled.

Kauffman and Powell (1977) report on small round specimens of *Pycnodonte newberryi* from the lower Turonian of Cimarron, Oklahoma. This form differs in being considerably smaller, round, and apparently lacking a sulcus and prominent posterior auricle. It occurs from the upper Cenomanian *Sciponoceras gracile* Zone upward to at least the base of the middle Turonian in limestone beds of the Bridge Creek Limestone Member of the Greenhorn Limestone across much of the central Western Interior. This central Western Interior form may represent a distinct deep water species or possibly a dwarfed deep water variant, which survives long after typical more shallow water *Pycnodonte newberryi* has gone extinct. Kauffman (1989, personal comunication) reports that these are all juvenile specimens. Herein, these specimens are treated as undiagnostic juvenile specimens of *Pycnodonte*, that may represent more than one species.

Occurrence — At Black Mesa, common to abundant at the very top of the Dakota Formation in the area of extreme southwestern Black Mesa and in the lower part of the lower shale member of the Mancos Shale from below BM4, upper Cenomanian *Vascoceras diartianum* subzone of the *Sciponoceras gracile* Zone upward to BM12, upper Cenomanian *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone (Kirkland, 1990). Also at this level in east-central Arizona, western half of New Mexico, southwestern Colorado, and Utah.

Illustrated material — MNA N1048 from MNA loc. #265, top of the upper sandstone member, Dakota Formation; MNA N1162 from MNA loc. #262, lower shale member, Mancos Shale, base of *Neocardioceras juddii* Zone.

Pycnodonte newberryi umbonata n. subsp.

Plate 25, Figures F, H

Etymology — Named in reference to its distinctive umbonal ornamentation.

Diagnosis — Very close to typical *Pycnodonte newberryi* but is distinguished by being smooth in the umbonal area to a height of 2–3 cm.

Discussion — This subspecies of *Pycnodonte newberryi* is very close to the nominal subspecies, beyond its differences in juvenile ornament. This subspecies is always recovered from higher in the section than *Pycnodonte newberryi newberryi*. These differences are not thought to be due to ecophenotypic variation, as both forms occur under the same environmental conditions. As it is so close to the typical specimens, it is thought the differences in ornament represent only a difference in subspecies. This smooth subspecies of *Pycnodonte newberryi* is important in that it is usually common right at the Cenomanian-Turonian stage boundary and occurs widely over the Colorado Plateau.

Radial color bands have been observed on a number of specimens which are similar to those described for the typical variety of *Pycnodonte newberryi* by Stokes and Stifel (1964) and for *Pycnodonte* sp. aff. *P. kellumi* by Cobban (1977). This seems to indicate that such color bands are a pervasive feature of the lineage.

Occurrence — Common at Black Mesa, only known from a narrow interval between BM13 and BM14, very uppermost Cenomanian *Nigericeras scotti* subzone of the *Neocardioceras juddii* Zone into the very basal Turonian *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone (Kirkland, 1990, 1991). Elsewhere, recognized at this level in southern Utah, southwestern Colorado, and northeastern New Mexico.

Types — Holotype MNA N1473, paratype N1472, both from MNA loc. #305, lower shale member, Mancos Shale at Cenomanian-Turonian boundary, 3 m above BM13.

Pycnodonte sp.

Plate 36, Figure X

Description — Thin shell, small (average 0.5–1.5 cm high), subovate to subtriangular, highly inequivalve. Lower left valve inflated, moderately enrolled; beak low and broad, usually with small attachment area; poorly developed umbonal ridge; sulcus and posterior auricle indistinct; ornamented with irregular concentric growth lamellae and irregular broad rugae. Right valve flat and ornamented by irregular concentric growth lamellae.

Discussion — These specimens are similar to the examples of *Pycnodonte newberryi* described by Kauffman and Powell (1977) and occur widely in the central Western Interior in the lower Turonian. The specimens from the basal middle Turonian at Black Mesa differ in being generally proportionately higher and more rugate. It is likely that they represent a closely related taxon.

Occurrence — At Black Mesa, rare in the upper part of the lower shale member of the Mancos Shale, basal middle Turonian *Collignoniceras woollgari woollgari-Mytiloides hercynicus* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990). The species is more common at this level in marlstones north of Mesa Verde National Park in southwestern Colorado.

Illustrated material — MNA N5208 from MNA loc. #262, lower shale member, Mancos Shale below BM36.

Encrusting Pycnodontes

Paleoecology — Cemented epifaunal suspension feeders.

Pycnodonte kansasense? Bottjer, Roberts, and Hattin, 1978

Plate 26, Figure I

Pycnodonte kansasense Bottjer, Roberts, and Hattin, 1978; p. 1214, pl. 1, figs, 1–10; pl. 2, figs. 1–6.

Description — Small, thin-shelled, encrusting oyster, to 30 mm long; left valve attached over most of valve commonly with upturned margins; shape round to oblong dependent on packing of associated valves; right valve slightly convex; surface commonly pustulose or displays strong xenomorphism reflecting rugae of inoceramid substrate; surface ornament consists of fine growth lines and widely spaced thread-like radial ribs. Interior of valves with recessed subcentral muscle scar and chomata along hinge area extending all along posterodorsal and anterodorsal margin of valves. Shell structure of interlayered vesicular and laminar calcite.

Discussion — Specimens of *Pycnodonte kansasense* are very difficult to separate from specimens of *Pseudoperna bentonense*. Hattin (1987, personal communication) finds that, whereas the fine radial ornament is a useful criterion, the only certain way to distinguish these species is by examining the shell ultrastructure in thin-section. As a microscopic examination of all encrusting oysters at Black Mesa was beyond the scope of this study, many specimens referred to *Pseudoperna bentonense* may in fact represent *Pycnodonte kansasense*.

A number of thin encrusting oysters from high in the middle Turonian have been assigned to *Pycnodonte kansasense* on the basis of their having fine thread-like radial ornament. Specimens of *Pseudoperna bentonense* have smooth surfaces and are much more common and widespread.

Specimens at Black Mesa show a marked decrease in size with each generation, as remarked upon by Bottjer and others (1978). The size of subsequent generations is restricted by the upturned shell margins of the previous generation.

Occurrence. The types came from a narrow interval of the Jetmore Limestone Member of the Greenhorn Limestone in central Kansas correlative to BM28-BM30 at Black Mesa, upper *Mammites nodosoides* Zone. Specimens tentatively recognized at Black Mesa are found from BM24 to BM30 (Kirkland, 1990).

Illustrated material — MNA N5210 from MNA loc. #262, lower shale member, Mancos Shale in calcisilt marker bed BM28.

Genus *Exogyra* Say, 1820
Subgenus *Costagyra* Vyalov, 1936
***Exogyra (Costagyra) olisiponensis* Sharpe, 1850**
Plate 5, Figure A

Exogyra ponderosa Roemer; Stanton, 1893, p. 65, pl. VII, figs, 1, 2.
Exogyra cfr. *olisiponensis* Sharpe; Böse, 1918, p. 230, pl. 20, fig. 4.
Exogyra olisiponensis Sharpe; Reeside, 1929, p. 268, (in part) pl. 65, figs. 1–11; pl. 66, figs. 1–11; pl. 67, figs. 1–4, 7, 8; pl. 68, figs, 3–5; pl. 69, figs. 1–4; non ? pl. 67, figs. 5, 6; pl. 68, figs. 1, 2.

Description — Thick to very thick shell (up to 4 cm or more, average 1–2 cm); large (up to 12 cm high); shell, ovate highly inequivalve. Left valve coiled during early growth straightening on maturity, very inflated, cemented on coiled surface of shell; internal chomata may be present below beak; ligamental groove extends along hinge; shell ornamented by variably developed radial ribs that are narrower than concave interspaces; concentric lamellose surface may cause ribs to appear spinose. Right valve flat, ornamented by spiral growth lines and commonly radial ribs toward periphery.

Discussion — *Exogyra olisiponensis* is the type species of the subgenus *Costagyra*, which is distinguished from typical *Exogyra* in having chomata and radial ornament on the right valve.

Exogyra olisiponensis was originally described from the Turonian "Hippurites Limestone" of Portugal, with numerous varieties and/or subspecies subsequently described from the Mediterranean and Africa ranging from Cenomanian through Turonian (Reeside, 1929). Reeside (1929) described several varieties from a large variable population from the top of the Dakota Formation in the upper Cenomanian *Sciponoceras gracile* Zone in southeastern Utah and found the species to range from strongly to very weakly ribbed. Cobban (1977) described specimens of *Exogyra* sp. cf. *E. oxyntas* (Coquand) from the middle Cenomanian of west-central New Mexico, which could be distinguished from *Exogyra olisiponensis* in having more closely spaced ribs equal in width to interspaces covering all of left valve. A great deal of additional work is needed to determine if the variable, long-ranging species *Exogyra (Costagyra) olisiponensis* can be subdivided into meaningful species and subspecies through its range.

Occurrence — The type is from the Turonian of southern Europe, with the species ranging from the Cenomanian through Turonian in southern Europe, the Middle East, Africa, and South America. The species seems to be restricted to the upper Cenomanian in North America and is known from Mexico, New Mexico, and is most common in southern Utah. At Black Mesa, present in the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #265 and #963.

Illustrated material — MNA N1046 from MNA loc. #265, sandstone facies, upper sandstone member, Dakota Formation.

Paleoecology — Epifaunal suspension-feeder, the vast majority of individuals cemented to hard substrate throughout life, mutually cemented gregareous specimens common, with a few individuals which had cemented to small objects becoming free-living immobile recliners.

Genus *Rhynchostreon* Bayle, 1878

Paleoecology — Epifaunal suspension-feeder, adult mostly free-living immobile on the substrate as can be determined by the small to nonexistent attachment area. However, among all species described below, specimens that were fully cemented through life have been observed.

***Rhynchostreon levis* (Stephenson, 1952)**
Plate 5, Figures E, G, I

Exogyra columbella Meek; Reagan, 1927, p. 125, figs. 3–7.
Exogyra columbella levis Stephenson, 1952; p. 77, pl. 18, figs. 1–3.
Exogyra levis Stephenson; Cobban, 1977, p. 18, pl. 15, figs. 1–16; pl. 20, figs. 16–18 (in part).

Description — Thin, medium sized (to 6 cm high), exogyroid; shell ovate, highly inequivalve. Left valve highly inflated with fairly open exogyroid coiled umbo extending away from main part of valve; shell subevenly rounded; attachment area mostly small or lacking, resilifer forms groove below hinge; shell smooth with fine growth lines and variable developed radiating costae in umbonal area. Right valve flat, ornamented by spiral growth lines. Radial color bands present on some examples.

Discussion — *Rhynchostreon levis* was described by both Stephenson (1952) and Cobban (1977) as including both forms with a costate umbo and forms with a completely smooth umbo. Whereas the forms do overlap in occurrence, the dominance and commonly exclusive occurrence of one form verses another is universal. The smooth form occurs in the most shallow water environments occupied by this species. The environmental separation of these forms supports their separate discussion, although these forms most probably represent ecophenotypic variants, it is also possible that they represent distinct subspecies.

At present it is not possible to determine whether these are conspecific with any of the species from the eastern hemisphere, such as *Exogyra columba* Lamarck. Further study of these forms on both sides of the Atlantic is needed to clear up the systematics. This species can be distinguished from the slightly older *Rhynchostreon columbella* in its larger size and early loss of costae.

Occurrence — The types are from the middle Cenomanian Woodbine Formation of central Texas. At Black Mesa restricted to the upper Cenomanian, in the sandstone facies of the upper sandstone member of the Dakota Formation, *Metoicoceras mosbyensis* Zone upward in the lowerpart of *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone. Also in the middle and upper Cenomanian of central Montana, southern Utah, western Colorado, New Mexico, and Mexico.

Illustrated material — MNA N1471, N1502, N1503 from MNA loc. #305, sandstone facies, upper sandstone member, Dakota Formation.

Paleoecology — This form is found both in massive sandstones at the top of the Dakota Formation and in association with biostromal accumulations of *Pycnodonte* in the lower Mancos Shale, indicating a preference for moderate currents on firm open marine substrates.

Rhynchostreon levis (smooth form) (Stephenson, 1952)
Plate 5, Figures D, F

Exogyra laeviuscula Roemer; Stanton, 1893, p. 64, pl. VIII, figs. 5, 6.
? *Exogyra haarmanni* Böse, 1918; p. 230, pl. 18, figs, 4–8.
Exogyra laeviuscula Roemer; Reagan, 1927, p. 126, figs. 8–12.
Exogyra levis Stephenson; Cobban and Hook, 1989, p. 250, figs. 4A–C.

Diagnosis — Medium-sized exogyroid, like typical *R. levis*, but generally somewhat smaller; commonly with a weak umbonal ridge, more tightly coiled, and lacking any radial costae in the umbonal area.

Discussion — Cobban (1977) grouped both the smooth and costate forms of *R. levis* together. At Black Mesa both forms are common to abundant, however, their distribution shows little overlap. The smooth form tends to be found abundantly in the upper sandstone member of the Dakota Formation, and the typical costate form tends to be restricted to the top of the upper sandstone member and in the lower few meters of the Mancos Shale and is usually associated with *Pycnodonte newberryi*. These observations indicate that the costate form preferred deeper open marine condition than did the smooth form.

It is possible that the smooth form of *Exogyra levis* is conspecific with *Exogyra laeviuscula* Roemer, but this is impossible to test without comparing the type material. Stanton (1893) noted that his examples from southern Utah are larger and more tightly coiled than the Texas material. The example illustrated by Stanton (1893) compares very well with the Black Mesa examples.

Occurrence — At Black Mesa restricted to massive sandstones of the upper sandstone of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone through basal *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone; MNA loc. #264, #265, #296, and #298. Also observed in central and eastern Arizona, southern Utah, western New Mexico, and possibly Mexico.

Illustrated material — MNA N1504, N1505 from MNA loc. #265, sandstone facies, upper sandstone member, Dakota Formation.

Paleoecology — This form would appear to be tolerant of relatively high current regimes.

Rhynchostreon suborbiculata (Lamarck, 1801)
Plate 43, Figures G, K

Exogyra suborbiculata (Lamark); Stanton, 1893, p. 62, pl. V, fig. 6; pl. VI, figs. 1, 2; pl. VIII, fig. 1.

Description — Thin, large (up to 10 cm high) exogyroid; shell ovate to subtriangular, highly inequivalve. Left valve highly inflated with exogyroid coiled umbo, shell subevenly to evenly rounded; attachment area mostly small or lacking, resilifer forms groove below hinge; strong umbonal ridge; shell smooth with fine growth lines and variable developed radiating costae in umbonal area. Right valve flat, ornamented by spiral growth lines.

Discussion — *Rhynchostreon suborbiculata* is the type of the genus *Rhynchostreon* and as all the species described under this genus appear to belong to one lineage, they are included within the genus. *Rhynchostreon suborbiculata* is superficially similar to *Rhynchostreon levis* but can be readily distinguished by its larger size, subtriangular-shaped umbonal region, and strong umbonal ridge.

Occurrence — The type is from the Turonian of Europe and is widespread there and in India. At Black Mesa, present to common only in the Blue Point Tongue, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone: MNA loc. #1150. Also recorded in the Codell Sandstone Member of the Carlile Shale, middle Turonian *Prionocyclus hyatti* Zone in Huerfano Park, southern Colorado (Kauffman, 1961) and in the Coon Spring Sandstone Bed in the lowermost Mancos Shale, middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone in western Colorado and eastern Utah (Molenaar and Cobban, 1991).

Illustrated material — MNA N3481, N5063 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation.

Paleoecology — This species differs from others of the genus at Black Mesa in that a majority of specimens appear to have been firmly cemented throughout life. Most specimens from western Colorado have very small attachment areas indicating a free-living adult stage for specimens in that area.

Rhynchostreon sp. (small and smooth)
Plate 11, Figure L

? *Exogyra acroumbonata* Kauffman, 1961, Ph. D.; p. 198, pl. 14, figs. 27–30.

Description — Thin, small (1.5 cm) exogyroid; shell well-rounded to ovate; highly inequivalve. Left valve highly inflated with exogyroid coiled umbo, attachment area mostly small, or lacking; rather distinct umbonal ridge present; resilifer forms groove below hinge; shell smooth with fine growth lines. Right valve flat, ornamented by spiral growth lines.

Discussion — Kauffman (1961) erected the species *Exogyra acroumbonata* for small smooth exogyroids in the basal upper Cenomanian concretions in the middle Graneros Shale of Huerfano Park, Colorado. These specimens appear to have larger attachment areas than those found on specimens from Black Mesa, but Kauffman (1979, personal communication) feels that they are best referred to this species. It cannot be completely discounted that the Black Mesa specimens represent an offshore dwarf variety of *Rhynchostreon levis*.

Occurrence — At Black Mesa, present at all sites in concretionary marker beds BM8, BM10, and BM11 and associated with biostromal concentrations of *Pycnodonte newberryi*, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through the *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone (Kirkland, 1990).

Illustrated material — MNA N5161 from MNA loc. #262, lower shale member, Mancos Shale in concretionary marker bed BM8.

Genus *Gryphaeostrea* Conrad 1865

Paleoecology — Epifaunal suspension-feeders with species that are both free living on the substrate, and fully cemented.

Gryphaeostrea nationsi n. sp.

Plate 11, Figures A, B

Etymology — Named in recognition of J. Dale Nations, his research on the Cretaceous of Arizona, introducing the author to the Cretaceous of the Black Mesa region, and collecting the first specimens of this taxon from northern Arizona.

Diagnosis — Distinguished by its large size, elongate disk, and large auricles.

Description — Thin, medium-sized (to 6 cm high), subovate (higher than long), highly inequivalve. Left valve moderately inflated; attachment area small to absent; subcentral beak narrow and coiled opisthogyrous; during early growth coiling abruptly lessens and shell straightens and expands rapidly; near equal-sized auricles developed on mature specimens; resilifer below beak; lamellose shell ornamented by even angular rugae. Right valve flat to slightly concave, opisthogyrous, smaller, without auricles, ornamented by even angular rugae.

Discussion — The right valves of *Gryphaeostrea lamellosa* (Bergquist, 1941) are very similar to the right valves of *Gryphaeostrea nationsi* n. sp. in size and form, but the left valves are very different in being longer with prominent auricles. This species differs from *Gryphaeostrea elderi* in its large size, prominent auricles, and strong foliation of the shell. *Gryphaeostrea vomer* from the Maastrichtian is smaller, but otherwise is quite similar (Stephenson, 1941).

Occurrence — At Black Mesa generally uncommon at the very top of the Dakota Formation; MNA loc. #305, #308, into the basal Mancos Shale; MNA loc. #296, #989, #992, upper Cenomanian *Metoicoceras mosbyensis* Zone upward in the basal *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone in the southwestern part of the basin, where the species is common at Blue Point at the top of the Dakota Formation, MNA loc. #344.

Types — Holotype, MNA N1240; paratypes MNA N5549 both from MNA loc. #344; MNA N5551 from MNA loc. #308, all from sandstone facies, upper sandstone member, Dakota formation.

Paleoecology — The small attachment area and inflated left valve of this species indicates that as an adult it was free-living on the substrate. It would seem to be restricted to environments with firm substrates and low net sedimentation rates.

Gryphaeostrea elderi n. sp.

Plate 11, Figures J, K

Etymology — Named for William P. Elder for his research on the Cenomanian-Turonian stage boundary and his documentation of the distribution of this taxon in the Western Interior.

Diagnosis — Distinguished by its small size and lack of auricles.

Description — Thin, small (to 1.5 cm high), subovate (higher than long), highly inequivalve. Left valve moderately inflated; small beak narrow and coiled, opisthogyrous with attachment area rather small along anterior side of umbo; valve abruptly straightens beyond area of attachment and shell expands rapidly; resilifer below beak; lamellose shell ornamented by even angular rugae. Right valve flat to slightly concave, opisthogyrous, smaller, ornamented by even angular rugae.

Discussion — *Gryphaeostrea elderi* n. sp. is readily distinguished from other species by its small size and lack of auricles. Specimens have in the past been referred to *Aucellina gryphaeoides* Sowerby (Koch, 1977; Kirkland, 1983; Elder, 1986) as the shell separates from the matrix with great difficulty and the internal molds are superficially similar. The external ornament of *Gryphaeostrea elderi* is readily distinguished, and the shell structure is clearly oystreid.

Occurrence — At Black Mesa restricted to concretionary marker beds BM8 and BM10, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone and is most common in the northeast; MNA loc. #236, #989, #992. Elder (1989, personal communication) reports that the species ranges upward into the *Neocardioceras juddii* Zone in southwestern Colorado.

Types — Holotype MNA N5148; paratype MNA N5585 both from from MNA loc. #989, BM8; Lectotype MNA N5163 from MNA loc. #306, BM10; both from lower shale member, Mancos Shale.

Paleoecology — Whereas the attachment area is small, the small size of the shell and observations in the field indicate that the majority of specimens were cemented throughout life. The species is most commonly associated with biostromal accumulations of *Serpula intrica* on the north and east side of Black Mesa.

Family Ostreidae

Genus *Crassostrea* Sacco, 1897

Paleoecology — *Crassostrea* is a cemented epifaunal oyster which ranges from brackish to shallow open marine environments, but is abundant only in brackish water settings (Kauffman, 1967, 1969).

Crassostrea soleniscus (Meek, 1871)

Plate 4, Figure B; Plate 43, Figure J

Ostrea soleniscus Meek; White, 1884, p. 300, pl. XLII, fig. 1.
Ostrea soleniscus Meek; Stanton, 1893, p. 56, pl. II, fig. 1; pl. III, figs. 1, 2.
Ostrea soleniscus Meek; Stephenson, 1952, p. 74, pl. 16, figs. 1–4; pl. 17, figs. 7–10.
Crassostrea soleniscus (Meek); Fursich and Kirkland, 1986, p. 549, Fig. 5b.

Description — Thick, medium to large (in two size classes, medium 10–15 cm high, and large 25–40 cm high), generally much higher than long with anterior and posterior margins subparallel to divergent; inequivalve. Left valve deep, usually cemented for entire height; beak projecting above hinge line which forms extensive shelf overlying deep umbonal cavity; resilifer track well developed. Right valve with terminal beak, little inflated. Ornamented by lamellose growth lines and irregular rugae.

Discussion — The long-ranging species *Crassostrea soleniscus* is highly variable, and at Black Mesa the species is readily divided into populations of small individuals from brackish water shales and populations of large individuals from shallow marine sandstones. Whereas it is recognized that these differences are ecophenotypic in nature, it cannot be definitely determined whether size is controlled by salinity or substrate. With decreasing salinity many taxa have been recorded to decrease in size (Fursich and Kirkland, 1986), and increasing levels of fine suspended material reduce the feeding rate and maximum size of modern oysters (Loseanoff and Tommers, 1948; Korringa, 1952). A coiled variant was described by Stephenson (1952), but no specimens of this type have been observed at Black Mesa. This is the only taxon at Black Mesa to range through the entire Greenhorn cyclothem from the lagoonal shales of the Dakota Formation to the lower sandstone member of the Toreva Formation.

Occurrence — The type is from the Albian Bear River Formation in Wyoming and is reported to range from the Albian to Coniacian. At Black Mesa, small examples are locally common in the shale facies of the sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #264, #265, #308, #540, and #963. Large specimens are uncommon in the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyense* Zone through *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone; MNA loc. #264, #305, and #963. Also uncommon in the Blue Point Tongue; MNA loc. #1150 and in the lower sandstone member of the Toreva Formation; MNA loc. #342, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone. Locally very abundant in the basal Toreva Formation south of Black Mountain on the east side of the mesa; MNA loc. #878.

Illustrated material — MNA N4481 from MNA loc. #540, shale facies, upper sandstone member, Dakota Formation; MNA N5402 from MNA loc. #1150, top Blue Point Sandstone Tongue, Toreva Formation.

Genus *Pseudoperna* Logan, 1899

Pseudoperna bentonense Logan, 1899

Plate 26, Figures G, H; Plate 36, Figures AA, BB

Ostrea congesta var. *bentonensis* Logan, 1899a; p. 87.
Pseudoperna bentonense Logan; Hattin, 1975a, p. 66, pl. 10, figs. A, B, G, I.

Description — Thin, small (up to 3 cm high) shell, tends to be curved and subtriangular to ovate unless crowded where shell form is determined by space available; little inflated, inequivalve. Left valve cemented over most of surface with upturned margins; beak projecting; umbonal cavity present; inner margin of shell lined by short narrow chomata. Right valve slightly smaller, conforming to shape of left valve with both valves displaying xenomorphic growth; smooth shell is ornamented at most by very fine traces of growth lines.

Discussion — The variety *Ostrea congesta* var. *bentonensis* was named in passing in a short paper on the Colorado Formation (Logan, 1899a). It was described as a small, thin, almost flat, subtriangular shell with upper valves so thin that they are rarely preserved. *Ostrea congesta* var. *niobraraensis* (the type of *Ostrea congesta*) was reported to be thicker shelled with a considerably deeper left valve. The level from which *Ostrea congesta* var. *bentonensis* was reported to occur is now known as the Fairport Chalky Shale Member of the Carlile Shale, middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone where apparently the specimens to which Logan (1899a) refers are cemented to *Inoceramus cuvieri*. As far as can be determined, no type specimen has ever been designated.

At approximately the same time, Logan (1899b) described a large number of species of oysters from the lower Smoky Hill Member of the Niobrara Formation, for which he erected the genus *Pseudo-perna* for those displaying what he called a split beak. Stenzel (1971) has synonymized all of these species with *Pseudoperna congesta*.

Pseudoperna bentonense is very common and widespread, ranging through much of the lower shale member upward into the upper shale member of the Mancos Shale at Black Mesa. They are most abundant in the lower Turonian where they densely encrust many specimens of *Mytiloides* and large ammonites. They have also been observed to encrust lenses of calcarenite as multigenerational biostromal accumulations.

Occurrence — The species is described from the middle Cenomanian Fairport Chalky Shale Member of the Carlile Shale in central Kansas. Abundant at all sections at Black Mesa where it is uncommon in the upper Cenomanian *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone, becoming common to abundant through the lower Turonian and remains common through much of the middle Turonian up into the *Prionocyclus hyatti* Zone in the upper shale member of the Mancos Shale on the northeastern side of the mesa (Kirkland, 1990). Elsewhere, widespread throughout the Western Interior.

Illustrated material — MNA N5215 from MNA loc. #262, lower shale member, Mancos Shale, BM20; MNA N5216 from MNA loc. #262, middle shale member, Mancos Shale, five meters below BM70; MNA N5217 from MNA loc. #262, middle shale member, Mancos Shale, four meters below BM70; MNA N5219 from MNA loc. #262, lower shale member, Mancos Shale, BM30.

Paleoecology — Cemented epifaunal suspension-feeders, which Kauffman (1967, 1969) reports to be offshore deep water taxa which colonize shells on otherwise soft substrates. They are apparently an opportunistic specie controlled by physical factors in the environment (Levington, 1970), as they had to colonize small areas of hard substrate, grow to maturity, and reproduce prior to burial of the substrate.

Pseudoperna ? sp.

Plate 26, Figure J; Plate 36, Figure Y

Ostrea insolens Kauffman, 1961, Ph. D.; p. 237, pl. 18, figs. 1–34.
Ostrea sp. aff. *Curvostrea rediviva* Coquand; Cobban and Hook, 1983, p. 6.

Description — Very thin shell, small (up to 1.5 cm long), oblong (longer than high), little inflated, slightly inequivalve, strongly posteriorly curved, arcuate; beak pointed and positioned near anterior margin which curves evenly away from beak to broadly curved ventral margin; interior features unknown; ornamented by weak evenly spaced concentric rugae and fine raised growth lines. Transverse undulations crossing some shells are the effect of xenomorphic growth on inoceramid bivalves.

Discussion — *Pseudoperna* ? sp. compares rather well with *Curvostrea* (Cox and others, 1969). Stenzel (1971) reports that the genus *Curvostrea*, based on *Curvostrea rediviva* Coquand cannot be placed taxonomically as the internal features are unknown. As the specimens referred to *Pseudoperna* ? sp. from Black Mesa are similar to some of the more strongly curved specimens of *Pseudoperna bentonense* from Black Mesa, it is thought the origins of the genus, if valid, are in *Pseudoperna*. The validity of the genus is a serious question that cannot be answered without study of the internal features of these forms. It could well be established that these are but an ecophenotypic variety of *Pseudoperna bentonense*, which ranges well above and below the range of *Pseudoperna* ? sp. at Black Mesa. Thus the taxon is retained in *Pseudoperna* at present.

Forms similar to and probably conspecific with the Black Mesa *Pseudoperna* sp. have been reported from approximately the same stratigraphic level in both Colorado and New Mexico. Kauffman (1961) describes *Ostrea insolens* n. sp. from the upper Bridge Creek Limestone Member of the Greenhorn Limestone and in the basal Fairport Member of the Carlile Shale, lowest middle Turonian at Huerfano Park, Colorado. Cobban and Hook (1983) report the occurrence of *Ostrea* sp. (aff. *Curvostrea rediviva* Coquand) from the highest lower Turonian of west-central New Mexico. *Pseudoperna* sp. from Black Mesa and southern Colorado are not as thin as *Curvostrea rediviva* from the Cenomanian of France.

Even with the taxonomic problems, the distribution of small, thin, arcuate, encrusting oysters near the lower-middle Turonian boundary in the southwestern Western Interior suggests that the forms have significant biostratigraphic utility.

Occurrence — First described from the lower middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone in southern Colorado. At Black Mesa, locally common from above BM35, uppermost lower Turonian *Mammites nodosoides* Zone to just below BM64, lower middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990). Also possibly from the uppermost lower Turonian of west-central New Mexico.

Illustrated material — MNA N5221 from MNA loc. #989, lower shale member, Mancos Shale, just below BM48; MNA N5472 from MNA loc. #262, middle shale member, Mancos Shale, 10 m above BM54.

Paleoecology — Encrusting, suspension-feeder, like other *Pseudoperna* in its habits, but its distribution suggests that it required somewhat deeper water. The species appears to have been an opportunistic taxon as it is often found in great numbers on individual bedding planes.

Genus *Ostrea* Linne, 1758

Ostrea anomioides Meek, 1873

Plate 11, Figure Q

Ostrea anomioides Meek; White, 1884, p. 291, pl. XXXIX, figs. 4, 5.
Ostrea anomioides Meek; Stanton, 1893, p. 55, pl. I, figs. 5, 6.

Diagnosis — Thin shell, small (to 1.5 cm), ovate; dorsal margin nearly straight to moderately curved; slightly inflated slightly inequivalve; beak subcentral, little inflated; shell ornamented by raised growth lines.

Discussion — *Ostrea anomioides* ranges through the study interval, but is only known from the upper Cenomanian at Black Mesa where it is generally uncommon. The small size and generally poor state of preservation of specimens of this species from Black Mesa do not permit a detailed description. The species is reported to lack an attachment scar (Stanton, 1893; Kauffman, 1977).

Occurrence — The type specimens are from Coloradan strata near Gallatin, Montana. At Black Mesa generally rare in the lower part of the lower shale member of the Mancos Shale, upper Cenomanian *Metoicoceras mosbyensis* Zone upward into the upper *Neocardioceras juddii* Zone (Kirkland, 1990). Also reported from the Codell Sandstone Member of the Carlile Shale, middle Turonian *Prionocyclus hyatti* Zone.

Illustrated material — MNA N5174 from MNA loc. #989, lower shale member, Mancos Shale, BM8.

Paleoecology — Epifaunal suspension feeder which by its lack of attachment scar, would have had to be free-lying on the substrate.

Genus *Flemingostrea* Vredenburg, 1916

Flemingostrea prudentia (Stanton, 1893)

Plate 4, Figures A–C

Ostrea prudentia White; White, 1884, p. 299, pl. XL, figs. 5, 6.
Ostrea prudentia White; Stanton, 1893, p. 54, pl. I, figs. 3, 4.
Flemingostrea prudentia (White); Stenzel, 1959, p. 33.
Flemingostrea prudentia (White); Fursich and Kirkland, 1986, p. 549, Fig. 5a, b.

Description — Rather thick (0.3–0.7 cm) shell, medium to large, fairly large sized (to 9 cm high), nearly circular in outline, moderately inflated, slightly inequivalve; left valve only slightly larger than right; attachment scar most commonly very small; beak slightly projecting above short hinge area; below hinge on interior posterodorsal and anterodorsal margins bounded by densely spaced elongate chomata; ovate muscle scar subcentrally located; toward maturity ventral commissure forms weak-to-strong terabratulid fold with left valve convexly folded and right valve concavely folded. Shell ornamented by weak to moderately strong radial ribs and lamellose growth lines.

Discussion — Stenzel (1959) assigned *Ostrea prudentia* to the genus *Flemingostrea* on the basis of its distinctive terabratulid fold. The genus originates in the Cenomanian, and from his report it would seem the earliest known species is *Flemingostrea subradiata* (Cragin) from the middle Cenomanian Woodbine Formation of central Texas. From Stephenson's (1952) illustrations it would seem *Flemingostrea subradiata* is very close to the upper Cenomanian *Flemingostrea prudentia* if not conspecific with it.

Stenzel (1971), in describing the genus, noted the prevalence of prismatic calcite layers within the shell structure of *Flemingostrea*. Kauffman (1983, personal communication) has pointed out that, because *Flemingostrea prudentia* lacks layers of prismatic calcite, the species should not be included within the genus. The question arises, when does prismatic calcite first appear in the lineage ? Does prismatic calcite occur in the unidentified ancestor of the lineage or does this feature appear during the course of its evolution? It is possible that the early members of the lineage such as *Flemingostrea subradiata* and *Flemingostrea prudentia*, lacking a prismatic calcite layer, should be described as belonging to a new genus ancestral to *Flemingostrea*. Further study is needed to resolve these issues, and at present it is best to follow Stenzel (1959).

Occurrence — The type specimens are from upper Dakota Formation, late Cenomanian in southern Utah. At Black Mesa, although present in much of the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #264, #265, and #540, the species is only common to abundant in the lower part. Also present as rare, often worn, possibly reworked specimens in the overlying sandstone facies; MNA loc. #265.

Illustrated material — MNA N4481, N4493, N4494 from MNA loc. #540, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — Epifaunal suspension-feeders: Stenzel (1971) reported that they never have a large attachment area and that specimens of the genus and its close relatives are never found co-attached. The terabratulid fold characteristic of this group would seem to be an adaption for lifting both the inhalent and exhalent areas off the substrate. These features seem to indicate that this oyster was specialized for lying unattached on the substrate at maturity. Their distribution at Black Mesa indicates a preference for brackish water settings with firm substrates (Fursich and Kirkland, 1986).

Genus *Lopha* Roding, 1798

Discussion — The genus *Lopha* is reported to occur from the Miocene to Recent (Stenzel, 1971). Kauffman (1965; 1989, personal communication) has described *Lopha* from the Cretaceous and has indicated that the species described below are best retained within the genus *Lopha*.

Paleoecology — Cemented epifaunal suspension-feeders. Kauffman (1967, 1969a) notes that oysters of this genus are most common in relatively high energy open marine environments.

Lopha staufferi Bergquist, 1944
Plate 5, Figures B, C

Ostrea (*Alectryonia*) *staufferi* Bergquist, 1944; p. 15, pl. 9, figs. 1–10.
Lopha staufferi (Bergquest); Cobban, 1977, p. 20, pl. 19, figs. 8, 9.

Description — Moderately thick, medium-sized (to 8 cm high) shell; ovate with axis of growth curved posteriorly; moderately inflated, slightly inequivalve; beak not prominent; attachment area large and tends to be directed from beak posteriorly along dorsal margin; Shell ornamented by large angular plicae, which curve away from axis of growth and number from 8–10 on anterior half of shell where they are best developed; plicae are fewer and weaker on posterior side of shell, becoming obsolete toward dorsal margin; plicae form strong plicate margin along commissure. Shell otherwise ornamented by concentric lamellose growth lines.

Discussion — Cobban (1977) suggests that this species should be compared to species of this age in Europe and Africa. Among genera occurring in the Cretaceous, *Lopha staufferi* appears to be comparable to the genus *Cameleolopha* described from the Cenomanian of North Africa.

Occurrence — The type specimens are from the upper Cenomanian Coleraine Formation in the Mesabi Iron Range of Minnesota. At Black Mesa rare in the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #265, #926, and #963. Also at this level in the Twowells Sandstone Tongue of the Dakota Formation in west-central New Mexico.

Illustrated material — MNA N6378 from MNA loc. #926, sandstone facies, upper sandstone member, Dakota Formation.

Lopha bellaplicata bellaplicata (Shumard, 1860)
Plate 49, Figure G

Ostrea belliplicata Shumard; White, 1884, p. 292, pl. XLVII, figs. 1–3.
Lopha belliplicata belliplicata Shumard; Kauffman, 1965, pl. 3.
Nicaisolopha bellaplicata bellaplicata (Shumard); Kennedy, 1988, p. 13, pl. 23, figs. 26, 27.
Lopha belliplicata Shumard; Cobban and Hook, 1989, p. 254, fig. 9S.

Description — Rather thick shell, small (to 2.5 cm high), ovate to subquadrate; both valves relatively inflated, only slightly inequivalve; beak prominent with inflated umbo; attachment area of moderate size; shell expanding away from beak; evenly curved, plicate ventral margin. Shell ornamented by 10 to 20 strong, round, radial plicae wider than narrow interareas, crossed by raised concentric growth lines.

Discussion — *Lopha belliplicata belliplicata* has proved to be an excellent guide fossil for the middle Turonian *Prionocyclus hyatti* Zone (Kauffman, 1977b; Cobban, 1984a). It may be distinguished from *Lopha belliplicata novimexicana* (Kauffman, 1965) by its denser, finer plication and from *Lopha lugubris* (Conrad) by its generally smaller attachment area, inflated right valve. Some of the specimens from Texas are nearly twice as large as those from Black Mesa (Kennedy, 1988).

Occurrence — The type specimens are from the middle Turonian near the top of the Eagle Ford Shale, *Prionocyclus hyatti* Zone in central Texas. At Black Mesa, uncommon in the upper 20 m of the Mancos Shale into the lower sandstone member of the Toreva Formation, middle Turonian *Prionocyclus hyatti* Zone along the east and north sides of the mesa; MNA loc. #878, #988, and #989 (Kirkland, 1991). Also reported from New Mexico and southern Colorado.

Illustrated material — MNA N3580 from MNA loc. #878, lower sandstone member, Toreva Formation.

SUBCLASS HETERODONTA
ORDER VENEROIDEA
Superfamily Lucinacea
Family Lucinidae

Paleoecology — Lucinids are moderate to deep-burrowing bivalves. Unlike other bivalves they burrow with the shell held vertically and the hinge held horizontally by probing with the foot and clapping and rocking the shell. They construct a mucous-lined or agglutinated inhalent tube in the sediment through which they can non-selectively suspension-feed or collect organic detritus with their mucous-covered foot (Kauffman, 1967b, 1969b). They are one of the very few heterodont bivalves that retain the labial palps for detritus feeding and thus can be considered extreme generalists. Lucinids are very tolerant to hydrogen-sulfide rich, oxygen poor, sediments and may thrive in environments of low diversity and minimal suspended food material (Allen, 1958). Most species are chemosymbionts with anerobic sulfide and methane reducing bacteria (Dando and Southward, 1986) This extreme tolerance and flexibility helps explain the consistent occurrence of lucinids throughout the Greenhorn cyclothem at Black Mesa.

Genus *Lucina* Bruguiere, 1797
Lucina subundata Hall and Meek, 1856
Plate 13, Figures C, D; Plate 26, Figure O;
Plate 37, Figures A, E

Lucina subundata Hall and Meek; Meek, 1876, p. 133, pl. 17, figs. 2a–e.
Lucina subundata Hall and Meek; White, 1876, p. 184, pl. 18, fig. 12a.
Lucina subundata Hall and Meek; Stanton, 1893, p. 97, pl. XXII, figs. 5, 6.

Description — Moderately thick shell, rather small (average 1.5 cm long, maximum 2.5 cm long); subcircular, shell moderately and evenly inflated (gerontic individuals well inflated), slightly inequilateral, equivalve; beak small, and centrally located; dorsal margins fairly straight extending away from beak; dorsal sulcus well-developed extending to ventrally of straight anterior margin; ventral and posterior margins evenly curved. Shell ornamented by regularly spaced, strong, thin, raised growth lines separated by fine growth lines.

Discussion — The types are from the upper Pierre Shale in South Dakota, whereas the specimens illustrated by White (1876) and Stanton (1893) are from the upper Cenomanian of southern Utah. While the specimens from southern Utah are with little question conspecific with those assigned to *Lucina subundata* from Black Mesa, there is some question if Meek's

(1876) specimens are. If so, this species ranges through much of the Upper Cretaceous. The compacted shale specimens from Black Mesa compare rather well with similar specimens in the upper Mancos Shale (upper Coniacian) at Mesa Verde National Park in southwestern Colorado and specimens illustrated by Hattin (1982) from the Smoky Hill Chalk Member of the Niobrara Formation (Santonian) in central Kansas. A great deal of further study of well preserved material is required to understand the systematics of this species. While generally most common in the upper Cenomanian *Sciponoceras gracile* Zone, *Lucina subundata* is the most consistently encountered infaunal bivalve in the Mancos Shale throughout the lower and middle Turonian as well, and is generally more common in the southwest.

Occurrence — The type specimens are from the upper Pierre Shale (upper Campanian or lower Maestrichtian) along the Cheyenne River in South Dakota. Common at all sites at Black Mesa, restricted to the lower and middle shale members of the Mancos Shale, ranging from about a meter above the Dakota Formation in the northeast, upper Cenomanian *Metoicoceras mosbyensis* Zone upward to a couple meters above BM69, middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990). Elsewhere, widespread across the Western Interior.

Illustrated material — MNA N5156 from MNA loc. #262, lower shale member, Mancos Shale, BM10; MNA N5157 from MNA loc. #271, lower shale member, Mancos Shale, BM10; MNA N5473 from MNA loc. #262, lower shale member, Mancos Shale, just below BM37; MNA N5474 from MNA loc. #262, middle shale member, Mancos Shale, just above BM65; MNA N5479 from MNA loc. #262, middle shale member, Mancos Shale, 5 m below BM70.

Paleoecology — The distribution of this taxon at Black Mesa indicates that it preferred relatively deep water and fine-grained clastic substrates. The taxon is very rare in the pelagic limestone-shale facies in the central Western Interior.

Lucina n. sp.

Plate 37, Figure B

Diagnosis — Much like *Lucina subundata* but smaller (< 1 cm long) and much more inflated.

Discussion — Although clearly distinct, the preservation of the material at hand is inadequate to diagnose fully a new species.

Occurrence — This uncommon species ranges from a short distance above BM61 in the middle shale member, middle Turonian *Collignoniceras woollgari woollgari* subzone upward to a few meters above the top of the Hopi Sandy Member in the upper shale member, *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990).

Illustrated material — MNA N5233 from MNA loc. #262, middle shale member, Mancos Shale, just below BM70.

Paleoecology — This species is restricted to shallower water settings than *Lucina subundata*. Its more inflated shell indicates that it did not burrow as deep or as rapidly as the other lucinids occurring at Black Mesa.

Genus *Parvilucina* Dall, 1901

Parvilucina juvenis (Stanton, 1893)

Plate 3, Figures P, S–U; Plate 44, Figures H, I

Lucina juvenis Stanton, 1893; p. 98, pl. XXII, figs. 2–4.
Parvilucina juvenis (Stanton); Fursich and Kirkland, 1986, p. 549, fig. 5g.

Description — Moderately thick shell, rather small (average 1.0–1.5 cm long), nearly circular; shell moderately and evenly inflated, slightly inequilateral, equivalve; beak small, blunt, and centrally located; dorsal sulcus very weakly developed. Shell ornamented by regularly spaced, strong, raised growth lines separated by fine growth lines.

Occurrence — The type specimen is from the Codell Sandstone Member of the Carlile Shale, middle Turonian *Prionocyclus hyatti* Zone. At Black Mesa, present in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #264, #265, #308, #540, and #963 and is abundant at this level at Blue Point in the southwest; MNA loc. #344, also present in the Blue Point Tongue and the lower sandstone member of the Toreva Formation; MNA loc. #342, #878, and #988, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone to *Prionocyclus hyatti* Zone (Kirkland, 1990). Elsewhere widespread in the Western Interior.

Illustrated material — MNA N4501, N4502, N4503, N4511 from MNA loc. #540, shale facies, upper sandstone member, Dakota Formation; MNA N5062, from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation.

Paleoecology — This species would seem to be a nearshore form living both in relatively high-energy open marine sands and in brackish water shell-rich muds. Its great abundance to the exclusion of other taxa in the shale facies of the upper sandstone member of the Dakota Formation at Blue Point, where the shale is particularly dark and organic rich, seems to indicate that this taxon was particularly tolerant of low oxygen conditions and may have been somewhat opportunistic as well as probably a chemosymbiont.

Parvilucina sp.

Plate 37, Figure F

Diagnosis — Differs from *Parvilucina juvenis* in its thinner shell, more prominent posteriorly displaced beak, and finer ornament.

Occurrence — In the middle Turonian at Black Mesa from about BM61 in the middle shale member, *Collignoniceras woollgari woollgari* subzone to BM71 in the upper shale member *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990).

Illustrated material — MNA N5447 from MNA loc. #262, middle shale member, Mancos Shale, 7 m below BM64.

Paleoecology — This species appears to closely match the distribution of *Lucina* n. sp., but differs greatly in its morphology. It would appear to have been able to burrow rapidly, perhaps more deeply as indicated by its slender, thin shell. Thus, its presence suggests niche partitioning within the Lucinidae at Black Mesa.

Superfamily Crassatellacea

Family Astartidae

Genus *Opis* DeFrance, 1825

Opis elevata Stephenson, 1952

Plate 3, Figure E

Opis? elevata Stephenson, 1952; p. 96, pl. 22, figs. 2–6.

Description — Thin shell, small to medium-sized (to 2 cm high), subtriangular, inequilateral, equivalve, very inflated; beak prominent strongly curved with narrow high umbonal area; each valve expands so that it resembles a curved triangular cone. Shell ornamented by fine concentric growth lines.

Discussion — This rare distinctive taxon is the only infaunal bivalve to be found in both the shale facies and sandstone facies of the upper sandstone member of the Dakota Formation.

Occurrence — The type specimens are from the middle Cenomanian Templeton Member of the Woodbine Formation in central Texas. At Black Mesa very rare in both the shale facies; MNA loc. #540 and sandstone facies; MNA loc. #337 of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone on the south side of the mesa.

Illustrated material — MNA N4499 from MNA loc. #540, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — A very shallow infaunal suspension-feeder that seems to have been tolerant of both brackish and normal marine shallow water environments.

Family Crassatellidae

Genus *Crassatella* Lamarck, 1799

Crassatella ? sp.

Plate 44, Figure E

Description — Moderately thick, small (to 1.5 cm long) shell, subcircular, inequilateral, equivalve, little inflated with lenticular cross-section; beak blunt and slightly projecting; low distinct posterodorsal umbonal ridge present; posterodorsal margin broadly and evenly curves into ventral margin; anterodorsal margin long descending rapidly to curve rather sharply into broadly curved ventral margin: internal features unknown. Shell ornamented by dense fine raised growth lines.

Occurrence — Rare at Blue Point in the Blue Point Tongue, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone; MNA loc. #1150.

Illustrated material — MNA N5390 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation.

Paleoecology — Species of this genus are shallow to moderately deep infaunal taxa, which suspension-feed just below the sediment-water interface.

Family Cardiidae

Paleoecology — Cardiids are shallow infaunal taxa, which suspension feed with the shell margin at or near the sediment-water interface. The inflated, ribbed shell is an adaptation for slow burrowing and good anchorage, permitting these bivalves to remain buried under shifting sediment (Kauffman, 1969b; Stanley, 1970). All examples of this family recovered at Black Mesa were found in shallow marine sandstones.

Genus *Granocardium* Gabb, 1869

Granocardium trite (White, 1879)

Plate 6, Figure B (c)

Cardium trite White; Stanton, 1893, p. 100, pl. XXII, figs. 7, 8.
Granocardium trite (White); Cobban, 1977, p. 20, pl. 21, figs. 1–4, 7.
Granocardium trite (White); Cobban and Hook, 1989, p. 250, figs. 6B, C.

Description — Thin shell, small (1–2 cm high), subcircular to ovate, slightly higher than long, nearly equilateral, equivalve; highly and evenly inflated; enrolled prosogyrous beaks raised above short hinge line; margins evenly rounded. Shell ornamented by fine dense costae over entire shell; every third costa bears small sharp nodes.

Discussion — Specimens of this species are generally preserved as composite molds at Black Mesa and the internal features have not been observed.

Occurrence — The type specimens were recovered from the top of the Dakota Sandstone upper Cenomanian *Metoicoceras mosbyensis* Zone along the south end of the Waterpocket Fold in southern Utah, At Black Mesa, uncommon in the sandstone facies, upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #265, #337, #963. Also identified at this level in the Twowells Sandstone Tongue of the Dakota Formation in west-central New Mexico.

Illustrated material — MNA N277 from MNA loc. #265, sandstone facies, upper sandstone member, Dakota Formation.

Genus *Pleuriocardia* Scott, 1978

Subgenus *Dochmocardia* Scott, 1978

Pleuriocardia (*Dochmocardia*) *pauperculum* (Meek, 1871)

Plate 44, Figures K–M, P (a);
Plate 47, Figure G (a); Plate 48, Figure J (b)

Cardium pauperculum Meek; Stanton, 1893, p. 99, pl. XXII, figs. 9–12.
Pleuriocardia (*Dochmocardia*) *pauperculum* (Meek); Scott, 1978, p. 894, pl. 1, figs. 14, 15.

Description — Thin shell, small (1–1.5 cm high), subovate, slightly higher than long, slightly inequilateral; equivalve, highly and evenly inflated; enrolled prosogyrous beaks raised above short, nearly straight hinge line; two cardinal teeth; well developed umbonal ridge; margins evenly rounded and crenate, except for truncated posterior margin. Shell ornamented by strong noded costae over entire shell which are stronger toward the umbonal ridge.

Discussion — This species is common and widespread in shallow marine sandstones in the Western Interior. The lineage to which *Pleuriocardia* (*Dochmocardia*) *pauperculum* belongs has been studied in detail by Geary (1981).

Occurrence — The type specimens are from lower part of the Colorado Shale in the middle Turonian *Collignoniceras woollgari* Zone 20 miles west of Fort Bridger, Wyoming. At Black Mesa in the middle Turonian, it is abundant in the Blue Point Tongue at Blue Point; MNA loc. #1150, present in a sandstone interval 20 m below the Toreva Formation at Lohali Point; MNA loc. #989 (Kirkland, 1990), and locally common to abundant in the lower sandstone member of the Toreva Formation and its transition with the Mancos Shale across Black Mesa; MNA loc. #342, #878, and #988, *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone through *Prionocyclus hyatti* Zone. Also known from the lower middle Turonian to lower upper Coniacian from central Texas to Alberta, Canada (Geary, 1981).

Illustrated material — MNA N5091, N5096, N5555 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation; MNA N4851, N5411 from MNA loc. #342, lower sandstone member, Toreva Formation.

Superfamily Mactracea

Family Mactridae

Genus *Cymbophora* Gabb, 1869

Paleoecology — The bivalves of this genus are moderately deep infaunal suspension-feeders as can be determined by their deep pallial sinus. Their distribution indicates they preferred well-oxygenated sand substrates in fully marine environments.

Cymbophora emmonsi (Meek, 1877)

Plate 44, Figures S, T; Plate 48, Figure I

Mactra emmonsi Meek; Stanton, 1893, p. 121, pl. XXVII, figs. 9–13.
Mactra emmonsi Meek; Logan, 1898, p. 458, pl. XC, fig. 11.
Cymbophora emmonsi (Meek); Cobban and Hook, 1989, fig. 9Tb.

Description — Thin shell, small (to 2.5 cm long), moderately convex; shell subtriangular, slightly inequilateral, equivalve; beak prominent, prosogyrous; anterior margin narrowly rounded, posterior margin truncated; strong angular, posterior umbonal ridge. Surface ornament consists of fine growth lines.

Discussion — The strong umbonal ridge readily identifies this species of *Cymbophora*.

Occurrence — Holotype from Wasatch Range, Utah with Coloradan fauna. Common in middle Turonian sandstones of the Western Interior. At Black Mesa, it is uncommon in the Hopi Sandy Member in the southwest; MNA loc. #262 (Plate 53), uncommon in the Blue Point Tongue of the Toreva Formation; MNA loc. #1150 , and is common in the transitional beds and lower sandstone member of the Toreva Formation across Black Mesa; MNA loc. #342, #878, and #988, *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone through *Prionocyclus hyatti* Zone.

Illustrated material — MNA N5485 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation; MNA N5416 from MNA loc. #342, lower sandstone member, Toreva Formation.

Paleoecology — The distribution of this species suggests it tolerated deeper water than the other species present at Black Mesa.

Cymbophora utahensis Meek, 1877

Plate 45, Figure D (a); Plate 48, Figure G;
Plate 49, Figure L

Mactra (*Cymbophora* ?) utahensis Meek; Stanton, 1893, p. 120, pl. XXVII, figs. 16, 17.

Description — Thin shell, small to medium-sized (to 4 cm long), subtriangular, nearly equilateral; equivalved, moderately inflated; dorsal margins sloping evenly away from beak; anterior and posterior margins narrowly rounded; weak rounded posterior umbonal ridge; ventral margin evenly curved, surface ornament consists of dense raised growth lines.

Discussion — The nearly equilateral shell and concentric raised growth lines of this species set it apart from other species of the genus at Black Mesa. Whereas restricted to the middle Turonian at Black Mesa, this species is abundant in the upper Cenomanian *Neocardioceras juddii* Zone in the Cretaceous undifferentiated along the Mogollon Rim in central Arizona.

Occurrence — Types from the Wasatch Range, Utah found with a Coloradan fauna, widespread in sandstones of late Cenomanian through middle Turonian age in the Western Interior. At Black Mesa, it is present in the Blue Point Tongue, MNA loc. #1150, and is locally common in the transitional beds and in the lower sandstone member of the Toreva Formation; MNA loc. #342, #878, and #988, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone through *Prionocyclus hyatti* Zone.

Illustrated material — MNA N5100 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation; MNA N5409 from MNA loc. #342, lower sandstone member, Toreva Formation; MNA N5415 from MNA loc. #988, lower sandstone member, Toreva Formation.

Cymbophora huerfanensis (Stanton, 1894)

Plate 44, Figures O, Q, R; Plate 48, Figure F

Mactra huerfanensis Stanton, 1894; p. 122, pl. XXVII, figs. 14, 15.

Description — Thin shell, small to medium-sized (to 2.5 cm long); elongate oval shape, as much as twice as long as high; slightly inflated inequilateral; beaks blunt situated about one-third of length from posterior margin; postero-dorsal margin nearly straight, with anterior and posterior margins broadly rounded; surface ornament consists of fine growth lines.

Discussion — This species resembles *Tellina* (Stanton, 1893), but can be readily distinguished by its dentition. Kauffman (1961) has noted that this species is much more variable than *Cymbophora emmonsi* and *Cymbophora utahensis*.

Occurrence — Types from the middle Turonian *Prionocyclus hyatti* Zone in the Codell Sandstone Member of the Carlile Shale at Huerfano Park, Colorado. At Black Mesa, present in the Blue Point Tongue; MNA loc. #1150 and lower sandstone member of the Toreva Formation; MNA loc. #342 at Blue Point, *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5098, N5524 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation; MNA N5410 from MNA loc. #342, lower sandstone member, Toreva Formation.

Cymbophora sp.

Plate 4, Figures P, Q

Diagnosis — Very small (average of 0.5 cm long), internal molds similar in overall form to *Cymbophora emmonsi*, but slightly more elongate and having a less distinct umbonal ridge.

Discussion — The poor state of preservation of these specimens and their small size indicates that they could represent another genus of infaunal bivalve.

Occurrence — Restricted to the upper part of the shale facies of the upper sandstone facies of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone along the north side of Coal Mine Mesa; MNA loc. #264, #265, and #540.

Illustrated material — MNA N4516 from MNA loc. #264; MNA N4517 from MNA loc. #540; both from shale facies, upper sandstone member, Dakota Formation.

Paleoecology — The distribution of this species indicates a preference for brackish water environments in finer sediments than the other species of *Cymbophora* from Black Mesa.

Superfamily Solenacea

Family Cultellidae

Genus *Senis* Stephenson, 1952

Senis elongatus Stephenson, 1952

Plate 3, Figure M

Senis elongatus Stephenson, 1952; p. 120, pl. 30, figs. 8–13.

Description — Thin shell, medium-sized (to 7 cm long); shape elongate-ovate to rounded rectangular, approximately 3 times longer than high; slightly inflated; inequilateral with inconspicuous beak situated about 40% of length from anterior margin; dorsal and ventral margins nearly parallel; gaping at both posterior and anterior margin. Shell ornamented by fine concentric growth lines and weak undulations.

Discussion — This taxon is known from one pair of attached valves from the shale facies of the upper sandstone member of the Dakota Formation. It is locally abundant in siltstones and very fine sandstones in the upper Dakota Formation, upper Cenomanian in southern Utah.

Occurrence — The type specimens are from the Lewisville Member of the Woodbine Formation, middle Cenomanian in central Texas. At Black Mesa rare in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #540. Also known at this level in southern Utah.

Illustrated material — MNA N4532 from MNA loc. #540, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — The elongate gaping shell found in species of this genus indicates that it is a deep infaunal suspension-feeding bivalve. Its distribution indicates a preference for brackish water settings and silt to fine sand substrates.

Superfamily Tellinacea
Family Tellinidae

Paleoecology — Bivalves of this family burrow shallowly into the sediment with the commissure horizontal, and feed by a pair of long siphons on the bottom or on fine suspended material. Although buried rather shallowly, their streamlined form permits them to burrow under the sediment rapidly (Stanley, 1970).

Genus *Tellina* Linne, 1758
Tellina carlilana n. sp.
Plate 37, Figures I, J, M

Tellina modesta Meek, 1877; p. 157, pl. 15, figs. 4, 5.
Tellina modesta Meek; Stanton, 1893, p. 111, pl. XXV, fig. 3.
Tellina carlilana Kauffman, 1961, Ph. D.; p. 322, pl. 25, figs. 11–17.

Etymology — Renamed by Kauffman (1961) for the Carlile Shale.

Diagnosis — This common species is distiguished by its eliptical shape, subdued beaks, and smooth shell.

Description — Thin shell, small (to 1.5 cm long), shape subelliptical, twice as long as high, nearly equilateral; equivalve, little inflated; beak blunt, pointed, subcentral, situated slightly toward posterior margin; anterodorsal and posterodorsal margins gently curved; both anterior and posterior margins curve sharply into evenly curved ventral margin; margins smooth; surface of shell glossy, ornamented by fine concentric raised growth lines and weak undulatory rugae.

Discussion — Kauffman (1961) noted the *Tellina modesta* was preoccupied and so renamed this species *Tellina carlilana*. Internal features of this species are not known so that it cannot be assigned without question to *Tellina* and may represent another closely related genus. Likewise, it is not possible to assign it to subgenus. Elder (1987b) has reported tellinids that are similar if not conspecific with those from the upper Cenomanian *Neocardioceras juddii* Zone at Black Mesa. None of these specimens are available for comparison.

Occurrence — Meek's (1877) type is from East Canyon Creek in the Wasatch Range of Utah and was associated with a Coloradan fauna. At Black Mesa, in the middle shale member of the Mancos Shale from about a meter below BM70 through the Hopi Sandy Member into the basal upper shale member in the area of southwestern Black Mesa, middle Turonian upper *Collignoniceras woollgari woollgari* subzone into the *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (plate 53) and reported from the upper Cenomanian *Neocardioceras juddii* Zone. Also in the middle Turonian *Prionocyclus hyatti* Zone in southern Colorado and present lower in the section in New Mexico.

Paleoecology — The distribution of this species indicates that it dwelt in deeper water than did other species of tellinid from Black Mesa.

Types — Meek's (1877) type of *Tellina modesta* (USNM 22892) is a sandstone cast. Kauffman (1961) proposed a neotype from Huerfano Park in southern Colorado (UMMP 43615).

Illustrated material — MNA N5475, from MNA loc. #262, middle shale member, Mancos Shale, 3 m above BM68; MNA N5480, from MNA loc. #262, middle shale member, Mancos Shale, 3 m below base of Hopi Sandy Member; MNA N5480, from MNA loc. #262, Hopi Sandy Member, Mancos Shale, 6 m below top of Hopi Sandy Member.

Genus *Linearia* Conrad, 1860
Subgenus *Liothyris* Conrad, 1873
Linearia (Liothyris) whitei (Stanton), 1893
Plate 48, Figures H, J (a)

Tellina (Palaeomoera ?) whitei Stanton, 1893; p. 112, pl. XXV, figs. 4–7.

Description — Thin shell, small (around 3 cm long), ovate, inequilateral, slightly inequivalve; slightly inflated; beak blunt situated toward truncated anterior margin; anterodorsal margin gently curved; posterodorsal margin nearly straight; both anterior and posterior margins curve sharply into evenly curved ventral margin; distinct posterior umbonal ridge; two cardinal and two lateral teeth in each valve; medium-sized pallial sinus; weak internal rib extends to posterior adductor muscle scar. Shell ornamented by fine concentric raised growth lines.

Discussion — The tellinids have been the subject of an extensive review by Afshar (1969), that bears on the classification of *"Tellina" whitei*. Stanton (1893) questionably placed the species in the subgenus *Palaeomoera*, which differs from *Linearia whitei* in having fine radial ribs. The genus *Linearia* has been considered to include only tellinids with distinct radial ribs (Cox and others, 1970), but Afshar (1969) considers radial ribs to be of subgeneric importance as in the subgenus *Linearia* (*Palaeomoera*). Although Stanton (1893) did report very weak radiating lines toward the posterior end of the shell, radial ribbing is not visible on any of the specimens from Black Mesa. *"Tellina" whitei* would seem to best be assigned to *Linearia* (*Liothyris*), as the ovate shell has two cardinal and two lateral teeth in each valve, the beak is situated toward the posterior margin of valve, and the medium sized pallial sinus does not extend toward the anterior muscle scar. In fact, the species appears quite similar to the type species *Linearia* (*Liothyris*) *carolinensis* Conrad from the Maestrichtian of North Carolina.

Occurrence — The type specimens are from the Codell Sandstone Member of the Carlile Shale, middle Turonian *Prionocyclus hyatti* Zone in Huerfano Park, southern Colorado. At Black Mesa, present in the lower sandstone member of the Toreva Formation, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone through *Prionocyclus hyatti* Zone; MNA loc. #342 and #988.

Illustrated material — MNA N5411, N5412 from MNA loc. #342, lower sandstone member, Toreva Formation.

Paleoecology — Kauffman (1961) has noted that this species is generally uncommon except where it occurs with abundant *Cymbophora*. This is true at Black Mesa as well, thus indicating environments favorable for *Cymbophora* are favorable for *Linearia* (*Liothyris*) *whitei*. These environments are interpreted as high energy lower to middle shoreface.

Subgenus *Hercodon* Conrad, 1873
Linearia (*Hercodon?*) *striatimarginata* n. sp.

Plate 48, Figure L

Tellina striatimarginata Kauffman, 1961, Ph. D.; p. 324, pl. 25, figs. 6–9.

Etymology — Kauffman (1961) named this species for the radiating striae on the dorsal margin of shell.

Diagnosis — Distinguished by the combination of a subcentral beak together with only one internal rib.

Description — Shell thin, small to medium-sized (to 3.5 cm long), elliptical, twice as long as high, nearly equilateral: equivalve, slightly inflated; beak bluntly pointed, and situated slightly toward the posterior margin; anterodorsal and posterodorsal margins nearly straight inclining gently away from beak; anterior and posterior margins curve sharply into evenly curved ventral margin; two cardinal and two lateral teeth in each valve; medium-sized pallial sinus; weak internal rib extends to posterior adductor muscle scar. Shell ornamented by fine concentric raised growth line with fine irregular radiating striae above umbonal ridge.

Discussion — The presence of two cardinals and two lateral teeth in both valves, a medium-sized pallial sinus and an elongate shell with the beaks subcentrally located would seem to indicate that this species is close to the subgenus *Iredalesta*, but the presence of only one internal rib (not three) suggests that perhaps it should be placed in the subgenus *Hercodon*.

Closest to *"Tellina" stabulana* Stephenson (1952) from the the Cenomanian Woodbine Formation of central Texas, *Linearia striatimarginata* differs primarily in being more elongate and in having a subcentral beak.

Occurrence — The type specimens are from the Codell Sandstone Member of the Carlile Shale, middle Turonian *Prionocyclus hyatti* Zone in Huerfano Park, southern Colorado. At Black Mesa, present in the Blue Point Tongue and in the lower sandstone member of the Toreva Formation, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone at Blue Point; MNA loc. #342 and #1150.

Types — Holotype, UMMP 38053; paratypes UMMP 43617-43619; Codell Sandstone Member, Carlile Shale, Huerfano Park, southern Colorado, MNA N5405 from MNA loc. #342, lower sandstone member, Toreva Formation.

Paleoecology — The distribution of this species indicates a preference for relatively high energy sand substrates in the lower to middle shoreface.

Genus *Arcopagia* Sowerby, 1816

Elder (1987a, 1987b) and Kirkland (1990, 1991) treated these species as astartids, but following discussions with Elder (1992, personal communication), these species are now recognized as representing small, closely related tellinid species. These two species appear to be best compared with *Arcopagia*.

cf. *Arcopagia* sp. A

Plate 19, Figure J; Plate 25, Figure K (b)

Description — Thin shell very small (average 0.5 cm long), inequilateral, equivalve; rounded subtriangular, little inflated with a lenticular cross-section; beak blunt and slightly projecting; anteriorly, dorsal margin nearly straight descending gradually, posterodorsal margin short descending rapidly to evenly curved ventral margin; internal features unknown. Shell ornamented by weak concentric ridges and thread-like radial costae; radial color bands visible in a few specimens.

Discussion — The species is common and widespread on the western side of the Western Interior and in Texas in the uppermost Cenomanian, so it is of importance to secure material on which internal features such as dentition can be observed to assign confidently this taxon systematically.

Occurrence — At Black Mesa observed to range from above BM3 near base of upper Cenomanian *Vascoceras diartianum* subzone of the *Sciponoceras gracile* Zone to a short distance below BM14 in the basal lower Turonian *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone (Kauffman, 1969). The species is common to abundant in the upper Cenomanian *Neocardioceras juddii* Zone at all sections. Also present at this level in Utah, New Mexico, and central Texas.

Illustrated material — MNA N5158 from MNA loc. #262, lower shale member, Mancos Shale, BM11; MNA N5224 from MNA loc. #989, lower shale member, Mancos Shale, just above BM13.

Paleoecology — The abundance of this species tracks that of the deposit-feeding gastropod *Drepanochilus ruidium*. This may indicate that this taxon is well adapted to dwelling in sediment that has been stirred up by active deposit-feeders.

cf. *Arcopagia* sp. B

Plate 36, Figures S, Z

Diagnosis — This species is similar to cf. *Arcopagia* sp. A but has a more quadrate outline, and stronger concentric ornament without any radial ornament.

Discussion — This species occurs through a relatively narrow stratigraphic range within the lower middle Turonian that correlates to a noncalcareous interval on the southwestern side of the mesa.

Occurrence — Generally uncommon, but common on some bedding planes, in the lower half of the middle Turonian middle shale member ranging from just above BM55, *Collignoniceras woollgari woollgari-Mytiloides hercynicus* subzone to about half way between BM65 and BM66 in the *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990).

Illustrated material — MNA N5223, N5225 from MNA loc. #989, middle shale member, Mancos Shale, 4 m above BM65.

Family Tancrediidae
Genus *Meekia* Gabb, 1864
Meekia ? sp.

Plate 48, Figure D

Description — Small composite molds (to 3 cm long), ovate, longer than high, inequilateral; equivalve, moderately inflated; beak blunt, slightly projecting; anterodorsal margin gently sloping away from beak; anterior margin subcircular; ventral margin gently curved, subparallel to dorsal margin; posterodorsal margin dips away from beak before straightening into short posterior rostrum; posterior margin straight and nearly vertical, defining broad, blunt posterior rostrum. Shell ornamented by fine raised growth lines.

Discussion — These shells look somewhat like lucinids but are distinguished by their broad posterior rostrum. Speden (1970) noted that there is some dispute as to which superfamily this family belongs in. The material from Black Mesa does little to rectify this question, and it is retained in the Tellinacea following Cox and others (1969).

Occurrence — Known from a few specimens from the lower sandstone member of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone; MNA loc. #342.

Illustrated material — MNA N5401 from MNA loc. #342, lower sandstone member, Toreva Formation.

Paleoecology — Interpreted as an infaunal suspension-feeding bivalve.

Superfamily Arcticacea
Family Arcticidae
Genus *Veniella* Stoliczka, 1870

Paleoecology — Bivalves of this genus lack a pallial sinus and have thick robust shells and thus are thought to be shallow infaunal organisms that suspension-feed with the shell just below the sediment-water interface.

Veniella goniophora Meek, 1876
Plate 13, Figures E, F

Veniella goniophora Meek, 1876; p. 152, pl. 4, fig. 4, Text-fig. 12.
Veniella goniophora Meek; Stanton, 1893, p. 105, pl. XXIII, fig. 5.

Description — Moderately thick shell, small to medium-sized (to 4 cm long), subquadrate to subtrapizoidal, length slightly greater than height, inequilateral; equivalve, strongly inflated; beak enrolled and subterminal, umbo inflated; long posterodorsal margin nearly straight, joining at nearly right angle to straight truncated posterior margin; concave anterodorsal margin short and continuous with convex anterior margin; ventral margin gently curved and subparallel with posterodorsal margin; strong angular posterior unbonal ridge. Shell ornamented by fine growth lines and evenly spaced angular concentric ribs, which strengthen through ontogeny.

Discussion — This species is rare at Black Mesa in concretionary marker beds BM8 and BM10 at nearly all sites (Kirkland, 1991). It is most common in the southwestern outcrops; MNA loc. #813 and #814. Its occurrence in southern Utah at this level follows this same pattern, with the species fairly common in the southwestern part of the state.

Occurrence — The type specimens are from along the Missouri River near Fort Benton, found with a Coloradan fauna. At Black Mesa, rare (most common in the southwest) and restricted to the lower part of the lower shale member of the Mancos Shale in concretionary marker beds BM8 and BM10, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone. Also found at this level in southern Utah.

Illustrated material — MNA N5065 from MNA loc. #989, lower shale member, Mancos Shale, BM8; MNA N5075 from MNA loc. #814, lower shale member, Mancos Shale, BM8.

Paleoecology — This species' distribution indicates a preference for shallow open marine environments with fine-grained substrates.

Veniella mortoni (Meek and Hayden, 1862)
Plate 45, Figures A, B

Veniella mortoni (Meek and Hayden); Meek, 1876, p. 154, pl. 4, figs. 3a, b.
Veniella mortoni (Meek and Hayden); Stanton, 1893, p. 104, pl. XXIII, figs. 6–9.

Description — Thick shell, medium-sized (to 5 cm long), subtrapizoidal, length nearly equal to height, inequilateral; equivalve, strongly inflated; beak enrolled and subterminal, umbo inflated; long posterodorsal margin gently curves away from beak and then curves rather sharply to join ventral margin; concave anterodorsal margin short and continuous with convex anterior margin; ventral margin gently curved; dentition strong with three thick cardinal teeth and one lone lateral tooth on massive hinge plate; strongly developed, rounded posterior umbonal ridge. Shell ornamented by strong, raised growth lines.

Discussion — This species is very abundant in the Blue Point Tongue of the Toreva Formation. It occurs as isolated disarticulated valves and in lenses of dozens of articulated specimens, which appear to be current sorted, representing mass mortality events. It is most abundant in the main body of the unit.

Occurrence — The type specimens are from Chippewa Point on the upper Missouri River near Fort Benton, found with Coloradan fauna. At Black Mesa, abundant, restricted to the Blue Point Tongue of the Toreva Formation, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone at Blue Point; MNA loc. #1150. Also rare in the Codell Sandstone Member of the Carlile Shale and in the upper Blue Hill Shale Member in central Colorado, middle Turonian *Prionocyclus hyatti* Zone.

Illustrated material — MNA N5080, N5081 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation.

Veniella n. sp. ?
Plate 45, Figure C

Diagnosis — Like *Veniella mortoni* but posterior margin much more elongate, with length a third longer than height.

Discussion — This species could be a variety of *Veniella mortoni*, but the shape of the hundreds of specimens of *Veniella mortoni* observed at Black Mesa are quite uniform.

Occurrence — Uncommon, restricted to the Blue Point Tongue of the Toreva Formation, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone at Blue Point; MNA loc. #1150.

Illustrated material — MNA N 5078 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation.

Genus *Tenea* Conrad, 1870
Tenea sp.
Plate 13, Figure G; Plate 44, Figure J

Description — Thin shell, small (1.0–1.5 cm long), subcircular, inequilateral; equivalve, strongly and evenly inflated; subcentral beaks small, pointed, projecting, and recurved, umbo moderately inflated; margins evenly curved around entire shell, internal features unknown; surface smooth, ornamented by fine growth lines.

Discussion — The specimens from upper Cenomanian and middle Turonian at Black Mesa assigned to this genus may well belong to more than one species. The generally rarity and state of preservation does not facilitate a detailed comparison.

Occurrence — Uncommon in concretionary marker beds BM8 and BM10 in the lower part of the lower shale member of the Mancos Shale, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone and uncommon in the Blue Point Tongue of the Toreva Formation, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone at Blue Point.

Illustrated material — MNA N5168 from MNA loc. #298, lower shale member, Mancos Shale, BM8; MNA N5527 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation.

Paleoecology — The thin shell of this shallow infaunal taxa might indicate that species in this genus require quiet water environments.

Family Pollicidae
Genus *Pollex* Stephenson, 1952
***Pollex* ? sp.**
Plate 37, Figure L

Description — Thin shell, very small (< 0.5 cm long), elongate subtrapezoidal, nearly twice as long as high, inequilateral; eguivalve, moderately inflated; beak blunt, moderately projecting and situated about one-third of the length from the posterior margin; anterodorsal margin nearly straight curving sharply into anterior margin, which curves evenly into ventral margin; posterodorsal margin slopes away from beak and is continuous with evenly curved posterior margin; ventral margin only slightly curved and subparallel with dorsal margin; internal features unknown. Shell ornamented by fine concentric growth lines.

Discussion — All specimens assigned to this species are compacted and generally poorly preserved. The generic assignment is very tentative.

Occurrence — At Black Mesa, uncommon in the middle Turonian from the middle shale member about one meter below BM65, *Collignoniceras woollgari woollgari* subzone to a few meters below the top of the Hopi Sandy Member, basal *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990).

Illustrated material — MNA N5227 from MNA loc. #262, middle shale member, Mancos Shale, one meter above BM65.

Paleoecology — The shape of the valves of this species indicates that it is an infaunal suspension-feeder. As the nature of the pallial sinus is not known for this family (Cox and others, 1970), the depth to which this taxon burrowed cannot be determined. Its distribution at Black Mesa indicates a preference for relatively shallow offshore environments.

Superfamily Corbiculacea
Family Corbiculidae
Genus *Fulpia* Stephenson, 1946
***Fulpia pinguis* Stephenson, 1946**
Plate 1, Figure C; Plate 3, Figures N, O, Q, R

Fulpia pinguis Stephenson, 1946; p. 68, pl.12, figs, 1–4.
Fulpia pinguis Stephenson; Stephenson, 1952, pl. 23, figs. 1–4.
Fulpia pinguis Stephenson; Fursich and Kirkland, 1986, p. 549, fig. 5h.

Description — Moderately thin shell, small (to 2 cm long), ovate to subcircular, moderately inequilateral; equivalve, moderately and evenly inflated; subcentral beak blunt and moderately projecting; margins evenly curved: low umbonal ridge. Shell ornamented by equally spaced thin raised growth lines separated by fine growth lines.

Discussion — The specimens from Black Mesa compare very well with those described by Stephenson (1946, 1952) from central Texas. The vertical striations on the cardinal teeth have not been observed on the specimens from Black Mesa.

Occurrence — The types are from the middle Turonian Woodbine Formation in central Texas. At Black Mesa, common in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #264, #265, #308, #540 and #963. Also observed at this level in southern Utah.

Illustrated material — MNA N4480, N4509, N4510, N4512 from MNA #540; shale facies, upper sandstone member, Dakota Formation.

Paleoecology — Shallow infaunal suspension-feeders that prefer brackish water environments.

Superfamily Veneracea
Family Veneridae

Paleoecology — Venerids are shallow to moderately-deep infaunal, suspension-feeding taxa depending on the size of the species and the length of the siphons.

Genus *Aphrodina* Conrad, 1869
***Aphrodina* sp. cf. *A. munda* (Stephenson, 1952)**
Plate 6, Figure I

Callista (Larma) munda Stephenson, 1952; p. 106, pl. 26, figs. 14–19.
Aphrodina sp. cf. *A. munda* Stephenson; Cobban, 1977, p. 21, pl. 7, figs. 1–3.

Description — Small composite molds (average of 3.5 cm long), subtriangular (length to height variable), inequilateral; equivalve, moderately inflated; beaks moderately projecting, umbo broad and inflated; posterodorsal margin broadly curved; anterodorsal margin concave; posterior and anterior margins rather sharply curved joining gently curved ventral margin; distinct posterior umbonal ridge. Shell ornamented by flattened concentric ribs separated by thin concentric grooves.

Discussion — This species differs primarily from *Aphrodina lamarensis* (Shumard) in its more equidimensional form and in its ornamentation (Stephenson, 1952; Hattin, 1965). This species does compare rather well with *Aphrodina munda* Stephenson (1952) from the middle Cenomanian Woodbine Formation in central Texas, but compares even better with specimens illustrated by Cobban (1977) from the high middle Cenomanian Paguate Sandstone Tongue of the Dakota Formation in west-central New Mexico. Specimens that are with little question conspecific with the Black Mesa examples are locally abundant in the Twowells Sandstone Tongue of the Dakota Formation in east-central Arizona.

Occurrence — The type specimens are from the middle Cenomanian Woodbine Formation in central Texas, with additional material reported at this level in west-central New Mexico. At Black Mesa, present in the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #265 and #963. Also known from this level in east-central Arizona.

Paleoecology — The distribution of this species indicates a preference for shallow marine sands.

Illustrated material — MNA N5521 from MNA loc. #963, sandstone facies, upper sandstone member, Dakota Formation.

Genus *Pharodina* Stephenson, 1952
Pharodina ferrana Stephenson, 1952
Plate 37, Figure K

Pharodina ferrana Stephenson, 1952; p. 109, pl. 27, figs. 1–7.

Description — One composite mold, fairly small (1.7 cm long), subtriangular, inequilateral; equivalve, highly inflated; beak highly enrolled and subterminal, umbo very inflated; long posterodorsal margin gently curved; slightly concave anterodorsal margin slightly shorter; posterior and anterior margins tightly curved; ventral margin gently curved; strong subangular posterior unbonal ridge. Shell ornamented by fine growth lines and weak folds below umbo on anterior side of shell.

Discussion — This species can be distinguished from *Veniella* n. sp. ? in its more inflated, enrolled umbo, and in the weak folds on the anterior half of shell. In these features it compares best with *Pharodina ferrana* Stephenson (1952).

Stephenson (1952) placed this genus in the Veneroidea, but Cox and others (1971) questionably places the genus in the Corbiculidae. The distribution of this taxa indicates that it was a normal marine form and for no other reason it is retained in the Veneridae.

Occurrence — The type specimens are from the middle Cenomanian Lewisville Member of the Woodbine Formation in central Texas. The one specimen at Black Mesa is from the upper shale member of the Mancos Shale about six meters below the base of the Blue Point Tongue; MNA loc. #262, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5226 from MNA loc. #262, upper shale member, Mancos Shale, 6 m below base of Blue Point Sandstone Tongue, Toreva Formation.

Paleoecology — The distribution of this species suggests that it preferred shallow open marine environments. The shape of the shell and lack of a distinct pallial sinus indicates that it had a shallow infaunal habitat.

Genus *Cyprimeria* Conrad, 1864
Cyprimeria cyprimeriformis (Stanton, 1893)
Plate 45, Figure D (b); Plate 48, Figure E

Tapes cyprimeriformis Stanton, 1893; p. 106, pl. XXIV, figs. 1–6.

Description — Moderately thick shell, medium to large-size (to 5 cm long); shape subcircular, inequilateral; equivalve, slightly inflated, lenticular cross-section; subcentral beaks slightly projecting; posterodorsal and anterodorsal margins sloping evenly away from beak into broadly and evenly curved posterior and anterior margins; these in turn grade into a gently curved, slightly flattened ventral margin; hinge plate massive with strong cardinal teeth. Shell ornamented by fine growth lines.

Discussion — This species is widespread in middle Turonian marginal marine sandstones in the Western Interior, but never seems to be a dominant member of the fauna. Similar material has been reported from the upper Cenomanian and has been considered conspecific (Stanton, 1893). Whereas the middle Turonian specimens assigned to this species are unquestionably conspecific, the one upper Cenomanian example from Black Mesa is an internal mold and although it compares well with the Turonian examples, it cannot be unquestionably assigned to *Cyprimeria cyprimeriformis*. The specimen could represent *Cyprimeria patella* Stephenson (1952) from the middle Cenomanian Woodbine Formation in central Texas.

Occurrence — The type specimens are from the middle Turonian Codell Sandstone Member of the Carlile Shale in Huerfano Park, southern Colorado. At Black Mesa, present at the top of the Blue Point Tongue: MNA loc. #1150, and in the lower sandstone member of the Toreva Formation; MNA loc. #342 and #988, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone through *Prionocyclus hyatti* Zone, with one possible example from the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone at the Coal Chute section; MNA loc. #963.

Illustrated material — MNA N5100 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation; MNA N5417 from MNA loc. #342, lower sandstone member, Toreva Formation.

Paleoecology — The lenticular cross-section of the shell and deep pallial sinus suggest that this species was a relatively deep infaunal burrower. Its distribution indicates a preference for shallow marine sands in relatively high energy environments of the lower to middle shoreface.

Genus *Cyclina* Deshayes, 1850
Cyclina ? sp.
Plate 37, Figures C, D

Description — Thin shell, small (to 0.7 cm long), subcircular, inequilateral; equivalve, slightly inflated, lenticular cross-section; subcentral beaks blunt and moderately projecting, umbo moderately inflated; posterodorsal margin sloping evenly away from beak into broadly and evenly curved posterior margin; anterodorsal margin slightly concave and curves evenly into rounded anterior margin; ventral margin gently curved; slightly flattened; internal features unknown; surface glossy, ornamented by fine growth lines.

Discussion — The distribution of this species overlaps that of *Cyclorisma orbiculata*, from which it can be distinguished in juveniles by its more central beak and weaker ornament.

Based on the size and overall form, this species is placed in *Cyclina*, but when the internal features are examined it may prove to belong to another genus.

Occurrence — This species occurs in the middle Turonian and ranges from BM65 in the middle shale member, upper *Collignoniceras woollgari woollgari* subzone up to the top of the Hopi Sandy Member, basal *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990).

Illustrated material — MNA N3596, N3597 from MNA loc. #989, Hopi Sandy Member, Mancos Shale, 13 m above base of Hopi Sandy Member.

Genus *Cyclorisma* Dall, 1902
Cyclorisma orbiculata (Hall and Meek, 1856)
Plate 11, Figure I; Plate 37, Figures G, H

Callista (*Dosinopsis*) orbiculata (Hall and Meek); Meek, 1876, p. 186, pl. 5, figs. 2a–c.
Callista (*Dosinopsis*) orbiculata (Hall and Meek); Stanton, 1893, p. 108, pl. XXIV, figs. 9, 10.
Cyclorisma orbiculata Stephenson, 1952; p. 110, pl. 26, figs. 10–13.

Description — Moderately thick shell, small (1.5–2.0 cm long), subcircular, inequilateral; equivalve, moderately inflated; subcentral beaks blunt and moderately projecting, umbo moderately inflated; posterodorsal margin sloping evenly away from beak into broadly and evenly curved posterior margin; anterodorsal margin slightly concave, curves evenly into rounded anterior margin; ventral margin evenly curved and continuous with anterior and posterior margins. Shell ornamented by moderately strong, dense, even, raised growth lines.

Discussion — Stephenson (1952) described a species apparently conspecific with *Callista orbiculata* (Hall and Meek) as *Cyclorisma orbiculata* n. sp. It is not known whether this was a mistake or not, but the material is conspecific and thus should be referred to Hall and Meek. At Black Mesa, specimens are scattered from the upper Cenomanian through middle Turonian.

Occurrence — The type specimens were from the base of the Benton Formation five miles below the mouth of the James River on the Missouri River. At Black Mesa, in the upper sandstone member of the Dakota Formation at Blue Point, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone; MNA loc. #344, and across the region it is scattered throughout the Mancos Shale from within the lower shale member, lower Turonian *Mammites nodosoides* Zone up into the base of the Hopi Sandy Member, *Collignoniceras woollgari woollgari* subzone, particularly in the southwest (Kirkland, 1991), also uncommon in the Blue Point Tongue *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone; MNA loc. #1150. Elsewhere widespread in the Western Interior.

Illustrated material — MNA N5179 from MNA #344, sandstone facies, upper sandstone member, Dakota Formation; MNA N5229 from MNA loc. #262, upper shale member, Mancos Shale, 8 m above top of Hopi Sandy Member; MNA N5476 from MNA loc. #262, middle shale member, Mancos SHale, 3 m above BM65.

Paleoecology — The distribution of this taxon seems to indicate that it was tolerant of a range of water depths and substrate conditions in open marine environments.

Genus *Legumen* Conrad, 1858

Legumen sp. cf. *L. ligula* Stephenson

Plate 44, Figure N

? *Legumen* sp.; Stanton, 1893, p. 107, pl. XXIV, fig. 11.
Legumen ligula Stephenson, 1952: p. 110, pl. 27, figs. 9–11.

Description — Thin shell, moderately small (to 3 cm long), elongate, shape oval to rounded subrectangular, inequilateral; equivalve, slightly inflated; beak small and low, situated near anterior margin; anterodorsal margin short and steep; posterodorsal margin long, straight; anterior and posterior margins evenly rounded joining straight ventral margin which is nearly parallel to anterior margin; surface ornamented by coarse growth lines.

Discussion — Stanton (1893) reported *Legumen* from the middle Turonian Codell Sandstone Member of the Carlile Shale in Huerfano Park in southern Colorado, but the description and illustration of the material makes it difficult to determine if it is conspecific with the Black Mesa specimens. The Black Mesa specimens are close to *Legumen ligula* Stephenson (1952) from the middle Cenomanian Woodbine Formation of central Texas.

Occurrence — At Black Mesa, present at the top of the Blue Point Tongue; MNA loc. #1150, and in the lower sandstone member of the Toreva Formation, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone through *Prionocyclus hyatti* Zone; MNA loc. #342 and #988.

Illustrated material — MNA N5432 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation.

Paleoecology — The thin, elongated shell of this genus suggests that it was a rapid burrower as compared to other venerids from Black Mesa. Its distribution indicates a preference for open marine sand substrates from the lower to middle shoreface.

ORDER MYOIDA

Superfamily Myacea

Family Corbulidae

Paleoecology — The small shells of species in this family are indicative of infaunal suspension-feeders. The small size and short siphons limit the depth to which they may burrow, and they have been observed to burrow very slowly. Perhaps as a means to prevent exposure in shifting sediments, the corbulids fix themselves in the substrate by attaching byssal threads to small sedimentary particles (Stanley, 1970). This may allow the corbulids to inhabit a wider variety of environments, including relatively high-energy environments.

Genus *Corbula* Bruguiere, 1797

Paleoecology — The distribution of this species at Black Mesa indicates a tolerance to a wide variety of environments (from middle shoreface to middle shelf), with the exception of low oxygen environments.

Corbula kanabensis Stanton, 1893

Plate 13, Figure I; Plate 37, Figure N

Corbula kanabensis Stanton, 1893; p. 125, pl. XXVII, figs. 5, 6.

Description — Thin shell, very small (to 0.8 cm long), subtrapezoidal, inequilateral; slightly inequivalve, highly inflated; right valve overlaps left valve most strongly toward anterior and forms flattened band around margin of shell; beak blunt and moderately enrolled; posterior margin inflated, evenly curved from beak to ventral margin, which gently curves up to posterior margin; posterodorsal margin straight, descending from beak to truncated posterior margin; strong, angular posterior unbonal ridge. Shell ornamented by fine raised growth lines.

Discussion — *Corbula kanabensis* is most abundant in the upper Cenomanian, but similar corbulids with an angular umbonal ridge occur throughout the entire section from the near the base of the Mancos Shale up section into the lower sandstone member of the Toreva Formation. Whereas the best preserved specimens appear to be conspecific with *Corbula kanabensis*, some may represent other species such as those described below.

Whereas the species is widespread, it does not occur in intervals that are strongly depauperate in taxa. Likewise it is most abundant in the southwestern part of the basin through much of the Mancos Shale.

Occurrence — The type specimens are from the upper Cenomanian *Sciponoceras gracile* Zone in the upper Kanab Valley of southern Utah and are most abundant at this level at Black Mesa. Widely distributed at Black Mesa from near the base of the Mancos Shale, upper Cenomanian *Metoicoceras mosbyensis* Zone, through the lower sandstone member of the Toreva Formation, middle Turonian *Prionocyclus hyatti* Zone (Kirkland, 1990).

Illustrated material — MNA N5067 from MNA loc. #989, lower shale member, Mancos Shale, BM8; MNA N5488 from MNA loc. #262, middle shale member, Mancos Shale, one meter below BM68.

Corbula sp. cf. *C. kanabensis* Stanton, 1893
Plate 45, Figure F

Diagnosis — This species differs from typical specimens of *Corbula kanabensis* in having a somewhat weaker umbonal ridge, a slightly concave anterodorsal margin and a more sloping posterior margin.

Discussion — The differences between this form and *Corbula kanabensis* may be of only subspecific significance or possibly due to ecophenotypic variation. A great deal of further study is needed on these corbulids.

Occurrence — Present to rather common in the Blue Point Tongue of the Toreva Formation, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone; MNA loc. #1150.

Illustrated material — MNA N5058 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation.

Corbula sp.
Plate 13, Figure J

Diagnosis — This species is similar to *Corbula kanabensis* but readily differs in being less inflated, more ovate, slightly more elongate, and in lacking a strong umbonal ridge.

Discussion — This species appears to be much rarer than the co-occurring *Corbula kanabensis*.

Occurrence — Only known from rare specimens in concretionary marker beds BM8 and BM10, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone; MNA loc. #262 and #306.

Illustrated material — MNA N5165 from MNA loc. #306, lower shale member, Mancos Shale, BM10.

Genus *Caryocorbula* Gardner, 1926
Caryocorbula nematophora (Meek, 1873)
Plate 1, Figure C; Plate 4, Figures D–G, L–O

Corbula nematophora Meek, 1873; p. 496.
Corbula nematophora Meek; Stanton, 1893, p. 124, pl. XXVII, figs. 3, 4.
Caryocorbula ? ovisana Stephenson, 1952; p. 129, pl. 32, fig. 9–15.
Caryocorbula ? varia Stephenson, 1952; p. 129, pl. 32, figs. 16–19.
Caryocorbula ovisana Stephenson; Fursich and Kirkland, 1986, p. 549, fig. 5j.

Description — Relatively thick shell, small (to 1.5 cm), subtriangular, inequilateral; slightly inequivalve with right valve slightly larger than left, moderately inflated; beak prominent, broad and enrolled, situated about one third of length from anterior margin; anterodorsal and posterodorsal margins slope evenly away from beak; ventral margin slightly curved; moderately developed posterior unbonal ridge; cardinal teeth relatively robust on right valve; Shell ornamented by highly variable concentric rugae and/or ribs that weaken across unbonal ridge; some specimens very weakly ornamented.

Discussion — Collections of *Caryocorbula* from Black Mesa are exceedingly variable in ornament. Much of this variation is due to ecophenotypic responses to differences in the environment, but genetic variation also may play an important role. Fursich and Kirkland (1986) have noted a progressive decrease in the strength of ornamentation with interpreted decreasing salinity.

Stephenson (1952) noted *Caryocorbula ovisana* was highly variable, but also erected the species *Caryocorbula varia* for populations of *Caryocorbula* that were more elongate, less inflated, and more finely ornamented. These populations would seem to fall within the range of *Caryocorbula ovisana* found at Black Mesa.

Meek's type of *Corbula nematophora* came from Cretaceous outcrops near Cedar City, Utah (Stanton, 1893). On visiting the type area, it was found that *Corbula ovisana* is conspecific with *Caryocorbula nematophora*.

Occurrence — The types are from the upper Cenomanian near Cedar City, Utah. At Black Mesa, very abundant in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoiceras mosbyensis* Zone; MNA loc. #264, 265, #308, #540, and #963. Also observed to be abundant at this level in southern Utah.

Illustrated material — MNA N4480, N4483, N4484, N4485, N4486, N4515 from MNA loc. #540, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — The distribution of this species indicates that it is a valuable indicator of brackish water conditions (Fursich and Kirkland, 1986). It may be determined that an index to the strength of ornament may be developed that would give an indication of relative salinity.

Genus *Parmicorbula* Vokes, 1944
Parmicorbula sp.
Plate 45, Figure E

Description — Relatively thick shell, very small (to 0.8 cm long), subtrapizoidal, inequilateral; highly inequivalve, strongly inflated; right valve overlaps left valve most strongly toward anterior and forms flattened band around margin of shell; subcentral beak blunt, broad, and moderately enrolled; anterior margin inflated and evenly curved from beak to ventral margin, which gently curves up to posterior margin; posterodorsal margin is concave and slopes gently away from beak; right valve with posterior rostrum, lacking on left valve; gently curved ventral margin; low posterior unbonal ridge. Shell ornamented by fine raised growth lines.

Discussion — The few specimens of this species found seem to compare well with *Parmicorbula* in their external features. The internal features are not known.

Occurrence — Present in the Blue Point Tongue of the Toreva Formation, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone; MNA loc. #1150.

Illustrated material — MNA N5057 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation.

Dakotacorbula n. gen.

Etymology — Named for the great abundance of this genus in the Dakota Formation on the southern Colorado Plateau.

Type Species — *"Corbula" senecta* (Stephenson, 1952)

Diagnosis — Distiguished by its highly inflated, round shell; very small hinge plate and long lateral teeth; adductor muscles on raised lamella, and lacking posterior rostrum.

Discussion — This genus is similar in some respects to *Corbulamella* (Meek and Hayden, 1856) from the Maestrichtian of South Dakota, but differs in the overall evenly rounded shape, less prominent umbo, and in having an umbonal ridge (Speden, 1970). The combination of features identified in this genus clearly distinguishes it from all described genera of corbulids (Cox, 1969).

Occurrence — This genus is known from the middle Cenomanian of Texas and the upper Cenomanian of northern Arizona and southern Utah.

Dakotacorbula senecta (Stephenson, 1952)
Plate 4, Figures H–K, R, S

"Corbula" senecta Stephenson, 1952; p. 135, pl. 33, figs. 5–8.
"Corbula" ponsana Stephenson, 1952; p. 136, pl. 33, figs. 3, 4.
"Corbula" anniculana Stephenson, 1952; p. 136, pl. 33, figs. 1, 2.
corbulid sp. A (cf. *'Corbula' senecta* Stephenson; Fursich and Kirkland, 1986, p. 549, fig. 5k.

Description — Relatively thick shell, very small (to 0.8 cm long), subtriangular to ovate, inequilateral; slightly inequivalve, strongly and evenly inflated; right valve overlaps left valve most strongly toward anterior and forms flattened band around margin of shell; subcentral beak blunt, broad, and moderately enrolled; anterior margin inflated and evenly curved from beak to ventral margin, which gently curves up to posterior margin; posterodorsal margin slopes gently away from beak to curve smoothly into gently curved ventral margin; no posterior rostrum present; low posterior unbonal ridge; adductor muscle scar strongly impressed in shell; hinge plate narrow, cardinal teeth small with long anterior lateral tooth. Shell ornamented by fine raised growth lines.

Discussion — Stephenson (1952) erected a number of species for well-rounded, "bean-shaped" corbulids from the middle Cenomanian Woodbine Formation in central Texas. The differences between these taxa seem to be minor and possibly ecophenotypic in origin. Very similar corbulids are present at Black Mesa and likely conspecific with the Texas specimens.

Whereas Stephenson (1952) was not able to observe the internal features of the Texas material, they are readily examined on many of the Black Mesa specimens. The internal features of this group reveal that they are quite unlike any described genera of Corbulidae and thus were recognized as representing an undescribed genus (Fursich and Kirkland, 1986).

As with other brackish water taxa, a great deal of variability may be characteristic of this species. Thus, the several related species described by Stephenson (1952) have been synonymized.

Occurrence — The types are from the middle Cenomanian Woodbine Formation in central Texas. At Black Mesa, common in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #264, #265, #308, #540, and #963. Also observed at this level in southern Utah.

Illustrated material — MNA N4487, N4488, N4489, N4490 from MNA loc. #540, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — The distribution of this species indicates that it preferred brackish water habitats (Fursich and Kirkland, 1986).

Superfamily Pholadacea
Family Teredinidae

Discussion — Fossil teredids are difficult to identify because the classification of species in this family is based on the soft parts and pallets. These are generally not preserved (Cox and others, 1969). Other than the one locality in which the reduced shells are preserved, the material from Black Mesa is grouped in the form genus *Teredolithus*.

Paleoecology — These are wood-boring, "worm-like" bivalves with highly reduced shells. They generally produce a calcareous lining in their borings. From these borings the various species suspension-feed. Their distribution is very widespread due to both drift in floating logs and diverse habitat preferences; wood substrates in brackish to deep marine environments.

Genus *Terebrimya* Stephenson, 1952
Terebrimya sp.
Plate 13, Figure M

Description — Very thin shell, small (to 0.8 cm long), teredoform; height about equal to length, inequilateral; equivalve with shells very enrolled so that a pair of valves would have a circular cross section gaping both anteriorly and posteriorly; beaks prominent and enrolled; umbonal ridge broadly rounded; subcentral umbonal groove bounded by fine ridges; central posterior margin extended in tongue-like projection beyond rest of shell; surface ornamented by fine, sharp, raised growth lines.

Discussion — The shells of the Black Mesa specimens compare very well with those of *Terebrimya lamarana* Stephenson (1952) from the middle Cenomanian Woodbine Formation in central Texas, but without knowledge of the soft parts and pallets it is impossible to determine if they are conspecific.

Occurrence — Several examples from a fossil log preserved in concretionary marker bed BM10, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone at Blue Canyon; MNA loc. #271 on the southwestern side of Black Mesa.

Illustrated material — MNA N5170 from MNA loc. #271, lower shale member, Mancos Shale, BM10.

Genus *Teredolithus* Bartsch, 1930
Teredolithus sp.
Plate 13, Figure L; Plate 45, Figure H

Description — Shipworm tubes preserved in fossil wood, as compacted casts, and as isolated calcareous tubes. Some tubes smooth, gradually expanding to a maximum diameter of around one centimeter with subhemispherical calcareous terminations. Other tubes with periodic raised concentric ribs. These may relate to the structure of the wood in which they bored.

Discussion — Shipworm remains are found scattered throughout the Greenhorn cyclothem at Black Mesa and seem to have colonized drifting logs. Their distribution equals that of wood in marine settings and seems to have little significance in environmental interpretations, beyond indicating a marine influence.

Occurrence — Widely scattered at all sites across Black Mesa from the upper sandstone member of the Dakota Formation up through the Mancos Shale into the lower sandstone member of the Toreva Formation.

Illustrated material — MNA N5172 from MNA loc. #306, lower shale member, Mancos Shale, BM10; MNA N5089 from MNA loc. #1150, top of Blue Point Sandstone Tongue, Toreva Formation.

ORDER HIPPURITOIDA
Superfamily Hippuritacea
Family Radiolitidae
Genus *Radiolites* Lamarck, 1801
Radiolites sp.

Description — Broken rudistid fragments, with coarse radial ribs and lamellose growth lines.

Discussion — Rudistid fragments are rare at Black Mesa and are widely scattered through the lower and middle shale members of the Mancos Shale. The available material seems to be assignable to the genus *Radiolites*.

Occurrence — Very rare at Black Mesa in the lower shale member, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone; MNA loc. #254 (Cobban, 1975), up section (*Neocardioceras juddii* Zone; MNA loc. #305 and #989) to a few meters below the base of the Hopi Sandy Member in the middle shale member of the Mancos Shale; MNA loc. #262, middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone.

Paleoecology — Rudistid bivalves are the major tropical reef builders during the Cretaceous. The radiolitids were cemented to the substrate at least early in ontogeny and could be free living when mature, with ribs developed for locking individuals together, sometimes with co-cementation. Symbiotic algae permitted them to grow rapidly in the reef environment (Kauffman and Johnson, 1988).

The scarcity, apparently small size (maximum estimated size of about 10 cm) and isolated occurrence of specimens suggests that these individuals represent examples of *Radiolites* at the extreme extent of their range of environmental tolerance in temperate waters. The occurrence of rudistids does not necessarily indicate that the bottom was within the photic zone as the small size of the Black Mesa specimens may indicate slow growth of individuals, who have lost the typical symbiotic algae. Water depths at sites where these specimens have been found are below storm wave base, where only extremely distal storm effects are observed or not at all. This suggests depths significantly greater than 30 m (Aigner, 1985). In clear water environments, 30 m would be in the photic zone, but significant amounts of suspended material would limit the depth of the photic zone. High rates of fine clastic sedimentation at Black Mesa suggest a reduced depth for the effective photic zone.

SUBCLASS ANOMALODESMATA
ORDER PHOLADOMYOIDA
Superfamily Pholadomyacea
Family Pholadomyidae

Paleoecology — Species in this family are deep infaunal suspension-feeding bivalves. Living representatives of the family are deep marine taxa, whereas the distribution of the group at Black Mesa indicates that many Cretaceous representatives preferred shallow marine environments. This is particularly true of the larger species, which are restricted to lower to middle shoreface and shallow shelf sandstones.

Genus *Pholadomya* Sowerby, 1823
Pholadomya coloradoensis Stanton, 1893
Plate 48, Figure M

Pholadomya coloradoensis Stanton, 1893; p. 116, pl. XXVI, fig. 2.

Description — Thin shell, small to medium-sized (to 4 cm long), ovate, longer than high, inequilateral; equivalve, well inflated; beak situated about one-third of length from anterior margin blunt, enrolled and projecting beyond hinge, umbo well inflated; anterior margin evenly curved posterior margin more acutely curved, ventral margin gently curved and subparallel to hinge. Shell ornamented by widely spaced, fine radial costae and concentric growth lines.

Discussion — The species is known from one specimen from the middle Turonian at Black Mesa. A similar species is present in the upper Cenomanian along the Mogollon Rim in central Arizona.

Occurrence — The type specimens are from the middle Turonian *Prionocyclus hyatti* Zone in the Codell Sandstone Member of the Carlile Shale in Huerfano Park, southern Colorado. One specimen known from Black Mesa, in the lower sandstone member of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone; MNA loc. #342.

Illustrated material — MNA N5399 from MNA loc. #342, lower sandstone member, Toreva formation.

Pholadomya sp.
Plate 6, Figure J; Plate 13, Figure K

Description — Very thin shell, moderately large (to 8 cm long), ovate, longer than high, inequilateral; equivalve, strongly inflated; beak situated about one-fourth of length from anterior margin, blunt, enrolled and projecting beyond hinge, umbo well inflated; anterior margin evenly curved, posterior margin more acutely curved, ventral margin gently curved and subparallel to hinge. Shell ornamented by concentric growth lines and weak concentric rugae along anterior half of shell.

Discussion — This species is known from a few rather poorly preserved specimens from the upper Cenomanian in the upper sandstone member of the Dakota Formation and lower Mancos Shale. Much better preserved specimens have been observed in the Twowells Sandstone Tongue of the Dakota Formation in east-central Arizona.

Occurrence — Uncommon in the upper Cenomanian at Black Mesa, in the sandstone facies of the upper sandstone member of the Dakota Formation, *Metoicoceras mosbyensis* Zone; MNA loc. #963 and between concretionary marker beds BM8 and BM10, and above BM10 upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone; MNA loc. #262.

Illustrated material — MNA N5519 from MNA loc. #963, sandstone facies, upper sandstone member, Dakota Formation; MNA N3551 from MNA loc. #262, lower shale member, Mancos Shale, just above BM10.

Genus *Goniomya* Agassiz, 1842
Goniomya n. sp.
Plate 13, Figure H

Description — Thin, very small (around 0.5 cm long), oblong shell, inequilateral; equivalve, moderately inflated; umbo subcentral; surface ornament consists of oblique rugae extending from anterodorsal and posterodorsal sides of shell, descending toward center line, where they are connected by short horizontal rugae.

Discussion — Only one distorted pair of valves was found at Black Mesa. This small species has also been reported from southern Utah by Koch (1977). Unfortunately, adequate material from which to describe this species has not been recovered yet.

Occurrence — Very rare in the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone of southern Utah and Arizona; MNA loc. #989, just above BM8.

Illustrated material — MNA N5160 from MNA loc. #989, lower shale member, Mancos Shale, just above BM8.

Superfamily Padoracea
Family Laternulidae

Paleoecology — Species in this family are deep infaunal suspension-feeding bivalves. Living representatives of the family are deep marine taxa, whereas the distribution of the group at Black Mesa indicates that many Cretaceous representatives preferred shallow marine environments, with species restricted to either middle shoreface environments or brackish water lagoons (Fursich and Kirkland, 1986).

Genus *Laternula* Roding, 1798
Laternula lineata (Stanton, 1893)
Plate 48, Figure K

Anatina ? lineata Stanton, 1893; p. 117, pl. XXVI, figs, 3, 4.
Laternula lineata (Stanton), Cobban and Hook, 1979, p. 11.

Description — Thin shell, medium-sized (4.5 cm long), subquadrate to ovate, slightly longer than high, inequilateral; slightly inequivalve, slightly inflated, somewhat flattened flanks; beaks little projecting; posterodorsal and anterodorsal margins sloping gently away from subcentral beak before turning rather sharply into nearly vertical posterior and anterior margins; these margins are subequal in height and curve smoothly into rather straight ventral margin. Shell ornamented by evenly spaced, concentric rugae which fade out on posterior half of shell.

Discussion — This species is known from one fairly well-preserved specimen that compares well with Stanton's (1893) type specimen.

Occurrence — The type specimens are from the Codell Sandstone Member of the Carlile Shale in Huerfano Park, southern Colorado, middle Turonian *Prionocyclus hyatti* Zone. One specimen known from Black Mesa, in the lower sandstone member of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone; MNA loc. #342. Also known from the middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone in central New Mexico.

Illustrated material — MNA N5403 from MNA loc. #342, lower sandstone member, Toreva Formation.

Paleoecology — The distribution of this species indicates a preference for shallow open marine sands.

Genus *Anatimya* Conrad, 1860
Anatimya virgata Stephenson, 1952
Plate 4, Figure T

Laternula virgata Stephenson, 1952; p. 88, pl. 21, figs. 10–12.

Description — Thin shell, medium-sized (to 3.5 cm long), elongate ovate, longer than high, inequilateral; slightly inequivalve, strongly inflated; beaks slightly projecting; posterio-dorsal and anterio-dorsal margins sloping very gently away from subcentral beak before turning rather sharply into nearly vertical posterior and evenly curved anterior margins; these margins are subequal in height and curve smoothly into the nearly straight ventral margin which is subparallel to dorsal margin. Shell ornamented by subequally spaced, concentric rugae and a few radial costae on posterior half of shell.

Discussion — The subparallel dorsal and ventral margins and radial ornament on the posterior half of shell suggest that this species should be included in the genus *Anatimya*.

Occurrence — The type specimen is from the middle Cenomanian Woodbine Formation in central Texas. At Black Mesa, rare in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #264, #265 and #540. Also observed at this level in southern Utah.

Illustrated material — MNA N4491 from MNA loc. #265, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — The distribution of this species indicates a preference for brackish water environments at Black Mesa (Fursich and Kirkland, 1986).

Superfamily Poromyacea
Family Poromyidae

Paleoecology — Species in this family are shallow infaunal to epifaunal bivalves that feed by scavenging on the bottom or feeding on live prey. Living representatives of the family are deep marine taxa, whereas the distribution of the group at Black Mesa indicates that many Cretaceous representatives preferred shallow marine environments ranging from brackish water lagoons to middle shelf.

Genus *Poromya* Forbes, 1844
Poromya lohaliensis n. sp.
Plate 13, Figures P, Q

Etymology — Named for its type locality at Lohali Point on the east side of Black Mesa, northeastern Arizona.

Diagnosis — Distiguished from other species by its distinctive ornament of fine, dense, granulate threads that cross the rugae on the disk of shell obliquely.

Description — Very thin shell, small (to 2 cm long), ovate, inequilateral; equivalve, moderately inflated; beak situated anterior to midline, blunt, moderately projecting and enrolled; anterior margin evenly curved; ventral margin evenly curved; posterodorsal margin nearly straight; posterior margin slightly curved to straight; strong angular ridge separates inflated disk from flattened posterior slope; surface ornamented by evenly spaced concentric rugae that stop at posterior ridge, posterior slope smooth; entire surface covered by extremely fine, dense granulate threads that cross rugae obliquely.

Discussion — This distinctive species is readily distinguished from species of *Psilomya* by the change in ornament across the angular posterior ridge.

Occurrence — Uncommon in concretionary marker bed BM10, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone MNA loc. #992.

Types — Holotype, N5150; paratype MNA N5149 both from MNA loc. #992, lower shale member, Mancos Shale, BM10.

Genus *Psilomya* White, 1874
Psilomya concentrica Stanton, 1893
Plate 44, Figure P (b); Plate 45, Figure D (c)

Psilomya concentrica Stanton, 1893; p. 119, pl. XXVI, figs. 8–10.
Psilomya concentrica Stanton; Stephenson, 1952, p. 92, pl. 22, figs. 13–20.

Description — Very thin shell, small (to 2.5 cm long), ovate, inequilateral; equivalve, moderately well inflated; prominent beak enrolled and situated about one-third of length from anterior margin; anterior margin evenly curved; ventral margin evenly and broadly curved; posterodorsal margin nearly straight; ventral margin slightly curved to straight; flattened posterior slope; posterior margin strongly curved. Shell ornamented by variably developed evenly spaced concentric rugae; entire surface covered by extremely fine radially distributed spine bases.

Discussion — *Psilomya concentrica* may be distinguished from *Psilomya elongata* in being less elongate and having rugae over the entire shell, and from *Psilomya meeki* in having concentric rugae as opposed to radial ribs. *Psilomya* sp. cf. *P. concentrica* differs in having stronger rugae and and a more broadly curved posterior margin.

The types of *Psilomya concentrica* are from the middle Turonian Codell Sandstone in Huerfano Park in southern Colorado, and Stanton (1893) suggested that specimens of *Psilomya* with even concentric rugae from the late Cenomanian of southern Utah are conspecific with the middle Turonian material. In addition, Stephenson (1952) described *Psilomya concentrica* from the middle Turonian in central Texas and indicated that the strength of the rugae are rather variable between specimens. The Black Mesa specimens are likewise variable in the strength of the rugae.

Occurrence — The type specimens are from the Codell Sandstone Member of the Carlile Shale, middle Turonian *Prionocyclus hyatti* Zone in Huerfano Park, southern Colorado. Across Black Mesa, uncommon in concretionary marker beds BM8 and BM10, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone (Kirkland, 1990) and locally common at Blue Point in the Blue Point Tongue; MNA loc. #1150 and in the lower sandstone member of the Toreva Formation; MNA loc. #342, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone. Also known from the upper Cenomanian of southern Utah and in the middle Cenomanian in central Texas.

Illustrated material — MNA N5096, N5100 from MNA loc. #1150, Blue Point Sandstone Tongue, Toreva Formation.

Psilomya sp. cf. *P. concentrica* Stanton

Plate 10, Figure R

Diagnosis — Much like *Psilomya concentrica* but has a much more broadly curved posterior margin and the rugae covering the entire shell appear to be slightly finer and stronger.

Discussion — This species would most likely have been included in *Psilomya concentrica*, but for that fact that large populations consistently differ from typical specimens of *Psilomya concentrica* in the dense rugae. The fine radially distributed spine bases readily distinguish this species as belonging to the genus *Psilomya*.

Occurrence — At Black Mesa, common in the upper Cenomanian *Vascoceras diartianum* subzone of the *Sciponoceras gracile* Zone on the north and east sides of the mesa; MNA loc. #296, #989, #990, and #992.

Illustrated material — MNA N5175 from MNA loc. #992, lower shale member, Mancos Shale, BM4.

Psilomya elongata Stanton, 1893

Plate 25, Figures G, I, J

Psilomya elongata Stanton, 1893; p. 119, pl. XXVI, figs. 11, 12.

Description — Very thin shell, medium-sized (to 4 cm long), elongate ovate, inequilateral; equivalve, moderately inflated; prominent beak enrolled and situated about one-fourth of length from anterior margin; distinct posterior unbonal ridge; anterior and posterior margins evenly curved; ventral margin evenly and broadly curved; posterodorsal margin nearly straight; ventral margin slightly curved to straight; flattened posterior slope; surface ornamented by evenly spaced concentric rugae only in umbonal region; entire surface covered by extremely fine radially distributed rows of spine bases.

Discussion — This large, distinct species of *Psilomya* is readily distinguished from the other species present at Black Mesa by its elongate shell. It would be easy to confuse with small examples of *Pholadomya* but for the radially distributed minute spine bases.

Occurrence — The type specimens are from the *Sciponoceras gracile* Zone in southern Utah. At Black Mesa, present at all sections, restricted to the lower part of the lower shale member of the Mancos Shale from BM8 to a short distance above BM13, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone (Kirkland, 1990).

Illustrated material — MNA N233, N5187, N5548 from MNA loc. #305, lower shale member, Mancos Shale, concretions between BM12 and BM13.

Psilomya meeki White, 1874

Plate 13, Figures N, O

Psilomya meeki White, 1874; p. 118, pl. XXVI, figs. 5–7.

Description — Very thin shell, small (to 2.5 cm long), ovate, inequilateral; equivalve, moderately inflated; prominent beak enrolled and situated about one-third of length from anterior margin; anterior margin evenly curved; ventral margin evenly and broadly curved; posterodorsal margin nearly straight; flattened posterior slope; posterior margin strongly curved; surface ornamented by distinct fine radial ribs on posterior slope, with entire surface covered by extremely fine radially distributed rows of spine bases.

Discussion — This species can be distinguished from all other species from Black Mesa assigned to *Psilomya* by its distinct radial ornament on its posterior flank. In this character, this species of *Psilomya* appear similar to the closely related genus *Liopistha*, which has fine radial ribs over the entire shell.

Occurrence — The type specimens are from the upper Cenomanian *Sciponoceras gracile* Zone in southern Utah. At Black Mesa present at all sites (Kirkland, 1990), restricted to the *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone.

Illustrated material — MNA N20 from MNA loc. #236; MNA N5159 from MNA loc. #989; both from lower shale member, Mancos Shale, BM8.

Psilomya sp.

Plate 26, Figure N

Diagnosis — Much like *Psilomya concentrica* in size and overall form but lacking rugae.

Discussion — This species of *Psilomya* is known only from compacted specimens from the lower and middle Turonian. In its lack of rugae, it appears closest to *Psilomya levis* Stephenson (1952) from the middle Cenomanian of central Texas. The material is too poorly preserved to relate confidently these specimens to any of the species described above. It is possible that these specimens represent weakly ornamented deeper water ecomorphs of *Psilomya concentrica*.

Occurrence — Widely scattered through the lower into the middle Turonian from just above BM15, lower Turonian *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone through the Hopi Sandy Member of the Mancos Shale, *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone on the southwestern side of the mesa (Kirkland, 1990).

Illustrated material — MNA N5230 from MNA loc. #262, lower shale member, Mancos Shale, just below BM35.

Family Cuspidariidae

Genus *Cuspidaria* Nardo, 1840

***Cuspidaria alaeformis* Stephenson, 1952**

Plate 3, Figures V, W

Cuspidaria alaeformis Stephenson, 1952; p. 93, pl. 22, figs. 7–12.

Description — Thin shell, small to medium-size (to 3 cm long), spoon-shaped, strongly inequilateral; equivalve; beak blunt, situated toward anterior side; from beak anterior margin broadly curved into gently curved ventral margin; postroventral margin becomes slightly concave; anterior part of shell strongly inflated; long posterior rostrum; posterodorsal margin nearly straight; surface ornamented by even strong rugae best developed on main part of disk.

Occurrence — The type specimens are from the middle Cenomanian Woodbine Formation in central Texas. At Black Mesa, present in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #264, #265, #308, #540, and #963. Also observed at this level in southern Utah.

Illustrated material — MNA N4499 from MNA loc. #540; MNA N4500 from MNA loc. #264; both from shale facies, upper sandstone member, Dakota Formation.

Paleoecology — Species in this genus are shallow infaunal to epifaunal bivalves that feed by scavenging on the bottom or feeding on live prey. Whereas, this genus today is characteristic of deep marine environments, the distribution of *Cuspidaria alaeformis* indicates that it is a brackish water species. All specimens of this species from Black Mesa are from brackish water lagoon environments (Fursich and Kirkland, 1986). In addition, the type specimens from central Texas were found in association with many taxa having exclusively brackish water distributions at Black Mesa (Stephenson, 1952). This indicates the problems inherent in trying to estimate water depth during the Cretaceous by comparing the distribution of modern related taxa to the distribution of one or a very few extinct taxa. The analysis of diverse faunas in association with an understanding of sedimentology are the only proper way to reconstruct paleoenvironments.

CLASS SCAPHOPODA

Paleoecology — Scaphopods burrow into the sediment by means of a foot protruding from the larger opening of the shell, which is held in sediment at an angle, with the smaller end of the shell exposed. Fine tentacles gather tiny organisms and detritus in the sediment, which are passed by cilia to the mouth. Most modern species live at shelf depths. Scaphopods are locally common in the deep sea.

Family Dentalidae

Genus *Dentalium* Linne, 1758

***Dentalium* sp.**

Plate 14, Figure DD; Plate 49, Figure E

Description — Small scaphopods 0.1–0.2 cm across aperture and 0.5–2 cm long, gradually tapering, tubular, shells appears straight with the only ornament visible consisting of fine growth lines.

Discussion — Rare, small, weakly ornamented scaphopods from the late Cenomanian at Black Mesa may represent an undescribed species. Among the few described species, it is closest to *Dentalium* (*Laevidentalium*) *pauperculum* Meek and Hayden (1860) from the Campanian of the central Western Interior (Kauffman, 1961), with which it may be conspecific.

Occurrence — Rare in concretions and shales in the late Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone all around Black Mesa (Kirkland, 1990). One specimen was encountered in the middle Turonian *Prionocyclus hyatti* Zone near base of sandy interval, unit 203, at the Lohali Point Section.

Illustrated material — MNA N5516 from MNA loc. #989, BM8, lower part, lower shale member, Mancos Shale; MNA N5296 from MNA loc. #989, 6 m above BM77, upper shale member, Mancos Shale.

Family Siphonodentaliidae

Genus *Cadulus* Philippi, 1844

***Cadulus praetenuis* Stephenson, 1952**

Plate 14, Figures BB, CC

Cadulus praetenuis Stephenson, 1952; p. 143, pl. 34, figs. 7–9.

Diagnosis — Tiny (3–4 mm long), smooth scaphopods; central portion slightly swollen; polished shell ornamented by fine growth lines.

Discussion — The specimens of *Cadulus* may be overlooked due to their very small adult size. Most specimens at Black Mesa were found in association with concentrations of minute gastropods, such as the accumulation from a concretion from between the BM8 and BM10 at Blue Point described by Elder (1987a). These specimens compare well with *Cadulus praetenuis* from the middle Cenomanian of Texas.

Occurrence — Uncommon in concretions in the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone at Black Mesa. The type locality is in the middle Cenomanian of central Texas.

Illustrated material — MNA N5360, N5361 from MNA loc. #271, BM10, lower part, lower shale member, Mancos Shale.

CLASS GASTROPODA

Discussion — There has been relatively little taxononmy published concerning Cenomanian and Turonian gastropods. The principle published reports include those by Stanton (1893), Stephenson (1952), and Kauffman (1961). Sohl (1967a) has provided updated generic assignments for many of the previously described taxa. Without examining the type specimens and in some cases recollecting the type localities, many identifications cannot be made with certainty.

Paleoecologic interpretations are made primarily by comparison with living relatives of the same genus or in most cases family. These data are most readily available in the popular shell identification books. The references most often used for this ecologic information are Morris (1966), Abbott (1968), Keen (1971), Keen and Coan (1974), Morris (1975), Emerson and Jacobson (1976), Morton (1979), and Rehder (1981). Further paleoecologic data are provided by Sohl (1967a; 1970, 1987).

ORDER ARCHEOGASTROPODA

Paleoecology — The Black Mesa representatives of this order are interpreted as being herbivores that prefer hard substrates. Most occurrences are from shallow marine settings at the base and top of the Greenhorn cyclothem, that may be readily interpreted as being within the photic zone with shell lags serving as firm substrates. However, various species and genera of archeogastropods are scattered through the upper part of the middle shale member of the Mancos Shale at Blue Point on the landward side of the basin (Kirkland, 1990). No examples of this order were found at a comparable level on the seaward side of the basin. These occurrences can be interpreted in three ways:

1. That the middle shale member of the Mancos Shale was deposited in the photic zone and their scarcity is explained by the scarcity of firm substrates.
2. That the specimens, which are all small in size (< 1 cm), were rafted into the environment on floating vegetation, which is common in the member.
3. That the specimens were transported by storms down-slope into the environment from shallower water environments within the photic zone.

Whereas it is not possible at this time to differentiate which interpretation is correct, the data indicate at least the proximity of the photic zone to the substrate in the area of southwestern Black Mesa during the deposition of the middle shale member.

Superfamily Euomphalacea
Family Weeksiidae
Genus *Weeksia* Stephenson, 1941
Weeksia n. sp.

Plate 41, Figures B, C

Description — One specimen 13 cm in diameter, discoidal; whorl expand rapidly; subrectangular, slightly wider than high, with upper and lower periphery angula; marked by weak elongate tubercles along the shoulder; the surface appears smooth.

Discussion — The discoidal shell, lack of ornament beyond peripheral nodes and rapid expansion of the whorl of this specimen from Black Mesa appears to compare well with the genus *Weeksia* from the Campanian and Maestrichtian of the Gulf (Wade, 1926; Stephenson, 1941; Sohl, 1960, pl. 5, figs. 35, 36). The Black Mesa specimen differs from the Gulf Coast species in appearing to be less planaspiral. The Black Mesa specimen is not sufficient for defining a new species.

Occurrence — One specimen from the top of the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point (MNA loc. #1150), middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5486 from MNA loc. #1150, top of Blue Point Sandstone Tongue, Toreva Formation.

Paleoecology — Modern Archeogastropoda are herbivorous snails that require firm substrates as they are poorly adapted to remove suspended material from the mantle cavity. The distinctive morphology of the extinct euomphalitids does not exclude this mode of life, but does little to support this interpretation beyond indicating that it was an epifaunal taxon. The one specimen of this group was from a shell bed in a shallow open marine sandstone, suggesting the availability of firm substrates and possible benthic aquatic plant materials.

Superfamily Patellacea
Family Acmaeidae
Genus *Acmaea* Escholtz, 1830
Acmaea sp.

Plate 36, Figure A

Description — Thin, cap-shaped shells 0.5–0.7 cm in diameter; nearly circular with apex slightly off center ornamented by weak concentric folds.

Discussion — Gastropods assigned to *Acmaea* are distinguished from the superficially similar *Anisomyon* in having a lower profile, smaller size, and concentric folds. The muscle scars that would readily permit these genera to be distinguished have not been observed in any examples of either genus recovered at Black Mesa. The few examples of *Acmaea* from Black Mesa do not represent juvenile examples of *Anisomyon*, as the stratigraphic distribution of these two genera does not overlap.

Occurrence — Rare at Blue Point, Black Mesa in the upper part of the middle shale member into the lower part of the Hopi Sandy Member of the Mancos Shale, middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5282 from MNA loc. #262, one meter below BM64, middle shale member, Mancos Shale.

Paleoecology — Herbivorous gastropods that prefer hard substrates. Specimens of this genus at Black Mesa are found in fine-grained rocks in which there are few large shells to serve as appropriate substrates, and the sediment was stirred by the common deposit feeders found in this interval. Terrestrial plant material is common, and these rare occurrences may represent individuals that were rafted offshore. It is also possible that these specimens represent rare individuals living at the limits of their environmental tolerance.

Superfamily Trochacea
Family Trochidae
Genus indeterminant
genus and species indeterminant

Plate 36, Figure B

Description — Small, thick-shelled, turbonate gastropod approximately 0.6 cm high and 0.8 cm wide; open umbilicus; three evenly rounded whorls preserved, ornamented by broad axial ribs that strengthen over shoulder.

Discussion — One gastropod mold with some shell adhering recovered from the middle shale member of the Mancos Shale appears to represent an undescribed species of trochid gastropod. It does not compare closely to any described genus of Cretaceous gastropod.

Occurrence — One specimen from the southwestern part of Black Mesa at Blue Point (MNA loc. #262) from about four meters above BM66 in the middle shale member of the Mancos Shale, middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5271 from MNA loc. #262, 4 m above, BM66, middle shale member, Mancos Shale.

Paleoecology — Trochid gastropods are herbivores which prefer firm substrates. The one specimen from Black Mesa assigned to this family is from shallow offshore marine muds and may represent an individual rafted offshore or may represent a rare occurrence at the limit of its habitat tolerance.

Family Neritidae

Paleoecology — Small herbivorous gastropods which prefer firm or vegetative substrates. The globose shell is an adaption for withstanding the effect of waves under high energy shallow water conditions. Examples of gastropods from this family from the offshore shales may be a result of rafting offshore on drifting vegetation, washed down slope, and/or represent individuals at the limit of their environmental tolerance. The distribution of both the genera recognized at Black Mesa indicates a tolerance of a broad range of salinities and environments.

Genus *Nerita* Linne

***Nerita* spp.**

Plate 36, Figure C; Plate 41, Figures D, E

Description — Small, thick-shelled globose gastropod, 1.5 cm high and 1.5 cm wide; whorl evenly rounded and rapidly expanding, with previous whorls visible at low apex; suture distinct and slightly incised; inner lip greatly thickened, umbilicus closed, ornamented by fine spiral costae and axial ribs curving away from aperture on adapical side of whorls.

Discussion — Although fitting in well with the concept of *Nerita* as used by other authors, the specimens from Black Mesa do not compare well with any described Cretaceous species. It is assumed that the material represents one or more undescribed species. Most of the Black Mesa material consists of compacted specimens and internal molds.

Occurrence — Compacted specimens present at the base of the shale facies of the upper sandstone member of the Dakota Formation at Blue Point and rarely as internal molds at this level elsewhere, upper Cenomanian *Metoicoceras mosbyensis* Zone, one specimen from below BM38 in the lower shale member of the Mancos Shale, basal middle Turonian *Collignoniceras woollgari woollgari-Mytiloides hercynicus* subzone of the *Collignoniceras woollgari* Zone. One well preserved specimen from the top of the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5273 from MNA loc. #262, below BM38, upper part, lower shale member, Mancos Shale; MNA N5487 from MNA loc. #1150, mainbody of Blue Point Sandstone Tongue, Toreva Formation.

Genus *Neritina* Lamarck, 1816

***Neritina* spp.**

Plate 2, Figures F, G; Plate 36, Figure G

Description — Very small, thick-shelled, globose gastropods, 0.2 cm high and 0.3 cm wide; whorl evenly rounded and rapidly expanding with only apical whorl visible at very low apex; suture distinct and slightly incised; inner lip greatly thickened, outer lip moderately thickened, umbilicus closed; shell smooth but for fine growth lines.

Discussion — The small size of the specimens of this genus and lack of distinctive ornament make comparison with described species difficult. However, other Cretaceous species with which the author is familiar are more ornate.

Occurrence — Present in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #264, #265, #540), also rare in the upper part of the middle shale member of the Mancos Shale at Blue Point in the southwest, middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N1034 from MNA loc. #265, shale facies, upper sandstone member, Dakota Formation; MNA N5272 from MNA loc. #262, 4 m above BM54, middle shale member, Mancos Shale.

ORDER MESOGASTROPODA

Superfamily Certhiacea

Family Cassiopidae

Genus *Craginia* Stephenson, 1952

***Craginia turriformis* Stephenson, 1952**

Plate 2, Figure N

Glauconia coalvillensis (Meek); Stanton, 1893, in part, p. 132, pl. XXVIII, fig. 11; not pl. XXIX, fig. 1, 2.
Craginia turriformis Stephenson, 1952; p. 155–156, pl. 36, figs. 30–36.
Gymnentome (Craginia) coalvillensis (Meek); Fursich and Kirkland, 1986, p. 549, fig. 5o.

Description — Large (up to 6.5 cm high and 2.6 cm wide), high-spired gastropod with an apical angle of approximately 30°; base somewhat convex with small deep umbilicus; about 12 subrectangular whorls with recessed suture; whorls ornamented by broad, flat to slightly concave, raised band extending over much of lower two-thirds of whorl; bounded by distinct revolving ridges; below band, shell beveled to suture at angular, basal, spiral ridge; above band, a rounded spiral ridge whorl lies on slope to suture, entire surface of whorls covered by fine spiral lines, growth line indicates the development of notch centered on adapical side of the band.

Discussion — Mennessier (1984) made *Craginia* a subgenus of *Gymnentome* Cossmann, 1909, but Cleevely and Morris (1988) support the retention of *Craginia* as a distinct, largely North American genus. It is characterized by large turreted shells with an adapically positioned sinus. It has been pointed out in both papers that cassiopids are quite variable, leading to a proliferation of species names. Thus, whereas the Black Mesa specimens differ in a number of sculptural details from the examples illustrated by Stephenson (1952) and Stanton (1893), their separation is not warranted without more extensive study.

Fursich and Kirkland (1986) and Kirkland (1990a) referred the Black Mesa specimens to *Craginia coalvillensis* (Meek). Research in progress by the author on extensive brackish water deposits in the Cenomanian and Turonian of southern Utah indicates that populations of *Craginia* from Turonian are consistently more carinate in whorl outline than are the Cenomanian specimens, *Craginia turriformis*. The Turonian carinate forms compare well with those described as *Cassiope whitfieldi* White (1877) and illustrated by Stanton (1893, pl. XXIX, figs. 1, 2). Meek (1873) never illustrated the types of his *Turritella coalvillensis* and Stanton (1893) synonomized White's species with these as one highly variable species. Research indicates that the brackish faunas at Meek's type locality at Coalville, Utah are in the Turonian and strongly suggest that *Craginia coalvillensis* is most probably the carinate taxon.

Occurrence — Present to rather abundant locally in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #264, #265, #540). Also present at this level throughout Utah and in the middle Cenomanian Woodbine Formation in Texas. The type locality is at Coalville, northern Utah.

Illustrated material — MNA N822 from MNA loc. #264, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — Cleevely and Morris (1989) reviewed the ecology of the Cassiopidae in detail. Previous interpretations of their distribution have been used to indicate that species in this family range from fresh to brackish water, but recent analysis indicates that their distribution is from brackish to shallow open marine. All North American occurrences of *Craginia* are associated with brackish water taxa (sometimes with taxa indicative of open marine conditions in mixed assemblages). It appears to prefer conditions of moderately lowered salinities supporting diverse brackish water assemblages and has not been observed to occur in low diversity brackish water assemblages or with fresh water taxa.

Cleevely and Morris (1989) interpret species in this family to feed on fine disseminated algae and detritus and discount the the possibility that they may have been suspension-feeders. This possibility should not be discounted in this extinct group as they have apertural features similar to those found in some turritellids. Perhaps as has been reported in the Turritellidae (Allmon, 1988), they employed both feeding modes. The distribution of species in this family indicate a tropical to subtropical distribution (Sohl, 1987; Cleevely and Morris, 1989).

Family Turritellidae

Paleoecology — The ecology of the genus *Turritella* has recently been readdressed by Allmon (1988), who found that whereas dominantly ciliary suspension feeders, several species also were deposit feeders and grazers part of the time. He also found that while mostly living at depths from 10 to 100 meters, some species were also found in intertidal settings and water up to 1500 meters deep and whereas most prefer water temperatures from 15 to 20 degrees centigrade, they ranged from 2 to 24 degrees centigrade. They prefer fine substrates but are found associated with practically all substrates. They burrow in subparallel to the sediment or lie on top of if it. Adults may be largely immobile; but juveniles may be quite active. The planktonic larval stage may be short or suppressed entirely, with the larval shell commonly very difficult to distinguish from the more mature shell. Endemic taxa are common.

The occurrence of abundant turritellids today may be related to coastal upwelling; they occur onshore of such sites, indicating a preference for areas of high productivity, but little tolerance of low oxygen conditions. The distribution of turritellids at Black Mesa would indicate a broad tolerance of substrate conditions, but little tolerance of reduced level of oxygen.

Genus *Turritella* Lamarck, 1799

Diagnosis — Medium-sized, slender, high, multiwhorled shells with simple oval aperture.

Discussion — There are many undescribed, apparently endemic species of *Turritella* in the Western Interior. Turritellids in the Greenhorn cyclothem have been generally referred to *Turritella whitei* Stanton (e.g., Sohl, 1967). Kauffman (1961, in manuscript) has recognized several new species from the Codell Sandstone Member of the Carlile Shale in southern Colorado. With the species described here it can be seen that a biostratigraphic zonation based on species of the genus *Turritella* should be possible for at least the south-central part of the seaway. Thus, additional taxonomic work on this genus is not only needed for taxonomic refinement of the group, but will provide a basis for a more refined biostratigraphy.

Turritella whitei Stanton, 1893
Plate 14, Figures D, E

Turritella uvasana Conrad; White, 1876, p. 195, pl. 18, fig. 11a, b.
Turritella whitei (in part), Stanton, 1893, p. 130, pl. XXVIII, fig. 12; non pl. XXVIII, figs. 13–16.

Description — Rather large (to 6 cm high and 1.7 cm wide), slender turriform gastropod with apical angle about 17°; 14 to more than 30 subrectangular whorls with slightly convex sides, each whorl ornamented by 8 fine, noded, spiral costae generally separated by finer costellae, growth lines show development of sulcus on side of aperture.

Discussion — *Turritella whitei* is readily distinguished from other Cenomanian and Turonian turritellids from the Western Interior by its fine dense ornamentation.

Stanton (1893) based the species on specimens from the late Cenomanian *Sciponoceras gracile* Zone from southern Utah, but included in his concept slightly smaller and more coarsely ornamented turritellids from the middle Turonian of southern Colorado. This has led to the usage of the term *Turritella whitei* for all the Cenomanian and Turonian turritellids in the Western Interior. Kauffman (1961) has recognized that the middle Turonian examples from the Western Interior represent distinct species.

Occurrence — The type material is from the late Cenomanian *Sciponoceras gracile* Zone near Kanab in southern Utah. At Black Mesa common in the lower part of the lower shale member of the Mancos Shale, late Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone, becoming less common in the *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone. Also recorded at this level throughout Utah, in southwestern Colorado, and in western New Mexico.

Illustrated material — MNA N5136 from MNA loc. #306; MNA N5132 from MNA loc. #324; both from BM10, lower pat, lower shale member, Mancos Shale.

Turritella cobbani n. sp.
Plate 36, Figure D

Turritella whitei Stanton; Cobban and Hook, 1989, fig. 8K.

Etymology — Named in recognition of the extensive research by Dr. William A. Cobban on the Western Interior Cretaceous seaway.

Diagnosis — Distinguished by its small size and 4–5 evenly spaced, strong, sharp spiral costae without nodes.

Description — Medium-sized (to 3 cm high, 1 cm wide), slender turriform gastropod with apical angle about 15°; 10 to more than 20 subrectangular whorls with moderately convex sides, ornamented by 4–5 evenly spaced, sharp, spiral costae; growth lines show development of sulcus on side of aperture.

Discussion — Distinguished from other turritellids present at Black Mesa by small size and high, sharp, non-nodate spiral costae. Cobban and Hook (1989) have illustrated this species from the late *Mammites nodosoides* Zone in west-central New Mexico.

Occurrence — Ranging from BM29 in the lower shale member up through a few meters below BM64 in the lower part of the middle shale member of the Mancos Shale at Blue Point in the southwestern part of Black Mesa, lower Turonian *Mammites nodosoides* Zone through basal middle Turonian *Collignoniceras woollgari woollgari-Mytiloides* *hercynicus* subzone of the *Collignoniceras woollgari* Zone. Rare in the lower part of its range and common near the top of its known range. Also at this level in west-central New Mexico.

Types — Holotype; MNA N5275 3 m above BM54, middle shale member, paratype; MNA N5276 1 m below BM54, lower shale member, both from MNA loc. #262, Mancos Shale.

Turritella codellana n. sp.

Plate 41, Figures N, O

Turritella whitei (in part), Stanton, 1893; p. 130, pl. XXVIII, figs. 13–16.
Turritella codellana Kauffman, 1961, Ph. D.; p. 432, pl. 32, figs. 10, 11, 17, 23, 24.

Etymology — Named for the Codell Sandstone Member of the Carlile Shale, where Kauffman first described this form.

Diagnosis — Distinguished by its slender shell and 4–5 evenly spaced rounded, weakly noded spiral costae that are narrower than interspaces.

Description — Medium sized (4.5 cm high and 1.2 cm wide), slender turriform gastropod with apical angle about 16°; 10 to more than 20 subrectangular whorls with moderately convex sides, ornamented by 4–5 evenly spaced, rounded, noded, spiral costae; growth lines show development of sulcus on side of aperture.

Discussion — *Turritella codellana* is distinguished from *Turritella whitei* by its smaller size and fewer coarse, even spiral ornament, lacking intervening costellae. It is distinguished from Kauffman's (1961) species *Turritella carlilana* and *Turritella huerfanensis* in the same features. It differs from *Turritella* n. sp. A in its smaller size and more weakly nodate costae, from *Turritella* n. sp. B in lacking intervening costellae, from *Turritella* n. sp. C in is larger size and nodate costae, and from *Turritella* n. sp. D in having finer nodes that are not axially elongate along the trend of the growth lines.

Occurrence — Described initially from the Codell Sandstone Member and ranging down section into the Blue Hill Shale Member of the Carlile Shale in Huerfano Park, southern Colorado, middle Turonian *Prionocyclus hyatti* Zone. The type locality is at Black Mesa, abundant in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone.

Types — Holotype; MNA N5528, paratype; N3472, N5090, all from MNA loc. #1150, main body, Blue Point Sandstone Tongue, Toreva Formation.

Turritella kauffmani n. sp.

Plate 36, Figure E

Etymology — Named for Dr. Erle G. Kauffman, who first recognized that there was a great deal more to the Cenomanian and Turonian turritellids than *Turritella whitei.*

Diagnosis — Distinguished by its 4–5 weak spiral costae, wider than interspaces, which bear strong, evenly rounded nodes arranged along weak axial ribs.

Description — Medium-sized (to 5 cm high, 1.2 cm wide), slender turriform gastropod with apical angle about 13°; 10 to more than 15 subrectangular whorls with convex sides, ornamented by 4–5 evenly spaced, rounded, strongly nodate, spiral costae, crossed by weak axial ribs growth lines show development of sulcus on side of aperture.

Discussion — This species of *Turritella* is distinguished by its weak axial ribs and strongly nodate costae and is common near the top of the middle shale member and near the base of the Hopi Sandy Member of the Mancos Shale at Blue Point.

Occurrence — Only known from Blue Point in southwestern Black Mesa from 3 m above BM68 in the upper part of the middle shale member to the top of the Hopi Sandy Member of the Mancos Shale, middle Turonian upper *Collignoniceras woollgari woollgari* subzone into the basal *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990).

Types — Holotype, MNA N5280; paratypes, MNA N5277, N5281 all from MNA loc. #262, 3 m above base of Hopi Sandy Member, Mancos Shale.

Turritella n. sp. A

Plate 7, Figure C

Description — Large (5.5 cm high), turriform gastropod, known only from compacted specimens, around 15 subrectangular whorls with convex sides ornamented by 4–5 evenly spaced, strong, rounded, noded, spiral costae, growth lines not visible.

Discussion — The few compacted specimens of this species are distinct in their large size and strong, coarse ornament.

Occurrence — Uncommon at the top of the Dakota Formation at Yale Point in the northeastern part of Black Mesa, upper Cenomanian *Metoicoceras mosbyensis* Zone.

Illustrated material — MNA N5076 from MNA loc. #296, top of Dakota Formation.

Turritella n. sp. B

Plate 14, Figure H

Diagnosis — One medium-sized (0.8 cm wide) specimen consisting of three moderately convex whorls, ornamented by noded spiral costae with single intervening finely noded costellae.

Discussion — At first this specimen was assumed to represent a coarsely ornamented *Turritella whitei*, but observations of more than 100 specimens of *Turritella whitei* indicates that the ornament is quite consistent between individuals. In its ornamentation, *T.* n. sp. B appears closest to Kauffman's (1961) *Turritella carlilana.* It differs from other species present at Black Mesa in having intervening finely nodose costellae.

Occurrence — One specimen from the lower part of the lower shale member of the Mancos Shale in concretionary marker bed BM10 at Balakai Point in the area of southwestern Black Mesa (MNA loc. #306), late Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone.

Illustrated material — MNA N5131 from MNA loc. #306, BM10, lower part, lower shale member, Mancos Shale.

Family Thiaridae ?

Genus *Pyrgulifera* Meek, 1871

Pyrgulifera ornata Stephenson, 1952

Plate 2, Figure O

Pyrgulifera ornata Stephenson, 1952; p. 157, pl. 37, figs. 9–13.
Pyrgulifera costata Stephenson, 1952; p. 158, pl. 37, figs. 14–16.
Pyrgulifera costata tuberata Stephenson, 1952; p. 158, pl. 37, figs. 3, 4.
Pyrgulifera costata sublevis Stephenson, 1952; p. 159, pl. 37, figs. 1, 2.

Description — Variably ornamented; small (1.5–2 cm high, 1–1.5 cm wide), thick-shelled, globose to turbonate shell; 4–5 inflated whorls; aperture oval, shoulder variably developed, ornamented by 8–10 variably developed spiral ribs, which have progressively stronger tubercles toward adapical side of whorl and are oriented along growth lines.

Discussion — As with many brackish water taxa, *Pyrgulifera* displays a great deal of ecotypic variation. The examples from Black Mesa seem to show a degree of variation that encompasses the species and subspecies described by Stephenson (1952) from the middle Cenomanian of central Texas. A much more ornate species occurs in brackish water deposits in the lower Turonian of south western Utah.

Occurrence — The types are from the middle Cenomanian Woodbine Formation of central Texas. At Black Mesa present in shell beds in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #264). Also present at this level in southern Utah.

Illustrated material — MNA N925, from MNA loc. #265, shale facies, upper sandstone member, Mancos Shale.

Paleoecology — Modern thiaridids are typically fresh water taxa. The distribution of *Pyrgulifera* indicates that it is a brackish water taxon (Fursich and Kauffman, 1984; Fursich and Kirkland, 1986). The globose to turbonate shell form suggests that it was an epifaunal form which could hold the shell tightly against the substrate to withstand higher energy levels. The genus was probably an herbivore that grazed on algae.

Family Cerithiidae

Paleoecology — Species in this family are interpreted to feed on fine disseminated algae (diatoms) and detritus. Their streamlined shells suggest that they spend part of their time buried shallowly in the substrate.

Genus *Levicerithium* Stephenson, 1952

Discussion — Stephenson (1952) erected this genus for small turriform gastropods with flattened sides and variable spiral ornament. Sohl (1988, personal communication) has found that most species referred to the genus *Pseudomelania* should instead be referred to as species of *Levicerithium.*

Levicerithium basicostae Stephenson, 1952
Plate 2, Figures H–J

Levicerithium basicostae Stephenson, 1952; p. 161, pl. 58, figs. 9, 10.
Pseudomelania ? basicostata Stephenson, 1955; p. 57, pl. 4, figs. 4, 5.

Description — Small (2 cm high, 0.9 cm wide), moderately high spired, turriform shell, with apical angle of juveniles 40° decreasing to about 30° in adults; about 10 nearly flat sided whorls, suture incised; lower margin of body whorl sharply rounded, descending steeply to base; aperture lenticular with simple small siphonal canal and slightly calloused inner lip, four internal spiral ribs line outer wall of whorl and are generally only visible where shell material has exfoliated; sides of whorls smooth but for very faint spiral lirae, base with spiral costae.

Discussion — Readily distinguished from other species by its nearly smooth sides of whorl and the spiral ornament on the base of the whorl. As with many taxa found in brackish water settings, this species appears to be quite variable in the development of its ornament. A smaller species with a narrower apical angle occurs in brackish water deposits in the lower Turonian of southwestern Utah.

Occurrence — The type specimen is from the Lewisville Member of the Woodbine Formation in central Texas. At Black Mesa locally common in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (Kirkland, 1990). Also present at this level in southern Utah.

Illustrated material — MNA N901, N4525, N1035 from MNA loc. #265, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — The distribution of this species indicates that it is a brackish water taxa.

Levicerithium micronema ? (Meek, 1873)
Plate 2, Figures K–M

Turritella (Aclis ?) micronema Meek, 1873; p. 504.
Turritella micronema Meek; Stanton, 1893, p. 131, pl. XXIX, fig. 3.
?*Vascellum ? rivanum* Stephenson, 1952; p. 169, pl. 38, figs. 20, 21.
Pseudomelania sp. Fursich and Kirkland, 1986; p. 549, Fig. 5n.

Description — Small (1.5 cm high, 0.7 cm wide), moderately high spired, turriform shell, with apical angle of about 30°; about 10 nearly flat sided whorls with slight shoulder at incised suture; lower margin of body whorl sharply rounded, descending steeply to base, aperture lenticular with simple small siphonal canal and slightly calloused inner lip; four internal spiral ribs line outer wall of whorl and are generally only visible where shell material has exfoliated; sides of whorls with 6–8 evenly spaced flat-topped costae; base of whorl smooth.

Discussion — The occurrence of Meek's (1873) types of *Turritella micronema* suggests a brackish water setting. Stanton (1893) has questioned the placement of the species in *Turritella* as it is lower spired than is typical of *Turritella.* The degree of variation found in this material at Black Mesa would seem to include that seen in the types of *Turritella micronema.* There is little question that this material should be assigned to *Levicerithium.* This can only be considered a tentative species assignment until the types of *Turritella micronema* can be examined, as well as the type locality. It is readily distinguished from other Black Mesa species by the ribbed sides of whorl, which have a smooth base. As with many taxa found in brackish water settings, this species appears to be quite variable in the development of its ornament.

Occurrence — The type is from below a major coal seam at Coalville, Utah. At Black Mesa locally common in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (Kirkland, 1990). Also present at this level in Utah and possibly in slightly older strata in central Texas. A smaller species with narrower apical angle occurs in brackish water deposits in southwestern Utah.

Illustrated material — MNA N4523, N4524 from MNA loc. #265, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — The distribution of this species indicates that it is a brackish water taxa.

Levicerithium sp. cf. *L. timberanum* Stephenson, 1952
Plate 36, Figures F, H, I

Levicerithium timberanum Stephenson, 1952; p. 161, pl. 38, figs. 1–3.
Levicerithium planum Stephenson, 1952; p. 161, pl. 38, figs. 4, 5.
Levicerithium breviforme Stephenson, 1952; p. 161, pl. 38, figs. 8, 9.
Levicerithium microlirae Stephenson, 1952; p. 162, pl. 38, figs. 6, 7.

Description — Small (2 cm high, 1 cm wide), moderately high spired, stout turriform shell, with apical angle of about 42°; about 8 nearly flattened to slightly convex sided whorls with slight shoulder at incised suture; lower margin of body whorl sharply rounded, descending steeply to base; aperture lenticular with simple small siphonal canal and slightly calloused inner lip, shell nearly smooth, but for faint spiral lirae.

Discussion — *Levicerithium timberanum* Stephenson (1952) is the type species of *Levicerithium*. Internal ribs have not been observed on the Black Mesa material, but otherwise material appears to be close to Stephenson's *Levicerithium timberanum* in size, shape, and external morphology.

The Black Mesa material is quite variable in regard to shell size and the inflation of the whorls and seems to encompass several of the species assigned by Stephenson (1952) to *Levicerithium*.

Occurrence — The types are from the middle Cenomanian Lewisville Member of the Woodbine Formation in central Texas. Scattered present to common across Black Mesa from BM35 in the upper part of the lower shale member up through the Hopi Sandy Member of the Mancos Shale, basal middle Turonian *Collignoniceras woollgari woollgari-Mytiloides hercynicus* subzone into the basal *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone and present in the area of northeastern Black Mesa in the upper part of the upper shale member of the Mancos Shale from 25–10 meters below the base of the Toreva Formation, *Prionocyclus hyatti* Zone. This form also has been observed in the upper Cenomanian *Metoicoceras mosbyensis* Zone in the Hartland Shale Member of the Greenhorn Limestone near Boulder, Colorado.

Illustrated material — MNA N3599, N3600 from MNA loc. #989, 13 m above base of Hopi Sandy Member; MNA N5269 from MNA loc. #262, 2 m below base of Hopi Sandy Member, Mancos Shale.

Paleoecology — It would seem that many of Stephenson's (1952) occurrences of this species are in brackish water facies, while all occurrence of this form known to the author are in shallow open marine settings.

Levicerithium ? sp.
Plate 14, Figure I

Description — Small (2 cm high, 0.9 cm wide), moderately high spired, stout turriform shell, with apical angle of about 38°; about 8 nearly flattened to slightly convex sided whorls with slight shoulder at incised suture; lower margin of body whorl rounded, curving to base; aperture lenticular with simple small siphonal canal and slightly calloused inner lip; shell nearly smooth but for faint spiral lirae and flattened spiral rib below suture.

Discussion — Like *Levicerithium timberanum* Stephenson but has a more rounded base and a spiral rib located below suture.

Occurrence — Rare scattered throughout upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone.

Illustrated material — MNA N5144 from MNA loc. #989, BM8, lower part, lower shale member, Mancos Shale.

Paleoecology — The distribution of this uncommon species indicates a preference for open marine environments.

Genus *Vascellum* Stephenson, 1952
Vascellum sp.
Plate 2, Figure S

Description — Small (2.5 cm high, 1 cm wide), moderately high spired, stout turriform gastropod, with apical angle of about 30°; about 8 nearly flattened to slightly convex-sided whorls with slight shoulder at incised suture; lower margin of body whorl sharply rounded, curving gradually to base; aperture lenticular with simple small siphonal canal; shell ornamented by weak spiral ribs with strong flattened spiral rib below suture, weak axial ribs strongest below suture.

Discussion — Stephenson (1952) described several species of *Vascellum* from the middle Cenomanian Woodbine Formation in central Texas, and the Black Mesa specimens may be conspecific with one of those from Texas. Their poor state of preservation does not permit a close comparison.

Occurrence — At Black Mesa locally rare in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #264).

Illustrated material — MNA N4527 from MNA loc. #265, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — The distribution of this taxon indicates a preference for brackish water conditions.

Genus *Voysa* Stephenson, 1952
Voysa varia Stephenson, 1952
Plate 2, Figures P–R

Voysa varia Stephenson, 1952; p. 172, pl. 39, figs. 17–20.
Voysa varia levicostae Stephenson, 1952; p. 172, pl. 39, figs. 38, 39.
Voysa varia nodosa Stephenson, 1952; p. 172, pl. 39, figs. 27–31.
Voysa varia extensa Stephenson, 1952; p. 172, pl. 39, figs. 21, 22.
Voysa sp. Fursich and Kirkland, 1986; p. 549, fig. 5m.

Description — Very small (0.8 cm high, 0.3 cm wide), moderately high spired, turriform gastropod, with apical angle of about 20°; about 8 evenly convex sided whorls suture incised; lower margin of body whorl sharply rounded, descending steeply to base; aperture lenticular with simple small siphonal canal and calloused inner lip; sides of whorls with 4–6 variably noded spiral costae.

Discussion — Stephenson (1952) described 13 species and subspecies of *Voysa* from the middle Cenomanian Woodbine Formation of central Texas. As with many brackish water taxa, *Voysa* is highly variable. However, many of Stephenson's species are quite distinct from the material from Black Mesa, which compare well with the variable species *Voysa varia*.

Occurrence — The types are from the middle Cenomanian Woodbine Formation in central Texas. At Black Mesa locally common to abundant in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone.

Illustrated material — MNA N900 from MNA loc. #265, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — The distribution of this taxon indicates that it preferred brackish water taxa. The great numbers of specimens at some levels suggests that this may be an opportunistic species.

Family Cerithiopsidae

Paleoecology — As with species in the Cerithiidae, species in this family are interpreted to feed on fine disseminated algae, (diatoms) and detritus. Their streamlined shells suggest that they spend part of their time buried shallowly in the substrate.

Genus *Cerithiopsis* Forbes and Hanley, 1849
Cerithiopsis sohli n. sp.
Plate 14, Figures A, B, F, G

Cerithiopsis ? sohli Kauffman, 1961, Ph. D.; p. 367, pl. 26, figs. 16–18.
Cerithella sp. A, Hattin, 1975a; p. 44, pl. 5, figs. G–I.

Etymology — Named in honor of Dr. Norman Sohl in recognition of his many contributions to the study of North American Cretaceous gastropods.

Diagnosis — This small, ornate gastropod is distinguished by its 3 distinct spiral rows of conical nodes, which increase in strength toward base of whorl.

Description — Small (2.0 cm high, 0.6–0.8 cm wide), moderately high spired, turriform gastropod, with apical angle of about 20–30°; about 10 flat to slightly angular sided whorls, suture incised in narrow channel; lower margin of body whorl sharply rounded a short distance above suture, base nearly flat; aperture lenticular with small, recurved siphonal canal and slightly calloused inner lip; sides of whorls ornamented by 3 spiral rows of conical nodes, which are axially aligned leading to increasingly large nodes toward base, which is ornamented by spiral costae.

Discussion — Kauffman (1961) first described this distinctive species from the upper Cenomanian of southern Colorado. This species is one of the very few gastropods to occur widely in the carbonate facies in the central part of the Western Interior.

Occurrence — Originally described by Kauffman (1961) from the upper Cenomanian *Sciponoceras gracile* Zone in the lower part of the Bridge Creek Limestone Member of the Greenhorn Limestone of Huerfano Park in southern Colorado. At Black Mesa in the lower part of the lower shale member of the Mancos Shale throughout the upper Cenomanian *Sciponoceras gracile* Zone. Also recognized at this level elsewhere in Colorado, Utah, Kansas, southern Nebraska, Texas, and southeastern Montana.

Types — Holotype; MNA N5135, paratype; MNA N5134 from MNA loc. #298; Lectotypes; MNA N1148 from MNA loc. #262; MNA N1235 from MNA loc. #307; all from BM8, lower part, lower shale member, Mancos Shale.

Paleoecology — The distribution of this gastropod indicates that this offshore species ranges through a greater range of offshore environments and depths than just about any gastropod species present at Black Mesa. This widespread distribution is limited to a particularly favorable time within the Western Interior characterized by normal oceanic salinities and well oxygenated bottom water (e.g., Kauffman, 1984).

Cerithiopsis ? sp.
Plate 41, Figure L

Description — One very small (0.5 cm high, 0.2 cm wide), moderately high-spired, turriform gastropod, with apical angle of about 23°; about 7 flat to slightly angular sided whorls, suture incised in narrow channel; lower margin of body whorl sharply rounded a short distance above suture, base nearly flat; aperture sucircular, siphonal canal not visible; sides of whorls ornamented by broad slightly noded spiral rib at base of whorl.

Discussion — The very small size of this gastropod suggests that it may be immature. Its assignment to *Cerithiopsis* is provisional.

Occurrence — At Black Mesa, very rare in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (MNA loc. #1150).

Illustrated material — MNA N5059 from MNA loc. #1150, main body, Blue Point Sandstone Tongue, Toreva Formation.

Family Mathildidae

Discussion — Whereas this family has generally been placed in the Cerithiacea, Sohl (1960) has pointed out that the nature of the specialized protoconch suggests that the family perhaps should be included with the opisthobranchs. Until further research on the modern representatives of this family is carried out, its assignment to the Mesogastropoda is questioned.

Paleoecology — No ecologic studies on the Mathildidae are known to the author, but their distribution at Black Mesa seem to indicate a preference for relatively shallow open marine conditions. The shell form suggests an ability to burrow shallowly within the sediment. If assigned to the Cerithiacea, they may have grazed on diatoms, organic detritus and/or suspended material. If assigned to the Opisthobranchia, they may have been ecto-parasites or carnivore-scavengers.

Genus *Mathilia* Semper, 1865
Mathilia ? n. sp. cf. *M. ripleyana* Wade

Mathilia ripleyana Wade, 1924; p. 171, pl. 53, figs. 11, 16, 17.
Mathilia (*Mathilia*) *ripleyana* Wade; Sohl, 1960, p. 130, pl. 18, figs. 13, 18, 20–22.

Description — One small (0.7 cm wide) specimen consisting of 3 subtrapizoidal whorls with angular sides; turriform with apical angle about 28°; two principle spiral costae or low keels; the shell angles sharply away from the most prominent costa, which lies at widest point of shell about two-thirds distance below incised suture; the other major costa marks the angular margin between the side and base of whorl and lies above the site of the sutures between whorls; spiral costae separated by single finer costellae are evenly spaced over sides and base of whorl.

Discussion — The placement of this distinctive species in *Mathilia* is provisional based largely on its great similarity to *Mathilia* (*Mathilia*) *ripleyana* Wade, 1926 (Sohl, 1960). It does not have an anterior canal and the protoconch is not known.

Occurrence — One specimen from near Lohali Point (MNA loc. #992) on the northeast side of Black Mesa from concretionary marker bed BM10 in the lower part of the lower shale member of the Mancos Shale, late Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone.

Illustrated material — MNA N5130 from MNA loc. #992, BM10, lower part, lower shale member, Mancos Shale.

Mathilia ? n. sp.
Plate 41, Figure W

Description — One small (0.7 cm wide) specimen consisting of 3.5 subrectangular whorls with flattened to subangular sides; turriform with apical angle about 40°; suture incised in basal angle; the shell angles away toward base from the most prominent costa, which lies at widest point of shell about four-fifths distance from suture; 5 evenly spaced spiral costae above widest point of whorl; 2 additional spiral ribs lie above suture; base of whorl with additional spiral ribs.

Discussion — This species is reminiscent of *Mathilia* ? n. sp. cf. *M. ripleyana* Wade in its overall morphology, but without knowledge of the protoconch any generic assignment is uncertain.

Occurrence — At Black Mesa, very rare in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (MNA loc. #1150).

Illustrated material — MNA N5500 from MNA loc. #1150, main body of Blue Point Sandstone Tongue, Toreva Formation.

Genus *Gegania* Jeffreys, 1884
Gegania ? n. sp.
Plate 41, Figures U, V

Description — Small (1.6 cm high and 0.7 cm wide), turriform gastropod with 8–10 whorls, apical angle about 36°, suture incised, whorls evenly rounded, aperture lenticular extending into siphon, surface densely covered by fine flattened radial costae with much weaker axial ribs.

Occurrence — At Black Mesa, rare in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (MNA loc. #1150).

Illustrated material — MNA N5490, N5557 from MNA loc. #1150, main body of Blue Point Sandstone Tongue, Toreva Formation.

Superfamily Strombacea
Family Aporrhaidae

Paleoecology — Considerable study has been made on the ecology of the recent Aporrhaidae. The relationship of the distinctive morphology to the life habits of *Aporrhais pespelicani* has been studied in detail by Yonge (1937), observing specimens in aquaria. The ventrally directed siphonal canal serves to pull the shell into the substrate, while the outwardly expanded outer lip serves to limit downward movement and serves as a rigid roof beneath which the snail can search for particulate food material. The sinuses on the anterior and posterior inner margins of the expanded outer lip serve as the base for the inhalent and exhalent sand tubes. Yonge (1937) concluded the *Aporrhais* spent most of its time buried shallowly in the substrate, deposit feeding. Barnes and Bagenal (1952) observed that many adult *Aporrhais* were heavily encrusted by epibionts and thus spent considerable time at the sediment surface. Peron (1978) found that adult *Aporrhais* spends half the year buried and inactive and spends the other half of the year at the sediment surface actively feeding and reproducing; juveniles remain buried year round. *Aporrhais* lives in and on soft mud substrates; many of the extinct genera preferred sand substrates (Popenoe, 1983)

Genus *Anchura* Conrad, 1860
Anchura hopii n. sp.
Plate 41, Figures P–T

Etymology — Named for the Hopi Tribe on whose tribal land this species occurs in abundance.

Diagnosis — This aporrhaid differs from most described species of *Anchura* in being more weakly ornamented and in having a less expanded wing without posterior expansion. It differs from the Cenomanian species in central Texas in fewer spiral costae and axial ribs.

Description — Medium sized (to 4.5 cm high, 1.5 cm wide minus expanded outer lip, 2.5 cm wide including expanded outer lip); suture incised; apical angle of about 30°; 8–10 rounded whorls; aperture lenticular, inner lip with extensive callous, outer lip thickened and curving upward into a point, separated from main body of shell by anterior and posterior notch, long siphonal canal; spire ornamented by axial ribs and fine spiral costae; on body whorl, shape becomes angular, with axial ribs rising into nodes on crossing widest part of shell, from which spiral rib extends onto expanded outer lip.

Discussion — On examining the material from Black Mesa, Sohl (1986, personal communication) commented that aporrhaids of this type are intermediate between *Drepanochilus* and *Anchura*, differing from *Drepanochilus* in retaining axial ornament onto the body whorl and differing from *Anchura* in being less ornate and having a less expended wing without an expanded posterior extension. In these features, the Black Mesa material is closest to many of the species of *Anchura* described by Stephenson (1952) from the middle Cenomanian Woodbine Formation of central Texas. Overall the material is somewhat closer to *Anchura* in morphology than it is to that of *Drepanochilus*.

Occurrence — At Black Mesa, abundant in the Blue Point Sandstone Tongue and present in the lower sandstone member of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone.

Types — Holotype, MNA N3476; paratypes, MNA N3468, N5355, N5533, N5534 from MNA loc. #1150, main body of Blue Point Sandstone Tongue, Toreva Formation.

Paleoecology — Sohl (1967b, 1970) has found that *Anchura* is characteristically a Gulf Coast taxon. The distribution of the taxon indicates a preference for sheltered sand substrates.

Genus *Drepanochilus* Meek, 1876
Drepanochilus ruidium (White, 1876)
Plate 13, Figures Z–CC; Plate 25, Figure K (a)

Anchura ruida White, 1876; p. 120.
Anchura (*Drepanocheilus*) *ruida* (White); Stanton, 1893, p. 145, pl. XXXI, figs. 3, 4.

Description — Small-sized (to 1.5 cm high, 0.5 cm wide minus expanded outer lip, 1.0 cm wide including expanded outer lip); suture incised; apical angle of about 40°; 5–6 rounded whorls; aperture lenticular, inner lip with extensive callous, outer lip thickened and curving upward into a point, separated from main body of shell by anterior and posterior notch, moderately long siphonal canal; spire ornamented by axial ribs and fine spiral costae; on body whorl axial ornament is lost and spiral ornament dominates with dominant spiral rib defining angular margin of body whorl and extending onto upturned margin of expanded outer lip.

Discussion — This species is wide-ranging in the Cenomanian and Turonian shales at Black Mesa and is the most common gastropod encountered in the calcareous shales through much of the lower member of the Mancos Shale. Through the middle shale member it is replaced by *Levicerithium* sp. aff. *L. timberanum* Stephenson as the most common gastropod in the noncalcareous shale.

Occurrence — The types were from the upper Cenomanian *Sciponoceras gracile* Zone of southern Utah. At Black Mesa in the lower shale member, common to abundant in the upper Cenomanian *Sciponoceras gracile* Zone, generally abundant to very abundant in the upper Cenomanian *Neocardioceras juddii* Zone, present in the lower

Turonian *Watinoceras coloradoense* and *Mammites nodosoides* Zones, present to uncommon in the *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone ranging to near the top of the middle shale member of the Mancos Shale. Also present in New Mexico, Utah, Texas, southwestern Colorado, and western Montana.

Illustrated material — MNA N5128, N5125, N5126, N5123 from MNA loc. #271, BM10; MNA N5224 from MNA loc. #989, above BM13; lower part, lower shale member, Mancos Shale.

Paleoecology — The distribution of this taxon suggests that it preferred offshore calcareous shale, and did not favor deep water pelagic carbonates, or shallow marine sands. Sohl (1970) indicated that *Drepanochilus* preferred cooler water than did *Anchura* and is a characteristic element of Western Interior faunas. Elder (1986a, 1987b) suggests that the great abundance of this species in the *Neocardioceras juddii* Zone is evidence that the taxon was an opportunist taking advantage of large amounts of available organic detritus and low levels of competition and predation during periods of moderately reduced oxygen in the latest Cenomanian.

Genus *Perissoptera* Tate, 1865
Perissoptera prolabiata (White, 1876)

Plate 13, Figures W, X, Y

Anchura prolabiata White, 1876; p. 121.
Aporrhais (*Perissoptera*) *prolabiata* (White); Stanton, 1893, p. 44, pl. XXXI, fig. 2.

Description — Medium-sized (up to 3 cm high, 1.2 cm wide minus expanded outer lip, 1.8 cm wide including expanded outer lip); suture incised; apical angle of about 40°; 8 moderately rounded whorls; aperture lenticular, inner lip with extensive callous, outer lip thickened and curving upward into a long thin point and split into a lower broad lateral extension, separated from main body of shell by anterior and posterior notch, moderately long siphonal canal; spire ornamented by axial ribs which weaken on body whorl and do not extend onto expanded outer lip.

Discussion — Although widespread in the upper Cenomanian on the southwestern side of the seaway, the species is not common at any single locality.

Occurrence — The types were from the upper Cenomanian *Sciponoceras gracile* Zone of southern Utah. At Black Mesa, it occurs in the lower shale member, is present in the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through the *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone. One poorly preserved, compacted specimen that may represent this species was encountered near the base of the Turonian at the Lohali Point section, and Koch (1977) reported that species ranges into the middle Turonian. Also known from New Mexico, Colorado, and Texas.

Illustrated material — MNA N5133 from MNA loc. #298, BM10; MNA N1207 from MNA loc. #303, BM8; both from lower part, lower shale member, Mancos Shale.

Paleoecology — The distribution of this species indicates a preference for shallow calcareous clay substrates.

Genus *Pyktes* Popenoe, 1983
Pyktes fusiformis (Meek, 1877)

Plate 41, Figures X–Z; Plate 47, Figure G;
Plate 48, Figure J

Anchura? fusiformis Meek, 1877; p. 160, p. 15, figs. 2, 2a.
Pugnellus fusiformis (Meek); Stanton, 1893, p. 148, pl. XXXI, figs. 7–11.
Pyktes fusiformis (Meek); Popenoe, 1983, p. 755, figs. 4 H, K.

Description — Medium-sized (to 4.0 cm high, 1.5 cm wide minus expanded outer lip, 2.8 cm wide including expanded outer lip); suture incised; apical angle of about 50°; 4–6 slightly rounded whorls; aperture lenticular, inner lip with extensive callous, which on gerontic specimens thickly covers the entire shell; outer lip thickened and curving upward into a rounded lobe; separate short, blunt expansion extends anteriorly from expanded outer lip, which is separated from main body of shell by anterior and posterior notchs, moderate siphonal canal; shell smooth.

Discussion — This species has commonly been known as *Pugnellus fusiformis* Meek and has been used to characterize the Codell Sandstone Member of the Carlile Shale in the area of Huerfano Park in southern Colorado as the *Pugnellus* sandstone — for the great numbers of this species found in this unit (Stanton, 1893; Kauffman, 1961). However, recent research (Sohl, 1960; Popenoe, 1983) indicates that *"Pugnellus" fusiformis* is distinct from *Pugnellus sensu stricto*. Sohl (1960, 1967) placed the species in the subgenus *Gymnarus* Gabb on the basis of the upturned expanded outer lip. Popenoe (1983) raised *Gymnarus* to a genus and erected the genus *Pyktes* to include taxa largely lacking in axial ornament and possessing a short spatulate anterior extension of the outer lip. These features are apparent in *"Pugnellus" fusiformis*, and Popenoe (1983) included the species in the genus *Pyktes*.

Traditionally, *Pugnellus* and its close relatives have been included in the herbivorous family Strombidae as the notch for the exhalent sand tube has been misinterpreted as the strombid notch for the eye. Recognizing this misinterpretation, Popenoe (1983) included the group in the Aporrhaidae and pointed out that heavy layers of callous are laid down by a number of other aporrhaids on maturity. This reassignment leads to the realization that *Pyktes fusiformis* is not a herbivore but instead must be considered a detritivore as with the other aporrhaids. Its gregarious habits are easily explained as many fossil occurrences of aporrhaids are mass accumulations.

Occurrence — The types of Meek (1973) are probably from the second ridge at Coalville, Utah. At Black Mesa, present in the Blue Point Sandstone Tongue and rather abundant in the lower sandstone member of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone. It is very abundant in the Codell Sandstone Member of the Carlile Shale and present in the underlying Blue Hill Shale Member, middle Turonian *Prionocyclus hyatti* Zone in Huerfano Park, southern Colorado. Also known from New Mexico and Wyoming.

Illustrated material — MNA N5497, N5387, N3477 from MNA loc. #1150, main body of Blue Point Sandstone Tongue, Toreva Formation; MNA N4851, N5411 from MNA loc. #342, lower sandstone member, Toreva Formation.

Paleoecology — The distribution of this taxon indicates a preference for sand substrates and possibly preferring normal marine open coastlines to more sheltered settings.

Superfamily Calyptraeacea
Family Trichotropididae
Genus *Cerithioderma* Conrad, 1860

Paleoecology — Little could be found in the literature regarding the ecology of *Cerithioderma*. Keen (1971) reported that modern representatives of the genus are deep water taxa found 2–3 kilometers below sealevel in the Pacific. The distribution of the Cretaceous material indicates a shallow open marine habitat at that time. The turriform shape indicates a potential for shallow burrowing in the substrate.

Cerithioderma occidentalis (Stanton, 1893)

Plate 41, Figure M (a)

Mesostoma occidentalis Stanton, 1893; p. 139, pl. XXX, figs. 7, 8.
Cerithioderma occidentalis (Stanton); Sohl, 1967, p. 32.

Description — Small (to 1 cm high, 0.5 cm wide), moderately high-spired, turriform gastropod, with apical angle of about 30°; about 8 rounded whorls, suture incised; lower margin of body whorl continuous with somewhat flattened base; aperture inclined, ovate, and simple; reticulate ornament with either axial or spiral elements dominating and small nodes present where axial and spiral ornament intersect.

Occurrence — The types are from the Codell Sandstone Member of the Carlile Shale, middle Turonian *Prionocyclus hyatti* Zone in Huerfano Park, southern Colorado. At Black Mesa, present in the Blue Point Sandstone Tongue and lower sandstone member of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone and rare associated with an unnamed sandstone interval in the upper shale member of the Mancos Shale about 20 m below the base of the Toreva Formation, middle Turonian *Prionocyclus hyatti* Zone at the Lohali Point section (Kirkland, 1990).

Illustrated material — MNA N5395 from MNA loc. #1150, main body of Blue Point Sandstone Tongue, Toreva Formation.

Cerithioderma darcyi n. sp.

Plate 14, Figure C

Etymology — Named for the author's youngest daughter.

Diagnosis — Much like *Cerithioderma occidentalis* Stanton, but differing in its smaller size and finer, weaker ornamentation.

Description — Small (to 0.8 cm high, 0.4 cm wide), moderately high-spired, turriform gastropod, with apical angle of about 30°; about 8 rounded whorls, suture incised; lower margin of body whorl continuous with somewhat flattened base; aperture inclined, ovate, and simple; weak reticulate ornament with spiral elements dominating and small nodes present where axial and spiral ornament intersect.

Occurrence — At Black Mesa in the lower shale member, present in the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through the *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone (Kirkland, 1990). Also present in Utah, New Mexico, and Montana.

Holotype — MNA N5129 from MNA loc. #324, BM10, lower part, lower shale member, Mancos Shale.

Genus *Gyrotropis* Gabb, 1877

Gyrotropis nationsi n. sp.

Plate 42, Figures I, J

? *Craginia* sp. aff. *C. coalvillensis* (Meek); Kauffman, 1961, Ph. D., p. 421, pl. 28, figs. 15, 16.

Etymology — Named for Dr. J. Dale Nations in recognition of his research on the Cretaceous of Arizona.

Diagnosis — Distinguished by its distinctive ornament of carinate keels and spiral costae.

Description — Medium-sized (to 5 cm high, 3.5 cm wide), stout, carinate, fusiform shell; apical angle of 65 to 75°; with 6–8 rapidly expanding, angular whorls; shoulder long and sloping to strong carinate keel below which is a shallow depression followed by a second slightly weaker carinate keel; below the second keel the shell slopes toward the siphonal canal; where an additional low keel appears at an equal distance on medium-sized shells; on the largest shells two equispaced low keels are present for a total of four, fine spiral costae are also present over surface of shell; axial ornament weak, best developed on and between keels leading to the keels having a scalloped appearance to keels; suture between whorls at position of second keel; aperture rounded extending into moderately long siphonal canal, inner lip flaring; deep open umbilicus.

Discussion — *Gyrotropis* is close to and may be descended from *Lirpsa* Stephenson (1952), from which it differs in being more tightly coiled and in having a stronger primary keel as well as more minor keels. Kauffman (1961) has illustrated a gastropod identified tentatively as *Craginia* from the Codell Sandstone Member of the Carlile Shale of southern Colorado that may be conspecific with the Black Mesa material.

Occurrence — At Black Mesa, present to fairly common in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (MNA loc. #1150). Also a possible example from the Codell Sandstone Member of the Carlile Shale, middle Turonian *Prionocyclus hyatti* Zone in Huerfano Park, southern Colorado.

Types — Holotype, MNA N5086; paratype, MNA N5525, from MNA loc. #1150, main body of Blue Point Sandstone Tongue, Toreva Formation.

Paleoecology — This genus appears to be closely related to the modern genus *Trichotropis* which is a cool to cold water species. They feed by sorting minute food particles from the sediment, which are carried into the mantle via the inhalent siphon. There does not appear to be any supporting evidence to indicate that *Gyrotropis* was a cool water species. Its distribution seems to indicate a preference for sand substrates and/or shell beds in shallow, warm, normal marine waters.

Superfamily Naticacea

Family Naticidae

Paleoecology — Snails of this family crawl on and actively burrow in fine sand to mud, just under the sediment-water interface by means of a large muscular foot which largely envelops the shell. They are carnivores feeding on infaunal bivalves and gastropods, which they surround with their foot prior to boring through the shell with their radula, possibly aided by an acid secretion (Carriker, 1981; Guerrero and Reyment, 1988).

Genus *Eunaticina* Fischer, 1885

Eunaticina textilis Stanton, 1893

Plate 13, Figures T, U

Sigaretus (*Eunaticina*?) *textilis* Stanton, 1893; p. 139, pl. XXX, figs. 5, 6.

Description — Small (1.3 cm high, 1 cm wide), globose shell, three to four rapidly expanding well-rounded whorls overlapping much of succeeding whorls; suture incised; apical angle of about 90°; aperture subovate; surface ornamented by fine distinct, spiral, grooved lines that are close-spaced over entire shell.

Discussion — The fine spiral grooves and very low spire of this species makes it readily distinguished from other naticids present at Black Mesa.

Occurrence — The type specimens are from the upper Cenomanian *Sciponoceras gracile* Zone in the upper Kanab Valley in southern Utah. At Black Mesa in the lower shale member, present in the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through the *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone. Also present at this level in Colorado, Texas, and New Mexico.

Illustrated material — MNA N5143 from MNA loc. #306, BM10, lower part, lower shale member, Mancos Shale.

Genus *Euspira* Agassiz (in Sowerby), 1838

Euspira stantoni n. sp.

Plate 13, Figures R, S

non *Natica concinna* Hall and Meek, 1856; p. 384, pl. 3, figs. 2a–d.
Lunatia concinna (Hall and Meek), Stanton, 1893; p. 134, pl. XXIX, figs. 9, 10.

Etymology — Named for the late Dr. T. W. Stanton for his many contributions in Cretaceous invertebrate paleontology, such as first illustrating this common Cenomanian naticid.

Diagnosis — Distinguished by its small size and faint spiral lirae together with an aperture with fairly straight inner lip with little callous and moderately oblique outer lip.

Description — Small (1.5–2 cm high, 1.2–1.5 cm wide) subglobose to turbonate shell, somewhat higher than wide, with a moderate spire, subovate whorl section with slight distinct shoulder; a rounded outer side and straighter inner side; inner lip fairly straight and slightly thickened by callous; outer lip moderately oblique; small, deep umbilical slit; surface appears smooth, except for fine growth lines and faint spiral lirae.

Discussion — Specimens of *Euspira stantoni* from the late Cenomanian at Black Mesa are definitely conspecific with those described by Stanton (1893) from southern Utah as *Lunatia concinna*. The type specimen, however, is from the upper Pierre Shale, with referred specimens from the Maestrichtian Fox Hills Sandstone (Meek, 1876). Sohl (1967b) pointed out that *Euspira concinna* of Meek is a synonym of *Euspira obliqua* (Hall and Meek, 1856), and *Euspira concinna* of Stanton should be described as a new species.

Euspira stantoni, as noted by Stanton (1893), differs from Meek's taxon in its smaller size with a slightly straighter inner lip with smaller callous deposit and a somewhat less oblique outer lip. Its external ornament is nearly identical. *Euspira* is readily distinguished from *Gyrodes* in its higher spire and more turbonate form.

Occurrence — Stanton (1893) described material from the upper Cenomanian *Sciponoceras gracile* Zone in the upper Kanab Valley in southern Utah. Specimens are common in concretions of the *Sciponoceras gracile* Zone across the southern Colorado Plateau. At Black Mesa specimens also occur in the *Neocardioceras juddii* Zone. Specimens, which may be referable, occasionally occur crushed in shales of the lower and middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone up into the Hopi Sandy Member at Blue Point and less commonly at Lohali Point. Also present in southwestern Colorado, New Mexico, and Texas.

Types — Holotype, MNA N5140 from MNA loc. #989; paratype, MNA N2078 from MNA loc. #298; both from BM8, lower part, lower shale member, Mancos Shale.

Paleoecology — Specimens of *Pycnodonte newberryi* from the base of the *Neocardioceras juddii* at Blue Point commonly have straight-sided borings 1–2 mm in diameter near the umbo of the larger left valve. These borings lack the beveled sides characteristic of naticid borings, but are attributed to naticids as muricids are not known from the late Cenomanian of Black Mesa. They are most likely evidence of predation of *Euspira* on *Pycnodonte*, as *Euspira* is much more common than other naticids at this level, although *Eunaticina textilis* is present as well. Guerrero and Reyment (1988) have described boring by one species of living naticid that results in straight-sided, non-beveled holes in the shells of their prey. Sohl (1967a) has pointed out that *Euspira* is the characteristic naticid of mud and clay facies in the Cretaceous of the Western Interior.

Genus *Gyrodes* Conrad, 1860

Paleoecology — Large beveled borings up to 0.4 cm in diameter found in the shallow infaunal bivalve *Veniella* (e.g., Plate 45, Figure B) from the Blue Point Sandstone Tongue are believed to have been made by *Gyrodes*, as *Gyrodes* is the only genus of naticid recognized at this level at Black Mesa. Sohl (1967a) has pointed out that *Gyrodes* is the characteristic naticid found in shallow marine sandstone deposits.

Gyrodes depressa Meek, 1877

Plate 41, Figures G (a), J, K

Gyrodes depressa Meek, 1877; p. 159, pl. 15, figs. 1, 1a.
Gyrodes depressa Meek; Stanton, 1893, p. 135, pl. XXIX, figs. 11–14.

Description — Medium-sized (2.5 cm high, 3.5 cm wide), depressed subglobose gastropod; spire low, 3–4 rapidly expanding inflated whorls; early whorls subovate with well rounded shoulder becoming obsolete before body whorl which becomes more elongate and inclined away from deep, open umbilicus; shell smooth but for fine growth lines.

Discussion — *Gyrodes depressa* may be most readily distinguished from co-occurring *Gyrodes conradi* in lacking or having only a very indistinct shoulder. Immature specimens of *Gyrodes depressa* and *Gyrodes conradi* are often difficult to separate. Stanton (1893) illustrates a range of forms to document the wide range of variation found in this species and notes that considered separately several species would have been erected, but when studied as a population all the various forms are seen to intergrade.

Stephenson (1952) synonymized *Gyrodes depressa* as illustrated by Stanton (1893) from the middle Turonian of southern Colorado with his species *Gyrodes fluvianus* from the middle Cenomanian Woodbine Formation of central Texas. Stephenson (1952) stated that the poorly preserved internal mold illustrated by Meek (1877) has a narrow shoulder and weak shoulder angle. However, this would appear to be within the range of variation of the material illustrated by Stanton (1893). Stephenson's (1952) species appears to have much stronger incised growth lines. Until a range of material from the type locality can be studied the concept of *Gyrodes depressa* will remain uncertain.

Occurrence — The type specimens are from the lower part of the Cretaceous section at Coalville, Utah and range up to the second sandstone (Cenomanian-Turonian in Ryer, 1975). At Black Mesa, present in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point and in the lower sandstone member of the Toreva Formation throughout the basin, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone through *Prionocyclus hyatti* Zone. Also present in Utah, Colorado, and New Mexico.

Illustrated material — MNA N5501, N5484, N5408 from MNA loc. #1150, top of Blue Point Sandstone Member, Toreva Formation.

Gyrodes conradi Meek, 1876
Plate 41, Figures F, G (b), H, I

Gyroides conradi Meek, 1876; p. 310, text-figs. 33–36.
Gyroides conradi Meek; Stanton, 1893, p. 136, pl. XXIX, figs. 7, 8.

Description — Medium-sized (to 3 cm high, 3.5 cm wide), depressed subglobose gastropod; spire low, and flattened; 3–4 rapidly expanding inflated whorls; whorls subovate with lower margin angular vertically elongate; angular shoulder depressed toward incised suture or marked by groove prior to suture, giving spire a channeled appearance; deep open umbilicus; shell smooth except for fine growth lines, which tend to strengthen markedly over the shoulder.

Discussion — Readily identified by vertically elongate whorls with a channeled shoulder.

Occurrence — The type was found on the Cheyenne River, South Dakota in supposed Fort Benton shales. At Black Mesa, present in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, and in the lower sandstone member of the Toreva Formation throughout the basin, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone through *Prionocyclus hyatti* Zone. A few compacted specimens from Blue Point that may represent this species in the upper half of the middle shale through Hopi Sandy Members of the Mancos Shale possibly extending its range downward into the *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone. Also widely destributed in Utah, Colorado, and New Mexico, where it ranges down into the lower Turonian *Mammites nodosoides* Zone.

Illustrated material — MNA N5093, N5483 from main body and MNA N3474, N5408 from top of Blue Point Sandstone Tongue, Toreva Formation.

Gyrodes sp. cf. *G. tramitensis* Stephenson, 1952
Plate 13, Figure V

Description — Medium-sized (to 2.5 cm high, 3 cm wide), very depressed subglobose gastropod; spire low, and flattened; 3–4 rapidly expanding inflated whorls; whorls subovate with lower margin angular with low axially directed nodes; angular slightly noded, shoulder flattened; suture incised; deep open umbilicus; shell smooth except for weak nodes on upper and lower margin of whorl and fine growth lines.

Discussion — Specimens of *Gyrodes* from the late Cenomanian, while superficially close to *Gyrodes conradi*, may in fact be closer to *Gyrodes tramitensis* Stephenson (1952) in having a somewhat nodate shoulder and in having whorls that are a bit broader than is normally observed in *Gyrodes conradi* Meek. However, the preservation does not permit a definite identification.

Occurrence — At Black Mesa, very rare in the sandstone facies of upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #265 and #963) and represented by one specimen from marker bed BM10 in the lower shale member of the Mancos Shale at the Lohali Point section (MNA loc. #989), upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone.

Illustrated material — MNA N5137 from MNA loc. #989, BM10, lower part, lower shale member, Mancos Shale.

Superfamily Tonnacea
Family Cymatiidae
Genus *Charonia* Gistel, 1848

Paleoecology — Modern examples of *Charonia* are large to very large shallow water gastropods that feed on starfish. The small gastropods tentatively referred to *Charonia* probably fed on smaller prey items as starfish are not known from Black Mesa.

Charonia ? kanabense (Stanton, 1893)
Plate 14, Figures M, N

Tritonium kanabense Stanton, 1893; p. 150, pl. XXXI, fig. 12.

Description — Small (to 2 cm high, 1 cm wide), fusiform shell; slender spire moderately high, apical angle of about 40°; body whorl inflated; 6 to 8 well rounded whorls; aperture subovate with moderately long recurved canal, outer lip strongly dentate; surface ornamented by strong axial ribs and noded spiral costae and costellae; particularly strong varices indicate resting phases during growth; the impression of a denticulate outer lip is preserved on internal molds.

Discussion — Without further study the assignment of this species to the recent genus *Charonia* must be considered provisional following Stanton (1893). It is likely that further study will indicate that this species and its close relatives will be assigned to a new genus.

Occurrence — The types are from the upper Cenomanian *Sciponoceras gracile* Zone in the upper Kanab Valley of southern Utah. At Black Mesa rare in the lower shale member of the Mancos Shale, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone.

Illustrated material — MNA N5114 from MNA loc. #989, BM8; MNA N5115 from MNA loc. #271, BM10; both from lower part, lower shale member, Mancos Shale.

Charonia ? soozi n. sp.
Plate 26, Figures B, C; Plate 42, Figures A, B

Etymology — Named for Sooz Kirkland for her untiring help on this manuscript.

Diagnosis — Close to *Charonia ? kanabensis* but shell slightly larger and more inflated with coarser ornamentation.

Description — Small (to 2.5 cm high, 1.5 cm wide), stout fusiform shell; spire moderately high, apical angle of about 50–60°; body whorl inflated; 4 to 6 well rounded whorls; aperture subovate with moderately long recurved canal, outer lip strongly dentate; surface ornamented by strong axial ribs and noded spiral costae and costellae.

Discussion — Kauffman (1961) has described a specimen of this species as *Charonia kanabensis* from the Codell Sandstone Member of the Carlile Shale of Huerfano Park in southern Colorado.

Occurrence — Widespread, but uncommon in the lower Turonian *Watinoceras coloradoense* and *Mammites nodosoides* Zones in the area of southwestern Black Mesa, and present in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone. Also present in the Codell Sandstone Member of the Carlile Shale of Huerfano Park in southern Colorado, middle Turonian *Prionocyclus hyatti* Zone.

Illustrated material — Holotype; MNA N5556, paratype; N5509 from MNA loc. #1150, main body, Blue Point Sandstone Tongue, Toreva Formation. Lectotypes; MNA N5268 just below BM35, MNA N5285 concretion above BM21, both from MNA loc. #262 lower shale member of the Mancos Shale.

ORDER NEOGASTROPODA

Paleoecology — Most of the neogastropods are carnivores or scavengers feeding on a wide variety of prey items. Most forms rest hidden in the sediment with only the tip of the siphon and perhaps the top of the shell exposed. However, active hunting is usually performed on the sediment surface.

Superfamily Buccinacea
Family Nassariidae

Paleoecology — Modern nassarids are scavengers feeding on dead organisms. They spend much of their time shallowly buried in fine sediment and on detecting decaying flesh come out in large numbers to feed on the body. Both forms placed in this family from Black Mesa have distributions indicating that they are brackish water taxa.

Genus *Admetopsis* Meek, 1873
Admetopsis subfusiformis (Meek), 1873
Plate 2, Figures T, U, V

Admetopsis subfusiformis (Meek); Stanton, 1893, p. 159, pl. XXXIII, figs. 1, 2.

Description — Small to very small (1 cm high, 0.4 cm wide), subfusiform shell; with relatively high spire, apical angle of about 35°; 6 to 8 well rounded whorls; aperture subovate, thickened and calloused inner lip bearing the terminations of two columnar folds; short siphonal canal present; ornamented by a narrow subsutural collar; main part of whorl with weak spiral costae with several stronger distinct spiral costae on lower margin of whorl; weak axial ribs also variably present.

Discussion — As with many apparently brackish water taxa this species appears to be quite variable. It is possible that *Admetopsis rhomboides* (Meek, 1973), which occurs with *Admetopsis subfusiformis* at the type area, may be a more inflated version of *A. subfusiformis*. If so, *Admetopsis rhomboides* has one page priority. However, forms of this type were not recognized at Black Mesa. Superficially *Admetopsis subfusiformis* appears very similar to the co-occurring *Ambrosea nitida*, but differs in being more weakly ornamented and in having two and not three columnar folds.

Occurrence — The types reported by Meek (1973) are from near the base of the Cretaceous section near Coalville, Utah, upper Cenomanian (Ryer, 1975). At Black Mesa locally common in shell beds of the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone.

Illustrated material — MNA N4529, N4530, N4531 from MNA loc. #265, shale facies, upper sandstone member, Dakota Formation.

Genus *Ambrosea* Stephenson, 1952
Ambrosea nitida Stephenson, 1952
Plate 2, Figures W, X

Ambrosea nitida Stephenson, 1952; p. 148, pl. 35, figs. 12–15.

Description — Small (1 cm high, 0.5 cm wide), subfusiform shell with relatively high spire, apical angle of about 40°; 6 to 8 well rounded whorls; aperture subovate, inner lip bearing the terminations of three columnar folds; ornamented by a narrow subsutural collar, below which there are 1–2 spiral costae; main part of whorl with weak spiral costae with several stronger distinctly noded spiral costae on lower margin of whorl; distinct axial ribs cross this ornament.

Discussion — Stephenson (1952) placed this species in the Pyramidellidae, but based on its striking similarities with *Admetopsis subfusiformis* it is provisionally placed in the Nassariidae.

Occurrence — The types are from the middle Cenomanian Lewisville Member of the Woodbine Formation in central Texas. At Black Mesa present in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone (MNA loc. #265).

Illustrated material — MNA N4526 from MNA loc. #265, shale facies, lower sandstone member, Mancos Shale.

Family Melongenidae
Genus *Rhombopsis* Gardner, 1916
Rhombopsis ? huerfanensis (Stanton, 1893)
Plate 42, Figure C

Tritonidea ? huerfanensis Stanton, 1893; p. 152, pl. XXXI, fig. 15.

Description — Small (2.5 cm high, 1.7 cm wide), stout fusiform shell with moderate spire; 4 to 6 rather rapidly expanding whorls; apical angle of about 60°; aperture subovate with moderate-sized siphonal canal; shoulder of whorl ornamented by nodes that are axially expanded away from spire, fine spiral costae also present.

Discussion — Superficially similar to *Charonia soozi* but somewhat larger, lacking a denticulate outer lip, and having coarser and more subdued ornamentation.

Occurrence — The types are from the Codell Sandstone Member of the Carlile Shale of Huerfano Park in southern Colorado, middle Turonian *Prionocyclus hyatti* Zone. At Black Mesa, uncommon in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (MNA loc. #1150).

Illustrated material — MNA N5510 from MNA loc. #1150, main body, Blue Point Sandstone Tongue, Toreva Formation.

Family Fasciolariidae

Paleoecology — Fasciolarids feed on a wide variety of prey items. They open bivalves by applying pressure with their muscular foot, slipping the outer lip of aperture between the valves and twisting the shell to pry it open.

Genus *Bellifusus* Stephenson, 1941

Discussion — *Bellifusus* is most readily distinguished from the other fasciolarids in having a distinct constricted collar below the suture in combination with ornament with spiral elements.

Bellifusus ? gracilistriatus n. sp.
Plate 42, Figure F

Bellifusus ? gracilistriatus Kauffman, 1961, Ph. D.; p. 387, pl. 28, figs. 19–22.

Etymology — Named in recognition of this taxon's fine ornamentation.

Diagnosis — This fasciolarid is readily distinguished by its ornamentation of fine spiral costae.

Description — One small (0.8 cm wide) specimen of fusiform gastropod consisting of three and one half whorls; apical angle of about 45°; whorls with moderate shoulder; weak collar below suture; axial ribs strongest at shoulder; entire surface of shell covered by fine spiral costae.

Discussion — The one specimen from Black Mesa is distinct from all other gastropods observed. It would seem to compare well with Kauffman's (1961) form *Bellifusus ? gracilistriatus* from the Codell Sandstone Member of the Carlile Shale at Huerfano Park, Colorado. It most likely represents an immature individual.

Occurrence — Kauffman's (1961) types are from the Codell Sandstone Member of the Carlile Shale of Huerfano Park in southern Colorado, middle Turonian *Prionocyclus hyatti* Zone. At Black Mesa, known from one specimen from the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point (MNA loc. #1150), middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone.

Types — From Kauffman (1961) "Holotype, a large nearly complete, external mold, UMMP 43161; paratypes, fragments of medium-sized specimens, UMMP 43658, a relatively complete medium-sized shell, USNM 22927.

Illustrated material — MNA N5515 from MNA loc. #1150, main body, Blue Point Sandstone Tongue, Toreva Formation.

Bellifusus sp. cf. *B. willistoni* (Logan, 1898)
Plate 36, Figures K, P

Rostellites willistoni Logan, 1898; p. 461, pl. CXX, fig. 3.
Bellifusus willistoni (Logan); Hattin, 1962, p. 79, pl. 22, figs. C, D.

Description — Compacted medium-sized (to 3.5 cm high), fusiform gastropods; moderate high spired; 6 to 8 well rounded whorls; constricted collar below suture; aperture not visible, siphonal canal long; rather broad axial ribs fading on lower part of whorl; distinct spiral costae visible on lower part of whorl.

Discussion — Specimens from the type locality in the Blue Hill Shale Member of the Carlile Shale in central Kansas get as much as three times larger than any specimens observed at Black Mesa, however, they agree well in overall morphology.

Occurrence — The type specimens are from septarian concretions in the upper part of the Blue Hill Shale Member of the Carlile Shale at Williams Butte in Mitchell County, Kansas, middle Turonian *Prionocyclus hyatti* Zone. At Black Mesa, widely scattered in the upper two thirds of the middle shale member of the Mancos Shale, middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5266 from MNA loc. #262, above BM68, middle shale member, Mancos Shale.

Bellifusus n. sp.
Plate 36, Figure J

Diagnosis — Compacted specimens close to *Bellifusus willistoni* but for higher, more flattened whorls and relatively thinner axial ornamentation.

Discussion — Only known from compacted shale specimens, this distinct gastropod appears to range unchanged from the late Cenomanian to the middle Turonian. Higher in the section it is replaced by *Bellifusus* sp. cf. *B. willistoni*.

Occurrence — Widely scattered from about BM5 in the basal lower shale member into the basal middle shale member of the Mancos Shale, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through the middle Turonian *Collignoniceras woollgari woollgari-Mytiloides hercynicus* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5265 from MNA loc #262, 2 m above BM54, middle shale member, Mancos Shale.

Genus *Graphidula* Stephenson, 1941
Graphidula walcotti (Stanton, 1893)
Plate 14, Figures O, P

Fasciolaria ? walcotti Stanton, 1893; p. 153, pl. XXXII, fig. 5.

Description — Small (to 0.7 cm wide); slender fusiform shell; high spired, apical angle of 28°; whorls high and slender; aperture lenticular with long siphonal canal, inner lip thickened, with termination of three strong columnar plications; no distinct shoulder; ornamented by dense fine axial ribs crossed by much finer dense spiral costae.

Discussion — No complete specimens of this fascularid has been found at Black Mesa, but the material that has been found compares well with *Graphidula walcotti*. Complete specimens have been observed from southern Utah.

Occurrence — The types are from the upper Cenomanian *Sciponoceras gracile* Zone in the upper Kanab Valley of southern Utah. At Black Mesa rather rare in the lower shale member of the Mancos Shale from BM5 to about BM13, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone. Also known from Colorado, New Mexico, and Texas.

Illustrated material — MNA N5110 from MNA loc. #989, BM8; MNA N5111 from MNA loc. #306, BM10; both from lower part, lower shale member, Mancos Shale.

Graphidula sp.
Plate 14, Figure Q

Diagnosis — Much like *Graphidula walcotti*, but with stouter whorls, with a distinct shoulder and shorter spire.

Discussion — Only known from a few incomplete specimens, which in their shorter spire, distinct shoulder, and stouter whorls, appear distinct from *Graphidula walcotti*.

Occurrence — At Black Mesa rare in marker beds BM8 and BM10 in the lower shale member of the Mancos Shale, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone.

Illustrated material — MNA N5112 from MNA loc. #262, BM10, lower part, lower shale member, Mancos Shale.

Genus *Dolicholatirus* Bellardi, 1884
Dolicholatirus ? sp.
Plate 14, Figure R

Description — One large (3 cm wide) incomplete specimen consisting of about two and one half whorls of an ornate fusiform gastropod; subsutural collar present, below which whorls are evenly inflated; ornamented by broad oblique axial ribs crossed by strong thin spiral costae; growth lines strong.

Discussion — This is the largest gastropod known from the *Sciponoceras gracile* Zone. Sohl (1964) described the first occurrence of *Dolicholatirus* from the Cretaceous in the Maestrichtian of Mississippi. If the specimen from Black Mesa is indeed assignable to this genus, it would increase its range considerably. It is close to Sohl's (1964) *Dolicholatirus torquata*, but the Black Mesa specimen has more oblique axial ribs.

Occurrence — At Black Mesa known from one specimen from Blue Canyon from marker bed BM10 in the lower shale member of the Mancos Shale (MNA loc. #271), upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone.

Illustrated material — MNA N5146 from MNA loc.#271 lower part, lower shale member, Mancos Shale.

undescribed genus

undes. gen. = *Fusus* (*Neptunea*) *venenatus*? (Stanton, 1893)

Plate 42, Figure S

Fusus (*Neptunea* ?) *venenatus* Stanton, (1893); p. 152, pl. XXXII, figs. 1, 2.

Description — One moderately distorted, large (about 5 cm wide) fragment consisting of two well rounded whorls; shell material attached to body whorl; aperture not visible; large fusiform gastropod with moderately developed shoulder; ornamented by widely spaced large varices and uneven sized spiral ribs.

Discussion — Sohl (1967a) reports that *Fusus* (*Neptunea*) *venenatus* Stanton represents an undescribed genus. Stanton (1893) reports that the species is highly variable in its spire height, width of shell, whorl profile, and development of peripheral nodes on the shoulder. The specimen from Black Mesa appears to differ considerably from those illustrated by Stanton (1983), but Kauffman (1961) illustrates a specimen that compares very well and notes that all the forms observed by him intergrade.

Occurrence — The types are from the Codell Sandstone Member of the Carlile Shale of Huerfano Park in southern Colorado, middle Turonian *Prionocyclus hyatti* Zone. At Black Mesa, very rare in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (MNA loc. #1150).

Illustrated material — MNA N5267 from MNA loc. #1150, top of Blue Point Sandstone Tongue, Toreva Formation.

Superfamily Volutacea

Family Xancidae

Genus *Pyropsis* Conrad, 1860

Paleoecology — Carnivorous marine gastropods that probably spent considerable time inactive and buried shallowly in the sediment with the tip of the siphon exposed.

Pyropsis sp. cf. *P. coloradoensis* Stanton, 1893

Plate 42, Figures D, E; Plate 48, Figure J (d)

Pyropsis coloradoensis Stanton, 1893; p. 154, pl. XXXII, figs. 6–8.

Description — Large (higher than 5 cm, to 4.5 cm wide), pyriform gastropod; spire low with apical angle of about 110°; 5 rapidly expanding inflated whorls; slight collar below incised suture gives suture channeled appearance; strong noded spiral rib on margin of distinct shoulder; side of whorl flat sloping slightly toward slightly weaker noded spiral rib below which whorl becomes constricted toward long siphonal canal; aperture long and narrow with thickened calloused inner lip; ornamented by spiral and axial costae with small nodes at intersections, 4–5 spiral costae on side of whorl between slightly more distinct primary costae.

Discussion — Stanton's (1893) illustrations of *Pyropsis coloradoensis* reveal a much more weakly ornamented species with a smoothly sloping spire. Examination of the type material is needed to compare with the specimens from Black Mesa. Kauffman (1961) illustrated a specimen from a septarian concretion in the upper part of the Blue Hill Shale Member of the Carlile Shale in Huerfano Park, southern Colorado, that is similar in the strength of its ornament, but differs in its more smoothly rounded whorls.

Occurrence — The types are from the Codell Sandstone Member of the Carlile Shale of Huerfano Park in southern Colorado, middle Turonian *Prionocyclus hyatti* Zone. At Black Mesa, present in the Blue Point Sandstone Tongue and lower sandstone member of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5085, N5084 from MNA loc. #1150, main body, Blue Point Sandstone Tongue, Toreva Formation.

Pyropsis n. sp.

Plate 14, Figures S, T

Etymology — Named in honor of Dr. Carl Koch, who first recognized this distinct taxon.

Diagnosis — This species is readily distinguished by its rather high angular spire that appears hexangular in top view.

Description — Medium-sized (up to 2.5 cm wide); pyriform gastropod; spire moderately low with apical angle of 80 to 90°; 4 rapidly expanding inflated whorls; upper part of whorls may have hexagonal appearance; slight collar below incised suture; broad noded spiral rib on margin of distinct shoulder; side of whorl flat, sloping very slightly toward slightly weaker broad-noded spiral rib below which whorl becomes constricted toward long siphonal canal which has only been observed on a few of internal molds, aperture long and narrow with thickened calloused inner lip; ornamented by fine beaded spiral costae which also cover broad primary ribs; fine raised growth lines also apparent.

Discussion — The smaller size and more angular shape of the whorls observed in this species readily distinguish it from *Pyropsis coloradoensis*.

Occurrence — At Black Mesa uncommon in marker beds BM8 and BM10 in the lower shale member of the Mancos Shale, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone. Also present in southern Utah at this level.

Types — Holotype, MNA N1218; paratype, MNA N5145, both from MNA loc. #271, BM10, lower part, lower shale member, Mancos Shale.

Family Volutidae

Paleoecology — Active carnivorous marine gastropods.

Genus *Paleopsephea* Wade, 1926

Paleopsephea arizonensis n. sp.

Plate 42, Figures G, H, M, N

Etymology — Named for its type locality in Arizona.

Diagnosis — Distinguished by absence of spiral costae and strong shoulder on whorl.

Description — Medium to fairly large, (to 6 cm high, 3 cm wide); fusiform gastropod, rather high spired, apical angle of 45–50°; 6–7 moderately inflated whorls; weak collar below suture; aperture lenticular with long siphonal canal equal to height of spire, inner lip forms thin callous over columnella, with termination of three strong columnar plications; strong, high shoulder ornamented by strong nodes which extend down flattened flank as broad axial ribs.

Discussion — The Black Mesa material compares well in overall form with the middle Cenomanian *Paleopsephea vadoana* Stephenson (1952), except that spiral ornament has not been recognized and there is a higher and stronger shoulder. This indicates that the Black Mesa specimens represent a distinct species.

Occurrence — The types are from the middle Cenomanian Templeton Member of the Woodbine Formation in central Texas. At Black Mesa, common in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (MNA loc. #1150).

Types — Holotype, MNA N5505; paratypes, N5506, N5531, N5532 from MNA loc. #1150, main body, Blue Point Sandstone Tongue, Toreva Formation.

Genus *Carota* Stephenson, 1952
Carota dalli (Stanton, 1893)
Plate 42, Figures O, P

Rostellites dalli Stanton, 1893; p. 156, pl. XXXIII, figs. 11–13.

Description — Large (7.5 cm high,3 cm wide), fusiform gastropod; moderately high spire, apical angle of about 50 to 70°; approximately 6–7 elongate whorls; suture incised with slight collar; shoulder with even spaced large, axially, elongate nodes; aperture elongate with sinus at position of shoulder and long siphonal canal, inner lip calloused, three columnar folds; ornamented by spiral costae best developed below shoulder, which are crossed by strong growth lines.

Discussion — Stephenson (1952) erected the genus *Carota* for Cretaceous volutids with a strong shoulder notch and strong nodes on moderately elevated spire. He reports that *Rostellites dalli* should be included within the genus.

Occurrence — The types are from the Codell Sandstone Member of the Carlile Shale of Huerfano Park in southern Colorado, middle Turonian *Prionocyclus hyatti* Zone. At Black Mesa, uncommon in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (MNA loc. #1150).

Illustrated material — MNA N5507 from main body; MNA N5082 from top of Blue Point Sandstone Tongue, Toreva Formation, MNA loc #1150.

Genus *Tectaplica* Wade, 1916
Tectaplica ? utahensis Meek, 1873
Plate 42, Figures K, L, Q, R

Fusus (Neptunea) utahensis Meek, 1873; p. 505.
Fasciolaria? (Cryptorhytis) utahensis (Meek); Stanton, 1893, p. 153, pl. XXXII, figs. 3, 4.
Tectaplica ? utahensis (Meek); Sohl, 1967a, p. 34.

Description — Medium-sized (5.5 cm high, 3 cm wide), fusiform shell with short conical spire; apical angle of 60 to 70°; 5–6 elongate whorls with angular shoulder bearing small axially oriented nodes; whorl flat to slightly convex above shoulder and broadly convex below shoulder; suture of succeeding whorls slightly overlaps shoulder, obscuring nodes, long siphonal canal, surface ornament consisting only of fine growth lines.

Discussion — Sohl (1967a) tentatively assigns this species to *Tectaplica* Wade.

Occurrence — The types are from the second ridge at Coalville Utah. At Black Mesa, present in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (MNA loc. #1150). Also present in the Codell Sandstone Member of the Carlile Shale of Huerfano Park in southern Colorado, middle Turonian *Prionocyclus hyatti* Zone as well as in New Mexico.

Illustrated material — MNA N5508, N5503, N5504 from main body; MNA N5502 from top of Blue Point Sandstone Tongue, Toreva Formation, MNA loc. #1150.

Superfamily Conacea
Family Turridae

Paleoecology — Turret shells make up the most diverse family of modern gastropods. Whereas some species live in shallow water, most live in deep water (Emerson and Jacobson, 1976). The exceedingly high diversity of these carnivorous gastropods suggests that members of this family are probably specialized for feeding on specific prey species.

Genus *Lutema* Stephenson, 1941
Lutema hitzi (Meek, 1876)
Plate 42, Figure T; Plate 49, Figures C, D

Turris (Surcula)? hitzi Meek, 1876; p. 386, fig. 50.
Pleurotoma? hitzi (Meek); Stanton, 1893, p. 161, pl. XXXIV, fig. 4.

Description — Medium-sized (to 6 cm high, 2.5 cm wide); slender fusiform gastropod; high spired, apical angle of 40 to 50°; siphon as long as spire; 6–8 whorls convex to subangular with obscure axially directed nodes on shoulder; surface covered by fine spiral lines; elongate lenticular aperture poorly preserves angular outer margin; growth line indicates presence of weak turrid sinus near suture.

Discussion — The final whorls are fairly well preserved and compare well with Stanton's (1893) illustration of the holotype. None of the specimens displays a well developed anal (turrid) notch on the outer margin of the aperture, although the presence of one is suggested by the trend of the growth line. Stephenson's (1941) genus *Lutema* seems to compare best with the present material.

Occurrence — The holotype was associated with a Coloradan fauna on the Missouri River. At Black Mesa, uncommon in the Blue Point Tongue, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone at Blue Point. Two specimens from a siderite concretion just above a sandstone interval nearly 20 m below the base of the Toreva Formation, *Prionocyclus hyatti* Zone, Lohali Point.

Illustrated material — MNA N5384 from MNA loc. #1150, main body, Blue Point Sandstone Tongue, Toreva Formation; MNA N5261, N5262 from MNA loc. #989, siderite concretions 19 m below the base of the Toreva Formation, upper shale member, Mancos Shale.

ORDER OPISTHOBRANCHIA
Superfamily Epitoniacea
Family Epitoniidae

Paleoecology — Modern wentletraps are ectoparasites, which feed on sea anemones by sucking fluids from the anemone through their proboscis. The presence of wentletraps in a fauna may be used to indicate the presence of nonpreservable sea anemones (Sohl, 1967a).

Genus *Acirsa* Morch, 1857
Subgenus *Hemiacirsa* de Boury, 1890
Acirsa (*Hemiacirsa*) *kelseyi* n. sp.
Plate 42, Figures U–W

Etymology — Named for the author's daughter Kelsey Lynn Kirkland.

Diagnosis — Shell large for genus distinguished by its 14–16 axial ribs per evenly rounded whorl and spiral costellae.

Description — Medium-sized (to 5 cm high, 2 cm wide); high spired turriform gastropod; apical angle of 25 to 35°; about 10 well rounded whorls; suture incised; base of whorl bounded by distinct spiral ridge; sides ornamented by 14–16 strong axial ribs per whorl and fine spiral costellae.

Discussion — This species compares well with the subgenus *Hemiacirsa* and represents the earliest occurrence of this subgenus (Sohl, 1964). *Acirsa kelseyi* differs from other described species from the Cretaceous in its larger size and more inflated whorls (Wade, 1927; Sohl, 1964).

Occurrence — At Black Mesa, present in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (MNA loc. #1150).

Types — Holotype; MNA N5511; paratypes, N5512 main body; MNA N5392 from top of Blue Point Sandstone Tongue, Toreva Formation, from MNA loc. #1150.

Superfamily Eulimacea
Family Eulimiidae

Paleoecology — Modern representatives of this family are parasitic on echinoderms. The smooth streamlined shell suggests an ability to move readily through the sediment.

Genus *Eulima* Risso, 1826
Eulima ? funicula Meek, 1873
Plate 14, Figures J, K

Eulima funicula Meek, 1873; p. 506.
Eulimella ? funicula (Meek); White, 1876, p. 197, pl. 18, fig. 6.
Eulimella ? funicula (Meek); Stanton, 1893, p. 140, pl. XXX, fig. 9.

Description — Very small (about 1 cm high, 0.4 cm wide), high spired turriform shells; apical angle of 30°; 8–10 flat to slightly curved whorls; suture slightly incised; side of whorl curves evenly to base; aperture ovate; shell surface glossy.

Discussion — The assignment of this species to *Eulima* is highly tentative as the apical whorls have not been observed. However, the highly polished surface is similar to that found in living species of *Eulima*.

Occurrence — The types are from the Cretaceous at Coalville, Utah. At Black Mesa rather rare in marker beds BM8 and BM 10 in the lower shale member of the Mancos Shale, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone.

Illustrated material — MNA N5120 from MNA loc. #306, BM10; MNA N5121 from MNA N loc. #989, BM8; both from lower part, lower shale member, Mancos Shale.

Superfamily Acteonacea

Paleoecology — Small carnivorous gastropods which tend to prefer fine substrates.

Family Acteonidae
Genus *Acteon* Montfort, 1810
Acteon propinguis Stanton, 1893
Plate 14, Figure U

Acteon propinguis Stanton, 1893; p. 161, pl. XXXIV, figs. 5–8.

Description — Small (1 cm high, 0.6 cm wide), ovate shell; spire low and tapered; apical angle of 75°; 5 well rounded largely overlapping whorls; suture incised; aperture obscured by matrix; surface ornamented by fine, punctate, spiral lines.

Discussion — These specimens, although considerably older than the types appear to compare quite well and are considered to be conspecific.

Occurrence — The types are from the Codell Sandstone Member of the Carlile Shale of Huerfano Park in southern Colorado, middle Turonian *Prionocyclus hyatti* Zone. At Black Mesa, rather rare in the lower shale member of the Mancos Shale, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone.

Illustrated material — MNA N5106 from MNA loc. #262, concretion between BM8 and BM10 (unit 17), lower part, lower shale member, Mancos Shale.

Genus *Eoacteon* Stephenson, 1955
Eoacteon ? sp.
Plate 14, Figure V

Description — Very small (0.6 cm high, 0.4 cm wide), subcylindrical shell; spire moderately high; apical angle of 50°; four narrow nearly flat sided whorls; aperture long and narrow; ornament unknown.

Discussion — One internal mold is known from Black Mesa, which in size and overall shape seems to agree with the genus *Eoacteon*.

Occurrence — At Black Mesa, one specimen from Blue Point in marker bed BM8 in the lower shale member of the Mancos Shale (MNA loc. #262), upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone.

Illustrated material — MNA N5107 from MNA loc. #262, BM8, lower part, lower shale member, Mancos Shale.

Genus *Pirsilia* Stephenson, 1952
Pirsilia sp.
Plate 2, Figure Y

Description — Very small (0.7 cm high, 0.4 cm wide), ovate shell with moderate spire, apical angle of 50°; 4 slightly convex whorls; suture incised; shell smooth but for fine growth lines.

Discussion — These small, relatively nondescript gastropods seem best assigned to the genus *Pirsilia*.

Occurrence — At Black Mesa locally common to abundant in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone. A few small specimens from the upper part of the middle shale member of the Mancos Shale at Blue Point, middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N1039, MNA loc. #265, shale facies, lower shale member, Dakota Formation.

Paleoecology — The distribution of this form indicates a tolerance of brackish water habitats by at least some species.

Family Ringiculidae

Genus *Ringicula* Deshayes (in Lamarck), 1838

Ringicula codellana Kauffman and Pope, 1961

Plate 19, Figure G; Plate 41, Figure M (b);
Plate 42, Figures X, Y

Ringicula codellana Kauffman and Pope, 1961; p. pl. figs. 1–3, 6–22.

Description — Very small (0.7 cm high, 0.6 cm wide); globose gastropod; spire low to moderate; apical angle of 65 to 80°; 3–5 rapidly expanding inflated whorls; body whorl inflated ; suture incised; aperture long and subovate to lenticular, outer lip greatly thickened, two columnar plications below body whorl; surface smooth but for fine growth lines.

Discussion — Specimens of *Ringicula* from both the late Cenomanian and middle Turonian seem best assigned to *Ringicula codellana*.

Occurrence — The types are from the Codell Sandstone Member of the Carlile Shale of Huerfano Park in southern Colorado, middle Turonian *Prionocyclus hyatti* Zone. At Black Mesa, present in the lower shale member, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through the *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone and common in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5101 from MNA loc. #814, BM11, lower part, lower shale member, Mancos Shale; MNA N5395, N5514, N5513 from MNA loc. #1150, main body, Blue Point Sandstone Tongue, Toreva Formation.

Family Scaphandridae

Paleoecology — Very small carnivorous gastropods which feed on small, soft-bodied invertebrates. The cylindrical shell is covered by mantle tissue permitting species in this family to burrow rapidly through the sediment.

Genus *Cylichna* Loven, 1846

Cylichna sp.

Plate 14, Figure AA

Diagnosis — Very small (0.3 cm high, 0.15 cm wide), slender cylindrical gastropod; apex sunken with aperture longer than rest of shell, surface smooth.

Discussion — Species of this genus are commonly difficult to separate from the much more common genus *Cylindrotruncatum* when preservation is poor. *Cylichna* is distinguished by its sunken spire.

Occurrence — At Black Mesa present in the lower part of the lower shale member of the Mancos Shale, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through the *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone.

Illustrated material — MNA N5103 from MNA loc. #262, concretion between BM8 and BM10 (unit 17), lower part, lower shale member, Mancos Shale.

Genus *Cylindrotruncatum* Sohl, 1963

Cylindrotruncatum spp.

Plate 14, Figures W–Z; Plate 42, Figure Z

Description — Very small (0.5 cm high, 0.3 cm wide), slender cylindrical gastropod; apex flush or slightly sunken with aperture longer than rest of shell expanding anteriorly; surface variably ornamented by fine spiral grooves and fine axial costellae which are best developed toward anterior and posterior margins of shell.

Discussion — Specimens assigned to this genus are widespread and locally common in many levels at Black Mesa. It is highly likely that there may be several species represented by this material.

Occurrence — At Black Mesa common in the lower part of the lower shale member of the Mancos Shale, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through the *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone, widely scattered in the middle shale member of the Mancos Shale, middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone and common in the Blue Point Sandstone Tongue of the Toreva Formation at Blue Point, middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N5102, N5104, from MNA loc. #262, concretion between BM8 and BM10 (unit 17); MNA N5105 from MNA loc. #989, BM8; MNA N5108 from MNA loc. #306, BM10; all from lower part, lower shale member, Mancos Shale; MNA N5554 from MNA loc. #1150, main body, Blue Point Sandstone Tongue, Toreva Formation.

ORDER BASOMMATOPHORA

Superfamily Siphonariacea

Family Siphonariidae

Paleoecology — Modern Siphonariidae are air breathing pulmonates, which live in shallow marine water clinging to hard surfaces and grazing on algae (Emerson and Jacobson, 1976).

Genus *Anisomyon* Meek and Hayden, 1860

Anisomyon n. spp.

Plate 26, Figures D, E

Description — Medium-sized (average 2–3 cm); thin oval conical patelliform shells; surface smooth except for fine growth lines.

Discussion — *Anisomyon* has been placed in the Siphonariidae on the basis of its band of muscle attachment. None of the crushed material from Black Mesa displays this muscle scar. Radial ornament characteristic of many species (e.g., *A. centrale* Meek and *A. borealis* Morton) are visible only on a few specimens from the upper Cenomanian. Most of the specimens from the lower Turonian have a somewhat quadrate shape. It is difficult without further study to determine how many species of *Anisomyon* may be present at Black Mesa.

Occurrence — Widespread, though uncommon, throughout the lower shale member from BM-10 to BM-35, upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone through lower Turonian *Mammites nodosoides* Zone across Black Mesa. Specimens of this type have also been observed in the limestone marker bed correlative of BM-19 north of Boulder, Colorado.

Illustrated material — MNA N5264, above BM15; MNA N5270, BM30; both from MNA loc. #262, lower shale member, Mancos Shale.

CLASS CEPHALOPODA
SUBCLASS NAUTILOIDEA
ORDER NAUTILIDA
Superfamily Nautilaceae
Family Nautilidae
Genus *Kummeloceras* Matsumoto, 1983

Type species — *Kummeloceras yamashitai* Matsumoto, 1983.

Diagnosis — Medium sized, involute nautiliconic shell; surface smooth with fine growth lines. Suture with large ventral saddle, without ventral lobe, broad lobe on main part of flank, and low saddle near umbilical shoulder.

Discussion — Matsumoto (1983) erected the genus *Kummeloceras* for smooth nautiloids with an incipient umbilical saddle. If it was strengthened and moved outward onto the inner flank, a suture pattern like that found in *Nautilus, Cimomia*, or *Angulithes* would be developed. The genus is thought to be derived from *Cenoceras* by suppressing the fine reticulate ornament and strengthening the the ventral and umbilical saddles. *Kummeloceras* whorl sections range from moderately to fairly strongly inflated and may be distinguished from *Eutrephoceras* by their more curved sutures.

Occurrence — The genus *Kummeloceras* ranges from the upper Jurassic through lower Tertiary with the type species, *Kummeloceras yamashitai* Matsumoto, 1983, being from the middle Turonian of Japan (Matsumoto, 1984).

Paleoecology — The ecology of the recent genus *Nautilus* has been studied in considerable detail, with these studies being summarized most recently by Ward (1987). *Nautilus* is highly mobile, moving by means of water expelled from the mantle cavity through the highly mobile hyponome. While the air chambers of the phragmocone allow the animal to maintain neutral buoyancy, vertical motion through the water is largely due to active swimming. *Nautilus* lives on steep forereef slopes, where daily vertical migrations from 400–500 meters during the day to 150–300 meters at night, may be made with minimal horizontal motion. Specimens have not as yet been observed capturing live prey and the genus is thought to largely be a scavenger, feeding mainly on crustaceans.

The occurrence of *Kummeloceras* at Black Mesa is in sands representing water depths considerably less than 100 meters. Post mortem drift does not explain this occurrence as postmortem drift is now realized to be of minor importance in explaining the distribution of modern *Nautilus*. The somewhat simpler suture seen in *Kummeloceras* may support the shallower depth preference interpreted for this genus.

Kummeloceras sp.
Plate 8, Figures A, E

Description — Shell nautiliconic and very involute with a very narrow umbilicus. Whorl higher than wide with an arched venter, gently convex flanks, and steep sharply rounded umbilical walls. Surface apparently smooth. Suture smoothly curved with gently curved ventral saddle, distinct moderately deep lobe on flank, and small low saddle centered on the umbilical wall.

Discussion — The specimens from Black Mesa consist of internal molds. They are similar in shape to modern *Nautilus* and in addition to the suture may be distinguished by their smaller umbilicus. In fact, Matsumoto (1983, 1984) suggests this genus may have given rise to *Nautilus* during the Cretaceous.

Occurrence — At Black Mesa, *Kummeloceras* is only known from the top of the shale facies, upper sandstone member, Dakota Formation, *Metoicoceras mosbyense* Zone at the Coal Chute Section (MNA loc. #963). A nautiloid from the same zone (Twowells Sandstone Tongue of the Dakota Formation) at Mesa Redonda, east-central Arizona (Kirkland, 1982), probably represents this same species.

Illustrated material — MNA N3540 from MNA loc. #963, shale facies, upper sandstone member, Dakota Formation.

ORDER AMMONOIDEA ZITTEL, 1884
SUBORDER AMMONITINA HYATT, 1900
Superfamily Haplocerataceae Zittel, 1884
Family Binneyitidae Reeside, 1927
Genus *Borissiakoceras* Arkhanguelsky, 1916

Type species — *Borissiakoceras mirabile* Arkhanguelsky 1916.

Diagnosis — Small, compressed, moderately involute ammonites with flattened flanks and a rounded to flattened venter. Flanks smooth, or with flacoid ribs. Ventrolateral shoulder smooth or with small tubercles.

Discussion — This genus is apparently quite rare at Black Mesa. However, some small, smooth, unidentified ammonites may represent species of this genus, which would extend the known range of this genus at Black Mesa. Many specimens referred to this genus (e.g., Elder, 1987b) have been re-identified as being species of *Quitmaniceras*.

Occurrence — Middle Cenomanian through lower Turonian of the Western Interior (Cobban and Scott, 1972). Cenomanian of British Columbia, Gulf Coast, northern Australia, and France. Lower Turonian of northern Alaska, Gulf Coast, and Turkestan. Coniacian of Greenland and northern Russia?

Paleoecology — Batt (1987) designates taxa in this genus to his morphotype, ICCs, (42). Within the Western Interior it is widespread in shoreface sands through distal shoreface muds and is a temperate species apparently living in the upper part of the water column. Kennedy and Cobban (1976) report that this lineage is restricted to the Western Interior for much of its range.

Borissiakoceras orbiculatum Stephenson, 1955
Plate 16, Figure A

Borissiakoceras orbiculatum Stephenson; Cobban, 1961, p. 750, pl. 88, figs. 15–44, text-fig. 5a–f.
Borissiakoceras orbiculatum Stephenson; Kennedy, 1988, p. 18, pl. 1, figs. 23–26.

Diagnosis — Species with smooth ventrolateral shoulders and weak flacoid ribs.

Discussion — The one positively identified specimen (Plate 16, fig. A) is a distorted specimen from a concretion. Other specimens from the shales may have been interpreted as being immature specimens of taxa such as *Metoicoceras*.

Occurrence — At Black Mesa, very rare in BM8 through BM10 in the *Euomphaloceras septemseriatum* Subzone of *Sciponoceras gracile* Zone (Plate 51, 52). Elsewhere middle to late Cenomanian, *Cunningtoniceras amphibolum* Zone through *Sciponoceras gracile* Zone, Wyoming, Montana, Colorado, Kansas, and Texas.

Illustrated material — MNA N4929 from MNA loc. #262, concretion between BM8 and BM10, lower part, lower shale member, Mancos Shale.

Superfamily Desmocerataceae Zittel, 1895
Family Desmoceratidae Zittel, 1895
Genus *Moremanoceras* Cobban, 1971

Type species — *Tragodesmoceras scotti* Moreman, 1942.
Diagnosis — Medium-sized ammonite, moderate to very involute, and depressed rounded to subquadrate whorl section, smoothly rounded venter, with straight to sigmoidal constrictions, forming strong narrow ribs. Numerous thin intermediate ribs may occur on venter. Lacks constrictions on ribbed middle whorls, suture with short lobes, broad L lobe, and 3–4 auxiliary lobes.
Discussion These ammonites were separated from *Desmoceras* chiefly on differences in the suture (Cobban, 1972; Cobban and others, 1989).
Occurrence — Middle to late Cenomanian of Wyoming, Colorado, Texas, Arizona, and New Mexico.
Paleoecology — Species of this genus are placed in Batt's (1987) morphotypes; IDQF, 32 and ICQF, 33, and as determined by their jaw structure may have been predatory ammonites (Tanabe, 1983), that could tolerate deep water settings, but because of their thick-walled siphuncle were subject to post mortem transport in much shallower settings. They entered the seaway during transgression and left the seaway during the Late Cenomanian *Sciponoceras gracile* Zone.

***Desmoceras (Moremanoceras) scotti* (Moreman, 1942)**
Plate 10, Figure B

Tragodesmoceras scotti Moreman, 1942, p. 208, pl. 15, fig. 4.
Onitshoceras? scotti (Moreman); Matsumoto, 1960, p. 46, text-fig. 10a–c.
Desmoceras (Moremanoceras) scotti (Moreman); Cobban, 1971, p. 6, pl. 2, figs. 1–23, text-fig. 3–5.
Desmoceras (Moremanoceras) scotti (Moreman); Kennedy, 1988, pl. 1, figs. 1–13.
Moremanoceras scotti (Moreman); Cobban, Hook, and Kennedy, 1989, p. 18, figs. 18, 64 L–Z.

Description — Specimens partially crushed showing form and ornament of species, suture not visible.
Occurrence — Late Cenomanian, *Sciponoceras gracile* Zone, Texas, Wyoming, Colorado, New Mexico, and Arizona. All specimens collected by author from in or just below BM4 in the *Vascoceras diartianum* Subzone, northeastern Black Mesa at MNA loc. #296, #989, #990, #992. Cobban (1971) described a specimen found in a concretion with taxa indicating the *Sciponoceras gracile* Zone from northwestern Black Mesa.
Illustrated material — MNA N4942 from MNA loc #990, BM4, lower part, lower shale member, Mancos Shale.

Family Muniericeratidae Wright, 1952
Genus *Tragodesmoceras* Spath, 1922

Type species — *Desmoceras clypealoides* Leonhard, 1897.
Diagnosis — Medium to large compressed, moderately involute ammonites; numerous sigmoidal non-tuberculate ribs which arch forward over the narrow fastigate venter where ribs may rise into tubercles. Ribs originate near umbilical seam. Every eight to ten ribs strong and corresponding to an internal constriction. Ornament weakens on large adults. Suture complex.
Discussion — The material collected from Black Mesa consists of crushed shale specimens that can only be identified in early to middle growth stages on the basis of relative rib density. Large adult specimens for the most part cannot be identified to species except where associated with less mature specimens.
Occurrence — Fairly common in the lower Turonian (*Mammites nodosoides* Zone) through middle Turonian (*Collignoniceras woollgari* Zone) in the southern Western Interior. Rare in the lower Turonian through Coniacian (Santonian?) of Europe.
Paleoecology — Batt (1987) places species of this genus into his morphotype ECCr(v), 38 as juveniles, and ECCs(v), 39 as adults. They range from nearshore to offshore pelagic facies and may have been active predators, based on jaw structure. While widespread during the lower and middle Turonian, they are not very common.

***Tragodesmoceras bassi* Morrow, 1935**
Plate 34, Figure E

Tragodesmoceras bassi Morrow, 1935; p. 468, pl. 52, figs. 1a–c; pl. 53, figs. 3–5; text-figs. 1, 3.
Tragodesmoceras bassi Morrow; Cobban and Scott, 1972; p. 58, pl. 38, figs. 2, 3, 5–13; pl. 39.
Tragodesmoceras bassi Morrow; Hattin, 1975a; p. 43, pl. 6, fig. H, pl. 9, figs. A–C, E, non pl. 10, fig. E, H.

Diagnosis — A large species of *Tragodesmoceras* reaching more than 30 cm in diameter. Flanks flattened with about every third rib thickened and reaching the umbilicus. Adult whorls smooth.
Discussion — *Tragodesmoceras bassi* is distinguished from *Tragodesmoceras carlilense* Cobban (1971) primarily by its larger size and less dense ribbing. It differs from *Tragodesmoceras socorroense* in its somewhat smaller adult size, narrow whorls, and less dense ribbing.
Occurrence — At Black Mesa restricted to the *Mammites nodosoides* Zone (Kirkland, 1990); elsewhere present in this zone in Colorado, Kansas, and Nebraska. It is apparently most common along the eastern side of the seaway.
Illustrated material — MNA N4879 from MNA loc. #989, above BM26, middle part, lower shale member, Mancos Shàle.

***Tragodesmoceras socorroense* Cobban and Hook, 1979**
Plate 38, Figures A, B

? *Tragodesmoceras bassi* Morrow; Hattin, 1975a; pl. 10, figs. E, H.
Tragodesmoceras socorroense Cobban and Hook, 1979; p. 13, pl. 5, figs. 9, 10; pls. 6, 7; pl. 11, fig. 10, text-fig. 4.
Tragodesmoceras socorroense Cobban and Hook; Cobban and Hook, 1983; p. 7, pl. 2, figs. 10–14.
Tragodesmoceras socorroense Cobban and Hook; Cobban and Hook, 1989; p. 252, pl. 7, figs C, D.

Diagnosis — A very large species reaching more than 50 cm in diameter. Whorl section triangular, thickest at umbilical shoulder with every fourth or fifth rib thickened and extends to umbilicus, ribbing persists to last whorl.
Discussion — *Tragodesmoceras socorroense* differs from the younger *Tragodesmoceras carlilense* Cobban (1971) in its stronger ribbing retained in the adult, large size, and inflated whorls with strongly arched venter. It differs from the older *Tragodesmoceras bassi* in its denser ribbing, larger adult size with ribbing extending onto the body chamber.

Compacted specimens from Black Mesa are most readily distinguished by their dense ribbing. Rare, poorly preserved, very large specimens of *Tragodesmoceras* from the septarian concretion horizon BM33 likely represent *Tragodesmoceras bassi*.
Occurrence — At Black Mesa, uncommonly encountered from about BM33, highest lower Turonian *Mammites*

nodosoides Zone to about BM66, middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1991). Elsewhere known from this level in New Mexico and Wyoming.

Illustrated material — MNA N4862 from 4 m below BM67, MNA N4863 from 5 m below BM67, both from MNA loc. #989, middle shale member, Mancos Shale.

Superfamily Hoplitaceae Douville, 1890
Family Placenticeratidae Hyatt, 1900
Genus *Placenticeras* Hyatt, 1900

Type species — *Ammonites placenta* DeKay, 1828.

Diagnosis — Moderate to large, compressed ammonites. Inner whorls involute, with some species becoming evolute and inflated with strong ornament. Strongly dimorphic with microconchs more inflated with stronger ornament. With increased size umbilical tubercles migrate to mid-lateral and mid-lateral to inner ventrolateral positions. Outer ventrolateral tubercles alternating on each side of tabulate venter which becomes rounded on large specimens. Range from smooth, involute disks with narrow tabulate venters to strongly ornamented (strong ribs and tubercles), evolute, quadrate forms. Suture highly subdivided into adventive and auxiliary elements, simple or highly frilled.

Discussion — Kennedy and Wright (1983) have recently demonstrated that *Placenticeras* displays great variability and is dimorphic, thus a great many more species have been erected than is warranted. They also conclude that *Proplacenticeras* is a synonym of *Placenticeras*. This genus had previously included Cenomanian through Coniacian placenticeratids with simple sutures.

Occurrence — Upper Cenomanian through Maestrichtian, worldwide.

Paleoecology — Batt (1987) assigns species of this genus to morphotype; ICCs(v) and has shown that the presence of this genus is indicative of shallow marine facies.

Specimens at Black Mesa have a disjunct distribution and reflect the shallow water distribution recorded by Batt (1986). They have not been found in nearshore sandstones except for the occurrences in the Blue Point Tongue. This may indicate that this genus, while preferring nearshore environments, did not live in environments proximal to shoreline and may reflect a more offshore environment for deposition of the Blue Point Tongue.

Occurrence — At Black Mesa, Upper Cenomanian *Vascoceras diartianum* subzone of *Sciponoceras gracile* Zone (BM4) in northeastern Black Mesa (MNA loc. #296), upper *Euomphaloceras septemseriatum* subzone of *Sciponoceras gracile* Zone (only common in BM10, western Coal Mine Mesa, MNA loc. #814) in southwestern Black Mesa; throughout Black Mesa from BM36 upward into the Hopi Sandy Member in the middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone, *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone in southwestern Black Mesa (Kirkland, 1991). Also in the Late Cenomanian *Sciponoceras gracile* Zone of northeast Texas and southern Utah, Lower Turonian *Mammites nodosoides* Zone in New Mexico, Middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone in New Mexico, *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone in Minnesota, *Prionocyclus hyatti* Zone in Colorado and Kansas.

Illustrated material — MNA N4935 from MNA loc. #296, BM4, lower part, lower shale member, Mancos Shale; MNA N4836, 5 m below BM70, MNA N4831, N4832, N4833, concretions one meter below BM70, from MNA loc. #262, near top of middle shale member, Mancos Shale; MNA N3553 from MNA #1150, top of Blue Point Sandstone Tongue, Toreva Formation.

Placenticeras cumminsi Cragin, 1893
Plate 10, Figure A; Plate 16, Figures B, C;
Plate 38, Figures C–E, H; Plate 47, Figures A, C

Placenticeras pseudoplacenta Hyatt; 1903, p. 216, in part, pl. 43, figs. 3–11, non pl. 44.
Proplacenticeras pseudoplacenta (Hyatt); Hattin, 1962, p. 79, pl. 22, figs, F, G.
Proplacenticeras pseudoplacenta (Hyatt); Cobban and Hook, 1979, p. 14, pl. 8, figs. 1–5.
Placenticeras cumminsi Cragin; Cobban and Hook, 1983, p. 8, pl. 3, figs. 12–18, pl. 5, figs. 4–5.
Placenticeras cumminsi Cragin; Kennedy, 1988, p. 26–30. pl. 1, figs. 29–36, pl. 3, figs. 10–15, text-figs. 9, 10a, c, g, 11c, 12–19.

Diagnosis — A moderate sized (largest specimens indicate adults more than 20 cm in diameter), compressed placenticeratid with flacoid ribs, normally weak tubercles, and smooth body chamber.

Discussion — *Placenticeras cumminsi* is widespread at Black Mesa. It commonly is found as reasonably complete molds of body chambers in concretionary marker bed BM10 in the western Coal Mine Mesa area. In shales near the base of the lower shale member, throughout the middle shale member and Hopi Sandy Member they occur as crushed specimens. Well preserved specimens are found in concretions near the top of the middle shale member and in the top of the top of the Blue Point Tongue of the Toreva Formation at Blue Point.

Superfamily Acanthocerataceae Grossouvre, 1894
Family Acanthoceratidae Grossouvre, 1894
Subfamily Mantelliceratinae Hyatt, 1903
Genus *Eucalycoceras* Spath, 1923

Type species — *Acanthoceras pentagonum* Jukes-Browne, 1896.

Diagnosis — Medium-sized, involute, high-whorled, ammonites; flattened flanks and a broad venter; dense, flat, ribbing, with umbilical, lower and upper ventrolateral and siphonal tubercles.

Discussion — Cobban (1988c) has found two species (including the type species) in the late Cenomanian in the United States. In the literature, species of *Pseudocalycoceras* from the Western Interior have often been referred to as *Eucalycoceras*, otherwise species of this genus had not been described from the Western Interior prior to Cobban's (1988c) report.

Occurrence — Middle to late Cenomanian of Europe, Africa, Madagascar, India, and North America.

Paleoecology — Batt (1986) assigned ammonites of this type to morphotype ECCf, 35 and ECCrn and indicates they are largely restricted to proximal to medial offshore shale.

Eucalycoceras pentagonum (Jukes-Browne)
Plate 10, Figures G–K, N

Eucalycoceras pentagonum (Jukes-Browne); Spath, p. 144.
Eucalycoceras pentagonum (Jukes-Browne); Kennedy, 1971; p. 81, pl. 48, figs. 1–6; pl. 49, figs. 1a–c.
Eucalycoceras pentagonum (Jukes-Browne); Cobban, 1988c, p. 9, pl. 3, text figs. 6, 7.
Eucalycoceras pentagonum (Jukes-Browne); Cobban, Hook, and Kennedy, 1989, p. 27, figs. 28, 73A–D.

Description — Ammonites assigned to this species consist of medium to small (30–45 mm in diameter) crushed shells displaying dense flattened ribs wider or equal to interspaces. Nearly every rib arises from umbilical bullae and bears weak nodate inner ventrolateral tubercles and stronger outer ventrolateral clavae. The venter where visible (Plate 10, fig. G) bounded by clavate outer ventrolateral tubercles connected by broad ribs bearing weak siphonal clavae.

Discussion — The specimens from Black Mesa appear to be similar to *Eucalycoceras pentagonum* (Jukes-Browne) in the form of the ribs and *Eucalycoceras rowei* (Spath) in the pattern of ribbing and tuberculation (Kennedy, 1971). The form of the ribs of these specimens may be affected by compaction, but Cobban (1988c) illustrates specimens that appear very close to those from Black Mesa.

Occurrence — The type specimen is from the late Cenomanian of souther England. In the United States, from the *Metoicoceras mosbyensis* Zone in southwestern New Mexico, basal *Sciponoceras gracile* Zone in southeastern Colorado and the Black Hills region. At Black Mesa, this species is restricted to the *Vascoceras diartianum* subzone of the *Sciponoceras gracile* Zone in northeastern Black Mesa, mostly within and just below BM4 (MNA loc. #296, #989, #990, #992.

Illustrated material — MNA N4936 from MNA loc. #296, BM4, lower part, lower shale member, Mancos Shale; MNA N4948, N4949, N4950, N4952, from MNA loc. #992, below BM4, lower part, lower shale member, Mancos Shale.

Genus *Calycoceras* Hyatt, 1900

Type species. *Ammonites navicularis* Mantell, 1822.

Diagnosis — Medium to large, moderately evolute ammonites; rounded-depressed whorl section; strong ribs alternating long and short often alternating from umbilical shoulder on one side to mid-flank on other side; umbilical-lateral, lower and upper ventrolateral, and siphonal tubercles, which may disappear with increasing diameter.

Occurrence — Middle Cenomanian to Turonian, worldwide.

Paleoecology — Batt (1986) places Western Interior species in morphotypes; EDQr, 9 and ECQr, 10. This nekto-benthonic ammonite morphotype was found to be restricted to range from nearshore sandstones to offshore carbonates, indicating a deeper water tolerance than many large ornate ammonites. It is considered a warm temperate ammonite.

Calycoceras obrieni Young, 1957

Plate 9, Figures A, B

Calycoceras obrieni Young, 1957, p. 1171, pl. 150, figs 1–4, text-fig. 1f, h.
Calycoceras obrieni Young; Cobban and Kennedy, 1990, p. C3, pls. 1–5.

Diagnosis — Large calycoceratid retaining tubercles to adult size (as much as 35 cm).

Discussion — This species was originally described from the Twowells Sandstone Tongue of the Dakota Sandstone of east-central Arizona, then referred to the Mesaverde Formation (Young, 1957). Kennedy (1971) synonymized this species with *Calycoceras naviculare.* However, Cobban (1984) continues to retain this species name for this form. Personal observations of Western Interior material also indicate that this species differs in both morphology and stratigraphic distribution. Subsequently, Kennedy (1988) accepted its separation as a distinct species and has recently co-authored a paper with Cobban redescribing the material from the type area (Cobban and Kennedy, 1990).

Material from Black Mesa consists of sandstone casts of large individuals with particularly strong outer ventrolateral tubercles on the phragmocone.

Occurrence — Restricted to the late Cenomanian *Metoicoceras mosbyense* Zone of Wyoming, Utah, Arizona, and New Mexico. At Black Mesa from the upper sandstone member of the Dakota Formation in southwestern Black Mesa at Coal Mine Mesa (MNA loc. #265).

Illustrated material — MNA N3539 from MNA loc. #265, lower half, sandstone facies, upper sandstone member, Dakota Formation.

Calycoceras naviculare (Mantell, 1822)

Plate 10, Figures L, M

Calycoceras (*Metacalycoceras*) *auspicium* Anderson, 1958, p. 243, pl. 20, fig. 8.
Mantelliceras oregonense Anderson, 1958, p. 244, pl. 8, figs. 4, 4a, pl. 14, figs. 1, 1a.
Calycoceras naviculare (Mantell); Kennedy, 1971, p. 71, pl. 33, figs, 1a–b, pl. 34, 1a–b, pl. 35, figs. 1–2, pl, 36, figs, 1–2, pl. 37, figs. 1–3, pl. 47, figs. 1, 3, 5.
Calycoceras naviculare (Mantell); Cobban, 1971, p. 13, pl. 1, figs. pl. 10, figs. 1–8, pl. 11, figs. 1–2, pl. 12, figs. 1–2, pl. 13, figs.1–5, pl. 14, figs. 1–3, pl. 15, figs. 1–2, pl. 16, figs. 1–2, pl. 17, text-figs, 12–14.
Calycoceras sp. cf. *C. naviculare* (Mantell); Cobban and Scott, 1972, p. 60, pl. 21, figs. 1, 3, 4.
Calycoceras sp. cf. *C. naviculare* (Mantell); Hattin, 1975, 32, pl. 6L.
Calycoceras (*Calycoceras*) *naviculare* (Mantell); Kennedy, Juignet, and Hancock, 1981, p. 40, pls. 4–6, pl. 7, figs. 1–3, pl. 15, figs. 4–6, pl. 17, fig. 4, text-figs. 8, 9, 10c, 11a–c.
Calycoceras (*Calycoceras*) *naviculare* (Mantell); Wright and Kennedy, 1981, p. 34–36, pl. 4, pl. 5, figs. 1–3, text-figs. 13, 14c–e, (with synonymy).
Calycoceras (*Calycoceras*) *naviculare* (Mantell); Cobban, Hook, and Kennedy, 1989, p. 24, fig. 70A–T.

Diagnosis — Large calycoceratid (as much as 40 cm in diameter) that loses tubercles early in ontogeny.

Discussion — Material collected during this study consisted of crushed shale specimens associated with marker bed BM4 at northeastern Black Mesa. Cobban (1975) reported on an uncrushed specimen from a concretion in the *Sciponoceras gracile* Zone from Black Mountain on the east side of Black Mesa.

Calycoceras naviculare ranges into the central part of the seaway, lending further support to the *Sciponoceras gracile* Zone interval as representing a period of improved bottom conditions.

Occurrence — Within the Western Interior *Calycoceras naviculare* ranges throughout the late Cenomanian *Sciponoceras gracile* Zone, however it is most abundant in the *Vascoceras diartianum* subzone in western Kansas, Colorado, New Mexico, Utah, Arizona, and rarely in Texas. At Black Mesa, in the *Vascoceras diartianum* subzone of the *Sciponoceras gracile* Zone associated with BM4 at MNA loc. #236, #296, #989, #990 and #992 and in the *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone at MNA loc. #254. Also known from California, Europe, North Africa, West Africa, Madagascar, the Middle East, India, and Japan.

Illustrated material — MNA N4937, N4938 from MNA loc. #990, BM4, lower part, lower shale member, Mancos Shale.

Subfamily Acanthoceratinae Grossouvre, 1894

Genus *Cunningtoniceras* Collignon, 1937

Type species — *Cunningtoniceras cunningtoni* (Sharp, 1855).

Diagnosis — Large, moderately evolute acanthoceratid, with quadrate to rectangular whorl section; umbilical bullae joined to inner ventrolateral tubercles or later growth ventrolateral horns; additional ribs and/or tubercles (siphonal and/or outer ventrolateral) on venter during early to middle growth, lost at larger diameters, where opposite ventrolateral horns may be connected by weak looped ribs.

Discussion — *Cunningtoniceras* has long been considered a junior synonym of *Euomphaloceras* (ie. Wright, 1957; Kennedy, 1971; Cobban and Scott, 1972), but recently this separation has been accepted (Kirkland and Cobban, 1986; Cobban, 1987), as *Euomphaloceras* is a medium sized, spinose ammonite, not closely related to *Cunningtoniceras* (Wright and Kennedy, in press). *Cunningtoniceras* is closest to *Acanthoceras* from which it differs in the multiplication of ventral ornament. In addition, Cobban (1987) has included the well known middle Cenomanian ammonite *Acanthoceras amphibolum* Morrow in *Cunningtoniceras*.

Occurrence — Worldwide during the middle Cenomanian, only known from the southern Western Interior of Arizona and New Mexico during the upper Cenomanian *Metoicoceras mosbyense* Zone.

Paleoecology — Batt (1987) included forms of this genus in his morphotype ECQ(R)N, 3, which are interpreted as being nekto-benthonic taxa restricted to shallow water settings.

Cunningtoniceras novimexicanum Cobban, Hook, and Kennedy, 1989

Plate 9, Figures C, D

Cunningtoniceras novimexicanum Cobban, Hook, and Kennedy, 1989; p. 22, figs. 24, 68, I–K.

Diagnosis — Poorly preserved sandstone cast of a medium sized acanthoceratid, evolute with somewhat compressed, rectangular whorl section; evenly spaced ribs bearing worn tubercles, additional siphonal tubercles present.

Discussion — *Cunningtoniceras arizonense* was described from east-central Arizona in the Twowells Sandstone Tongue of the Dakota Formation (*Metoicoceras mosbyense* Zone) and is characterized by having a peak in rib density at diameters of from 9 to 12 centimeters with loss of the intercalated ventral ornament (Kirkland and Cobban, 1986). *Cunningtoniceras novimexacanum* differs in having rather sparsely ribbed whorls, at a comparable diameter. The specimen is not well enough preserved to compare against older middle Cenomanian species.

Occurrence — One specimen from the sandstone facies of the upper sandstone member of the Dakota Formation (late Cenomanian, *Metoicoceras mosbyense* Zone) in northwestern Black Mesa at Coal Chute (MNA loc. #963). Elsewhere, only known from the type area of southwestern New Mexico.

Illustrated material — MNA N3542 from MNA loc. #963, sandstone facies, upper sandstone member, Dakota Formation.

Genus *Pseudocalycoceras* Thomel, 1969

Type species — *Ammonites harpax* Stoliczka, 1864.

Diagnosis — Medium sized ammonites, with slightly compressed to depressed whorl section, ribs rursiradiate, flexuous to convex, branching from umbilical bullae or alternating long and short, venter with inner and outer ventrolateral and siphonal clavate tubercles, which disappear with approximation of ribs toward aperture.

Occurrence — Upper Cenomanian of Europe, Middle East, Madagascar, Angola, India, Texas, and Western Interior United States. At Black Mesa this genus found throughout *Sciponoceras gracile* Zone.

Paleoecology — Batt (1987) assigned this genus to morphotype ECCrn, 34. He found that these forms were found toward the margins of the seaway during early transgression and are found in the pelagic carbonates during sealevel high-stand. These forms were interpreted as being pelagic, inhabiting middle water depths.

Pseudocalycoceras angolaense (Spath, 1931)

Plate 10, Figures C–E; Plate 16, Figures F–H, K

Eucalycoceras dentonense Moreman, 1942, p. 205, pl. 33, figs. 4–5, text-fig. 2k.
Eucalycoceras indianense Moreman, 1942, p. 206, pl. 33, figs. 9–10, text-fig. 2ll.
Eucalycoceras lewisvillense Moreman, 1942, 206, pl. 33, figs. 6–7, text-fig. 2n, u.
Pseudocalycoceras dentonense (Moreman); Cobban and Scott, 1972, p. 63, pl. 13, figs. 11–29, pl. 15, figs. 1–7, 10–13.
Pseudocalycoceras dentonense (Moreman); Hattin, 1975, p. 32, pl. 6, figs F, G.
Pseudocalycoceras angolaense (Spath); Cooper, 1978, p. 96, text-figs, 4A–C, H–K, 6I–J, 10F–G, 14A, 18E–F, 19A, 23–25, 26F–K, (with synonymy).
Pseudocalycoceras dentonense (Moreman); Wright and Kennedy, 1981, p. 37, pl. 5, fig. 4, pl. 6, figs. 3, 6, 7, text-figs, 15A–B, E–H, 19S–T, (with synonymy).
Pseudocalycoceras angolaense (Spath); Kennedy, 1988, p. 42, pl. 4, figs. 1–2, 6–9, 11–12, pl. 5, figs. 1–12, pl. 8, figs. 7–8, pl. 22, figs. 8–9, text-figs, 10H, 11B, E, (with additional synonymy).
Pseudocalycoceras angolaense (Spath); Cobban, 1988c, p. 12, pl. 5, pl. 6, figs. 1, 2, 13, 14, 18, 19, text-fig. 10.
Pseudocalycoceras angolaense (Spath); Cobban, Hook, and Kennedy, 1989, p. 29, figs. 29, 73E–O, 74A–G.

Diagnosis — A species of *Pseudocalycoceras* with a well rounded venter and inner and outer ventrolateral tubercles closer together than outer ventrolateral and siphonal tubercles.

Discussion — *Pseudocalycoceras angolaense* is a very variable as well as dimorphic species. Whereas specimens identified as this species occur widely in the *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone, crushed shale specimens from the *Vascoceras diartianum* subzone can only be questionably referred to this species.

Occurrence — Late Cenomanian *Sciponoceras gracile* Zone in Colorado, Kansas, Utah, New Mexico, Arizona, and Texas, as well as Europe, West Africa, and Japan. At Black Mesa, well preserved material is found at all sites in concretionary marker beds BM8 and BM10 in the *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone, with crushed questionable material associated with marker bed BM4 in the *Vascoceras diartianum* subzone (Kirkland, 1990).

Illustrated material — MNA N4939 from MNA loc. #990, BM4; MNA N4955, from MNA loc. #992, below BM4; MNA N4916 from MNA loc. #306, BM10; MNA N4926 from MNA loc. #989, BM8; all specimens from lower part, lower shale member, Mancos Shale.

Genus *Sumitomoceras* Matsumoto, 1969

Type species — *Sumitomoceras faustum* Matsumoto and Muramoto, 1969.

Diagnosis — Moderately small, evolute ammonites with dense to distant rectiradiate, branching to alternating long and short ribs which in juvenile specimens cross the flattened venter transversely with umbilical bullae, inner and outer ventrolateral, and siphonal tubercles; adults lose ventral tubercles and venter of last whorl is broadly arched with constrictions occasionally bounding longer ribs.

Discussion — Wright and Kennedy (1981) had retained *Sumitomoceras* as a subgenus of *Tarrantoceras* for though it does not differ greatly, the differences together with a distinct stratigraphic range justify its retention as a subgenus as opposed to the view of Cooper (1978), who synonymized the genera. Subsiguently separation as a distinct genus has been accepted (Cobban, 1988c; Cobban and others, 1989).

Occurrence — Late Cenomanian *Sciponoceras gracile* Zone in the southern Western Interior of Colorado, New Mexico, Arizona, and Texas, also in eastern Europe, and Japan.

Paleoecology — Batt (1987) places this form into morphotype ECCr, 34 and found these forms not to be controlled by water depth and concludes that these types were pelagic, inhabiting middle water depths. This subgenus is restricted to the southern part of the seaway, so it may represent a warm temperate to subtropical group.

Sumitomoceras conlini Wright and Kennedy, 1981

Plate 16, Figures D, E

Tarrantoceras (*Sumitomoceras*) *conlini* Wright and Kennedy, 1981, p. 39, text-fig. 10B.
Tarrantoceras (*Sumitomoceras*) *conlini* Wright and Kennedy; Kennedy, 1988, p. 44, pl. 6, figs. 1–5, 8–13, 16–17, text-fig. 16A.
Sumitomoceras conlini Wright and Kennedy; Cobban, 1988c, p. 14, pl. 7, figs. 1–15, 26–28, text-fig. 11.
Sumitomoceras conlini Wright and Kennedy; Cobban, Hook, and Kennedy, 1989, p. 30, figs. 31, 72A–J.

Diagnosis — A relatively high-whorled, densely ribbed species.

Discussion — The one small whorl fragment from Black Mesa compares well with those described from central Texas by Kennedy (1988).

Occurrence — Very rare in the late Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone at Black Mesa, with one fragment from a chalky concretion (unit 17) from between concretionary marker beds BM8 and BM10 in the southwest at Blue Point (MNA loc. #262). Elsewhere restricted to the late Cenomanian *Sciponoceras gracile* Zone of southern Colorado, New Mexico, and Texas.

Illustrated material — MNA N1156 from MNA loc. #262, unit 17, lower part, lower shale member, Mancos Shale.

Genus *Alzadites* Kennedy and Cobban, 1990

Type species — *Alzadites alzadensis* Kennedy and Cobban, 1990.

Diagnosis — Micromorphic taxon, adult at 16.5 mm or less, with compressed whorls; on phragmocone distant ribs arise from tiny umbilical bullae extend to stong outer ventrolateral tubercles and outer ventrolateral and siphonal clavae; on body chamber tubercles weaken and ventral ribbing strengthens; constictions internal molds; simple little incised elements.

Discussion — Kennedy and Cobban (1990) have published a detailed review of the small ammonites from the Cenomanian of the Western Interior, where they described the juveniles of many groups and distinguished many micromorph taxa. A review of this paper indicates that several micromorph taxa were grouped together with juvenile ammonites of other taxa (Kirkland, 1990). The most obvious example of this is a species of *Alzadites*.

Occurrence — Known only from the late-middle to lower-upper Cenomanian of Wyoming and Montana and the late Cenomanian *Sciponoceras gracile* Zone of Utah and Arizona.

Alzadites incomptus Kennedy and Cobban, 1990

Alzadites incomptus Kennedy and Cobban, 1990; p. 399, pl. 4, figs. 40–42, 46–48, pl. 6, figs. 1–22.

Diagnosis — Very small (to 12 mm); phragmocone variably smooth to strongly ribbed often with constrictions in interspaces; ornament weakens on body chamber with delicate prorsiradiate ribs and often constrictions.

Discussion — There are a number of specimens of this taxon in the collections from Black Mesa, that are catalogued as juvenile specimens of *Metoicoceras geslinianum*.

Occurrence — At Black Mesa, uncommon in concretionary marker beds BM8 and BM10 in the *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone, also know from this level at the type locality in Kane County, southern Utah.

Genus *Neocardioceras* Spath, 1926

Type species — *Neocardioceras juddii* (Barrois and Guerne, 1878).

Diagnosis — Small, moderately evolute ammonite, with inflated to compressed whorls; ribs fine to coarse, arising single or branching from umbilical bullae with generally weak inner ventrolateral tubercles, which bend forward to oblique, clavate outer ventrolateral tubercles where ribs weaken and angle strongly forward rising to siphonal clavae forming a crenulate keel.

Occurrence — Late Cenomanian of the Western Interior and restricted to the *Neocardioceras juddii* Zone of Europe.

Paleoecology — Batt (1987) assigned this group to his morphotype ECCf(sk), 37 and found their distribution not to be restricted by water depth and considered these forms to be pelagic.

Neocardioceras juddii (Barrois and Guerne, 1878)

Plate 25, Figures M, N, Q, R

Neocardioceras juddii (Barrois and Guerne); Hook and Cobban, 1981, p. 9, pl. 1, figs. 6–8.
Neocardioceras juddii juddii (Barrois and Guerne); Wright and Kennedy, 1981, p. 50, pl. 9, figs. 1–3, 5–11, text-figs. 17, 1–2, 19H–I, (with synonymy).
Neocardioceras juddii juddii (Barrois and Guerne); Cobban, 1988c, p.17, pl. 8, text-fig. 14.
Neocardioceras juddii juddii (Barrois and Guerne); Cobban, Hook, and Kennedy, 1989, p. 31, figs. 33, 75F–DD, II–MM.

Diagnosis — A variable species of *Neocardioceras* with compressd forms with fine, sharp ribs and small sharp tubercles and more robust forms with fewer ribs and blunter tubercles.

Discussion — Most specimens from Black Mesa consist of crushed shale specimens. Uncrushed material has been recovered from concretions in the *Neocardioceras juddii* Zone in the area of southwestern Black Mesa.

Occurrence.— At Black Mesa, throughout the *Neocardioceras juddii* Zone, with great numbers found associated with the marker beds; BM12 and BM13 in the *Neocardioceras juddii* subzone (2 m below BM12 to just below or at the Cenomanian-Turonian boundary between BM13 and BM15 (Kirkland, 1990). Elsewhere it is restricted to the latest

Cenomanian *Neocardioceras juddii* Zone throughout the Western Interior and Europe.

Illustrated material — MNA N238, N4964, N4965 from MNA loc. #305, concretions associated with BM12 and BM13; MNA N4958 from MNA loc. #989, below BM12; all from lower part, lower shale member, Mancos Shale.

Neocardioceras minutum Cobban, 1988c

Plate 10, Figures F, O (b)

Tarrantoceras? sp. Cobban and Scott, 1972; p. 17.
Neocardioceras spp. Cobban, 1984b; p. 19, pl. 4, figs. 3, 5.
Neocardioceras minutum Cobban, 1988c; p.23, pl. 10, figs. 1–35, text-fig. 20.

Diagnosis — Small, crushed specimens of *Neocardioceras* with sharp ribs and strong fine tubercles.

Discussion — Cobban (1988c) described *Neocardioceras minutum* from strata correlative to the Hartland Shale Member of the Greenhorn Limestone (*Metoicoceras mosbyensis* Zone) in Wyoming. Material associated with marker bed BM4 in the area of northeastern Black Mesa compares well with *Neocardioceras minutum* and extends its stratigraphic range up into the basal *Sciponoceras gracile* Zone.

Occurrence — At Black Mesa restricted to shale in and just below BM4 in the late Cenomanian *Vascoceras diartianum* subzone of the *Sciponoceras gracile* Zone in northeastern Arizona (MNA loc. #296, #989, #990) and reported in Wyoming, Kansas, Colorado, and Oklahoma.

Illustrated material — MNA N4941, N4945 from MNA loc. #990, BM4, lower part, lower shale member, Mancos Shale.

Neocardioceras ? n. sp.

Plate 24, Figures C, D

Ammonite, gen. nov.? Cobban, Hook, and Kennedy, 1989, p. 33, fig. 76F–K.

Description — One well preserved three dimensional specimen; diameter 1.35 cm, umbilical ratio 30 %, and whorl width to height ratio of 14 %; whorl with carinate venter, flattened flanks, and narrow rounded umblical shoulder, approximately 40 fine prosiradiate ribs; ribs begin at umbilical shoulder, cross flank and bend forward at position of inner ventrolateral tubercles to keel; weak bullate umbillical tubercles variably present; all ribs bear weak inner and outer ventrolateral bullae, bullate to nodose siphonal tubercles form distinct keel.

Discussion — Cobban and others' (1989, fig. 56F–I) illustration of USNM 425212 compares closely with the specimen described from Black Mesa. It differs in having a smaller umbilical ratio (20 %) and although described as lacking umbilical bullae, weak umbilical bullae appear to be prest on som ribs. This specimen was questionably described as possibly representing a new undescribed genus related to *Neocardioceras*. The larger specimen assigned to this undescribed species (USNM 425213) was found at a different locality and may not belong to this species although it has similar fine ribs. The larger specimen does differ profoundly from *Neocardioceras* in having a broad, smooth, tricarinate venter. The specimen from Black Mesa is included provisionably in *Neocardioceras*.

Occurrence — Cobban and others' (1989) specimen was collected from the latest Cenomanian, *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone, Little Burro Mountains, southwestern New Mexico. The Black Mesa specimen is from concretionary marker bed BM11, latest Cenomanian *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone at MNA loc. #814, extreme western Coal Mine Mesa, southwestern Black Mesa.

Illustrated material — MNA N3498 from MNA loc. #814, BM11, lower part, lower shale member, Mancos Shale.

Genus *Quitmaniceras* Powell, 1963

Type species — *Quitmaniceras reaseri* Powell, 1963.

Diagnosis — Small, highly variable, moderately involute ammonites, that are nearly smooth to strongly ribbed, with variably developed umbilical, inner and outer ventrolateral tubercles and siphonal clavae or entire keel.

Discussion — Powell (1963) described *Quitmaniceras reaseri* and *Quitmaniceras brandi* from the lower Turonian of west Texas. Collection of more than 100 specimens of the genus from the type locality by Kennedy, Wright, and Hancock (1987) revealed that these two species represent variants of one highly variable species. Specimens range from weakly ornate oxycones to coarsely ornate forms with tabulate venters.

Occurrence — Lower Turonian *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone of Montana, Wyoming, Colorado, New Mexico, Arizona, and northern Mexico.

Paleoecology — Batt (1987) assigned taxa with these morphologies to his morphotypes; ECCrn, 34 to ECCs(v), 39, their distribution indicates that they may have been pelagic.

Quitmaniceras sp. cf. *Q. reaseri* Powell, 1963

Plate 32, Figures D, E, G

Quitmaniceras reaseri Powell, 1963, p. 313, pl. 32, figs. 5, 13, text-figs. 3h, j.
Quitmaniceras brandi Powell, 1963, p. 314, pl. 32, figs, 6, 8, 11–12, 14–16, text-figs. 3i,, p, q.
Quitmaniceras reaseri Powell; Kennedy, Wright, and Hancock, 1987, p. 30, pl 1, figs. 1–38, text-figs. 2A–C, (with synonymy).
Quitmaniceras reaseri Powell; Cobban, Hook, and Kennedy, 1989, p. 34, fig. 75EE–HH.

Diagnosis — As for genus.

Description — All specimens from Black Mesa consist of crushed shale specimens, of which the most distinctive are the weakly ornate forms. These specimens most likely conspecific with the one and only named species, but do to the nature of the preservation this is not certain.

Occurrence — As for genus. At Black Mesa ranges from just below BM15 to BM16 (Kirkland, 1990).

Illustrated material — MNA N4975, N5460, from MNA loc. #262, 2 m above BM15; MNA N5005 from MNA loc. #989, just below BM16; all from lower part, lower shale member, Mancos Shale.

Genus *Watinoceras* Warren, 1930

Type species — *Watinoceras reesidei* Warren, 1930.

Diagnosis — Small to medium, evolute to moderately involute ammonite, with conspicuous ribs which arise singly or in groups from umbilical bullae or are intercalated, arising at mid-flank, each rib bears a inner and outer ventrolateral tubercle; usually the venter is smooth and flattened rarely with ribs connecting opposite outer ventrolateral tubercles.

Discussion — All of the material collected from Black Mesa consists of crushed shale specimens, however, differences in ribbing and degree of involution are sufficient to assign these specimens to species recognized in the Western Interior by Cobban (1988a).

Watinoceras is believed to have arisen from *Neocardioceras* by the loss of the siphonal tubercles (Wright and Kennedy, 1981). A possible intermediate may have been *Quitmaniceras*.

Occurrence — Lower Turonian worldwide.

Paleoecology — Batt (1987) includes species of this genus in his morphotypes; ECCf, 35 and ECCrn, 34, which are found in a wide range of nearshore and offshore environments and represent pelagic forms.

Watinoceras reesidei Warren, 1930

Plate 33, Figure G

Watinoceras reesidei Warren, 1930, p. 67, pl. 3, fig. 2, pl. 4, figs. 9–12.
Watinoceras reesidei Warren; Hattin, 1975, in part, p. 37, pl. 8, figs. D, I.
Watinoceras reesidei Warren; Cobban and Scott, 1972, p. 75, pl. 28, fig. 4.
Watinoceras amudariense (Arkhanguelsky); Wright and Kennedy, 1981, in part.
Watinoceras reesidei Warren; Cobban, 1988a, p. 5, pl. 1, figs. 1–26, text-fig. 3.
Watinoceras reesidei Warren; Kennedy, 1988, p. 50, figs, 3–4, 6.

Diagnosis — A small, evolute *Watinoceras* with dense ribbing and a flattened venter on the adult body chamber.

Discussion — Wright and Kennedy (1981) synonymized *Watinoceras reesidei* with *Watinoceras amudariense*. Cooper (1978) had previously synonymized both these species as microconchs of *Watinoceras coloradoense*. Cobban (1988a) points out that, while as the early whorls are indistinguishable, the body chamber of *Watinoceras reesidei* has a flat venter without ribbing, whereas *Watinoceras amudariense* has a body chamber with an arched venter crossed by chevron ribbing.

Occurrence — At Black Mesa, this species is common in the upper *Pseudaspidoceras flexuosum* subzone through the *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone from a couple of meters below BM15 to just below BM21 (Kirkland, 1990). Elsewhere, it is found from northern Alaska south throughout the Western Interior to Texas and is particularly common in marker bed PBC21 in Kansas and southern Nebraska. It has not been unquestionably identified outside of North America.

Illustrated material — MNA N4974 from MNA loc. #262, one meter above BM15, lower part, lower shale member, Mancos Shale.

Watinoceras devonense Wright and Kennedy, 1981

Diagnosis — Small, species with very dense ribbing (50 or more per whorl) alternating primary and secondary; weak umbilical bullae and small inner and outer ventrolateral tubercles.

Occurrence — Lower Turonian of England and in the Western Interior of North America.

Watinoceras devonense flexuosum Cobban, 1988

Plate 27, Figure B (a); Plate 33, Figures E, F, H, I, K

Watinoceras reesidei Warren?; Cobban and Scott, 1972, in part, p. 75, pl. 27, figs. 7–10.
Watinoceras devonense flexuosum Cobban, 1988a, p. 10, pl. 1, figs. 27–40, text-fig. 5.
Watinoceras sp.; Cobban, 1988a, p. 13, pl. 1, figs. 46–49.

Diagnosis — Small, moderately evolute ammonite with flattened flanks; numerous flexuous ribs and narrow flattened venter; inner whorls vary from very weakly ornate to 0.8 cm to densely ribbed well before this diameter.

Discussion — Cobban (1988a) erected this subspecies for North American forms, which differ in their more compressed flanks, markedly flexuous ribs. The abundant material at Black Mesa though crushed, clearly represents this subspecies.

Cobban (1988a) also describes a small specimen found with the holotype of *Watinoceras devonense flexuosum* as *Watinoceras* sp. This specimen had weak ornament consisting of strong umbilical bullae, very weak flexuous ribs, and small outer ventrolateral clavae. He suggests that this specimen may represent a juvenile *Watinoceras*. Numerous specimens of *Watinoceras devonense flexuosum* from Black Mesa show the time of appearance of typical ornament is variable, ranging from a few millimeters to nearly a centimeter in diameter. Thus *Watinoceras* sp. of Cobban (1988a) is considered to be an example of *Watinoceras devonense flexuosum* with delayed appearance of ornament.

It is more densely ribbed than *Watinoceras reesidei* and is more involute than either that species or *Watinoceras hattini*.

Occurrence — Known from the lower Turonian *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone through the lower *Mammites nodosoides* Zone, from BM16 upward to BM21 at Black Mesa (Kirkland, 1990). Also known from east-central Arizona, southern Utah, and Colorado.

Illustrated material — MNA N3618, N4988, N4989, N4990, N4993, N5000 from MNA loc. #262, BM18, middle part, lower shale member, Mancos Shale.

Watinoceras coloradoense (Henderson, 1908)

Plate 33, Figures A, C, D

Watinoceras coloradoense (Henderson); Cobban and Scott, 1972, p. 76, pl. 27, figs. 11–19, pl. 28, figs. 1–3, 5–9, text-figs. 36–37.
Watinoceras coloradoense coloradoense (Henderson); Wright and Kennedy, 1981, p. 53, text-fig. 18C–F.
Watinoceras coloradoense (Henderson); Cobban, 1988a, p. 7, pl. 2, pl. 3, figs. 4–5, text-fig. 4 (with synonymy).

Diagnosis — A large, moderately involute *Watinoceras* with closely spaced juvenile ribbing, becoming more sparsely and strongly ribbed and noded with increasing size.

Discussion — Juveniles of *Watinoceras coloradoense* are difficult to distinguish from *Watinoceras reesidei*. They are best distinguished by their more involute whorls, decrease in rib density with increase in size, and their much larger adult size. *Watinoceras* sp. cf. *W. praecursor* is also similar, but is recognized by its relatively even inner and outer ventrolateral tubercles and lack of high clavate ventrolateral tubercles characteristic of *Watinoceras coloradoense*.

Occurrence — At Black Mesa it is widespread, ranging from just below BM16 to BM21 in the lower Turonian *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone to the lowermost *Mammites nodosoides* Zone (Kirkland, 1990). Widespread through the Western Interior from Canada south Texas. It is common and well preserved in PBC21 along the front range of Colorado. Also reported from Brazil and Turkestan.

Illustrated material — MNA N4981, below BM16, lower part, lower shale member, Mancos Shale; MNA N4995, BM18, MNA N5015, one meter above BM20, both from middle part, lower shale member, Mancos Shale; all from MNA loc. #262.

Watinoceras hattini Cobban, 1988

Plate 34, Figures A, B

Watinoceras reesidei Warren; Hattin, 1975, in part, pl. 8, fig. J, pl. 9, fig. F.
Watinoceras hattini Cobban, 1988a, p. 11, pl. 4, (with synonymy).

Diagnosis — A large, evolute *Watinoceras* with rather dense ribbing.

Discussion — Readily distinguished from similar sized *Watinoceras coloradoense* by its more evolute shell and denser ribbing. Early whorls more densely ribbed than *Watinoceras reesidei* and not as evolute as *Watinoceras devonense flexuosum*.

Occurrence — At Black Mesa restricted to the lower Turonian *Mammites nodosoides* Zone from BM23 to between BM26 and BM27 (Kirkland, 1990). Elsewhere, it is only known from Hattin's (1975) marker limestone, JT-6, (PBC26 possibly equivalent to BM25) in central Kansas.

Illustrated material — MNA N5020, below BM23; MNA N5025, below BM26; both from MNA loc. #262, middle part, lower shale member, Mancos Shale.

Watinoceras sp. cf. *W. praecursor* Wright and Kennedy, 1981

Plate 33, Figure B

Watinoceras coloradoense praecursor, Wright and Kennedy, 1981, p. 53, pl. 10, figs. 4, 8–9, 11, 15, 17–18, text-fig. 19G–H.
Watinoceras cf. *W. praecursor* Wright and Kennedy; Cobban, 1988a, p. 13, figs. 50–55.

Diagnosis — A small to medium, moderately involute *Watinoceras* with moderate rib density and nearly even-sized inner and outer ventrolateral tubercles.

Discussion — This species is quite similar to *Watinoceras coloradoense* and was erected as a subspecies of that taxon by Wright and Kennedy (1981), who considered it a more primitive variety, where the ribbing coarsens later in ontogeny, the tubercles are less strongly developed, and adults do not get nearly as large.

It is difficult to separate crushed shale specimens of *Watinoceras* cf. *W. praecursor* from coarsely ribbed specimens of *Quitmaniceras*, which most readily differ in having secondary ribs begin high on the flank and the presence of siphonal tubercles and/or a low keel.

Occurrence — At Black Mesa within the lower Turonian *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone from just above BM15 to just below BM16 (Kirkland, 1990). Comparable material has been found in a slightly earlier horizon (PBC15) in the same zone from southern Colorado. The species was described from the *Watinoceras coloradoense* Zone in southern England.

Illustrated material — MNA N4999 from MNA loc. #989, below BM16, lower part, lower shale member, Mancos Shale.

Watinoceras spp.

Plate 34, Figures C, D

Discussion — Some specimens of *Watinoceras* from the *Mammites nodosoides* Zone at Black Mesa are not readily assignable to species due to their preservation and the morphology that is visible. The first type (Plate 34, fig. C) has fine, strong ribbing as in the co-occurring *Watinoceras hattini* but is much too involute to represent an early growth stage of this species. The second type also has fine strong ribbing and in addition has constrictions as have been described for *Watinoceras thompsonense* Cobban (1988a), which has coarser ribbing and occurs in the stratigraphically lower *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone.

Illustrated material — MNA N5028 from MNA loc. #262, below BM23, middle part, lower shale member, Mancos Shale; MNA N5040 from MNA loc. #262, below BM28, middle part, lower shale member, Mancos Shale.

Watinoceras ? sp.

Plate 32, Figure K

Diagnosis — A moderately involute compacted ammonite 32 mm in diameter with densely ribbed inner whorls and weakly ribbed body chamber. On body chamber ribs arise from umbilical shoulder giving rise to weak umbilical bullae, flex forward bear very weak inner ventrolateral tubercles and continue to distinct, weak outer ventrolateral clavae. The presence or absence of ventral ornament cannot be determined.

Discussion — This specimen differs from all species of *Watinoceras* known to the author. Many species of *Watinoceras* have weakly ornamented early whorls (e.g., Cobban, 1988), but no species has greatly reduced ornament on the body chamber as is observed on this specimen. This specimen is therefore provisionally assigned to *Watinoceras*.

Occurrence — Known only from one specimen from the *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone at Lohali Point (MNA loc. #989).

Illustrated material — MNA N4987 from MNA loc. #989, below BM16, lower part, lower shale member Mancos Shale.

Subfamily Euomphaloceratinae Cooper, 1978

Genus *Euomphaloceras* Spath, 1923

Type species — *Euomphaloceras euomphaloceras* (Sharp, 1855).

Diagnosis — Small to medium sized, evolute ammonites with a depressed to quadrate whorl section; ornamented early whorls; primary ribs arise from umbilical bullae to join inner ventrolateral spines before weakening across venter, where they bear outer ventrolateral and siphonal tubercles; additional intercalated outer ventrolateral and/or siphonal tubercles which may be borne on secondary ribs such that there are more outer ventrolateral and siphonal tubercles than inner ventrolateral spines; ventral constrictions generally occur at some point during ontogeny.

Discussion — The strong ornament and spines of*Euomphaloceras* make it an extremely distinctive Upper Cretaceous genus. One of the most abundant widespread species has long been known as *Kanabiceras septemseriatum* (ie, Cobban and Scott, 1972; Kauffman, 1977b). *Kanabiceras* was shown to be a synonym of *Euomphaloceras* by Wright and Kennedy (1981), who in documenting the great variability found in species of this genus, found overlap in the morphology of variable populations of *Euomphaloceras euomphalum* and *Euomphaloceras septemseriatum*.

Large acanthoceratids showing multiplication of ventral ornament (i.e., *Euomphaloceras cunningtoni* Sharp) have long been included in the genus. Collignon (1937) placed these forms in the genus *Cunningtoniceras*. This separation has not come into widespread use until recently (i.e., Kirkland and Cobban, 1986; Cobban, 1987). The genus is closest to and gave rise to the lower to basal middle Turonian genus *Kamerunoceras*, which differs in having smooth, constricted inner whorls and regular adult ribbing (Kennedy and Wright, 1979). Wright and Kennedy (in press) are proposing that *Lotzeites* gave rise to *Euomphaloceras* in the middle Cenomanian and not was derived from *Acanthoceras* as is *Cunningtoniceras* (Kennedy, 1988).

Occurrence — Widespread in the upper Cenomanian of the United States Western Interior, Mexico, California, Japan, Africa, and Europe.

Paleoecology — Batt (1987) includes this genus in morphotypes; EDQp, 13 and EDCp, 14, and finds that these forms are subtropical to tropical taxa that range from proximal offshore muds to pelagic carbonates. Spines were obviously useful in discouraging predation and also may been used to prop the animal above the substrate. If these ammonites were nekto-benthonic, they would have been tolerant of dysaerobic conditions in the central part of the seaway. Indeed, they may have been pelagic taxa, which would explain their intercontinental distribution. *Euomphaloceras* ranges farther north than other genera of the family, indicating a tolerance of cooler water or a period particularly warm climatic conditions during its range.

Euomphaloceras septemseriatum (Cragin, 1893)

Plate 16, Figures I, J, L–O

Acanthoceras ? kanabense Stanton, 1893, p. 181, pl. 36, figs. 6–8.
Kanabiceras kanabense (Stanton); Reeside and Weymouth, 1931, p. 11.
Neocardioceras septem-seriatum (Cragin); Adkins, 1931, p. 60, 72.
Lyelliceras stanislausense Anderson, 1958, p. 247, pl. 8, figs. 5, 5a.
Kanabiceras septemseriatum (Cragin); Cobban and Scott, 1972, p. 72, pl. 12, figs. 5–27.
Euomphaloceras (Kanabiceras) septemseriatum (Cragin); Cooper, 1978; p. 106, Figs. 4N–O, 10A–E, 12E–H, 18G–H, 19G–L, 26A–B, 28.
Euomphaloceras septemseriatum (Cragin); Wright and Kennedy, 1981, p. 55, pl. 12, figs, 1–8, pl. 13, figs, 1–6, pl. 14, figs. 5–9, (with synonymy).
Euomphaloceras septemseriatum (Cragin); Kennedy, 1988, p. 53, pl. 8, figs. 1–6, 9, pl. 9, figs. 1–3, 5–7 9–12, pl. 22, fig. 3, text-figs, 10E, 11D.
Euomphaloceras septemseriatum (Cragin); Cobban, Hook, and Kennedy, 1989, p. 35, figs. 35, 76Q–T, Z–FF, HH–PP.

Diagnosis — Small to medium sized; finely ornamented species, with variably developed ventral chevron ribs bearing ventrolateral clavae and siphonal tubercles which form keel. Quadrate whorl section depressed to varying degrees with moderately arched venter. The details of ornamentation, while variable between individuals, are remarkably uniform throughout ontogeny. The inner ventrolateral tubercles of major ribs on internal molds represent the bases of long, thin, solid, spines several centimeters in length covered by fine longitudinal striations. The umbilical wall of each succeeding whorl is modified to accommodate these spines. Shorter spines may be borne on outer ventrolateral tubercles and umbilical bullae.

Description — The largest example from Black Mesa (Plate 16, figs. I, J) is 82 mm in diameter with an umbilical ratio of 31% and at a diameter of 75 mm has a whorl breadth to height ratio of 1.07.

Discussion — *Euomphaloceras septemseriatum* is abundant and widely distributed worldwide and is thus an important index fossil for the upper Cenomanian. Until the research of Cooper (1978) and Wright and Kennedy (1981) established the great similarity of this species with *Euomphaloceras euomphalum*, it had been known under the genus *Kanabiceras* (i.e., Kennedy, 1971; Cobban and Scott, 1972).

The species has been described in detail by Cobban and Scott (1972), Cooper (1978), Wright and Kennedy (1981), and Kennedy (1988). Measurements of numerous specimens by these authors indicate that the umbilical ratio ranges from 31% to 44%, averaging 36.9, and the whorl-breadth-to-height ratio ranges from 1.12 to 1.57, averaging 1.36.

Kennedy (1988) recognized dimorphism with microconchs up to five centimeters in diameter, which may show a short interval before the adult aperture retaining only growth lines, fore shadowing the adult ornament of *Euomphaloceras irregulare*. The macroconchs are up to 11 centimeters in diameter. He found that maturity is marked by a decline in rib strength and the outward migration of umbilical tubercles.

It differs from *Euomphaloceras euomphalum* primarily in having generally denser ribbing, chevron-shaped ventral ribbing, clavate outer ventrolateral tubercles, and siphonal tubercles developed into or on a siphonal keel. It differs from *Euomphaloceras merewtheri* in having a nodate keel. It differs from *Euomphaloceras irregulare* in its more depressed whorl section, smaller adult size (upward of 10 cm), and in retaining typical ornament close to the adult aperture. It differs from *Euomphaloceras costatum* in its smaller size, less regular ornament, and more strongly ribbed inner whorls.

Occurrence — Common at Black Mesa in shales and concretions throughout the *Sciponoceras gracile* Zone from just below BM4 in northeastern Black Mesa just above BM10 across Black Mesa (Kirkland, 1990). Elsewhere, at the same level throughout the United States Western Interior from Montana southward into Texas and northern Mexico, also in Brazil, western Africa, Europe, and Japan.

Illustrated material — MNA N1073 from MNA loc. #262, concretion between BM8 and BM10 (unit 17); MNA N4931 from MNA loc. #262, BM10; MNA N1525 from MNA loc. #813, BM8; all from lower part, lower shale member, Mancos Shale.

Euomphaloceras irregulare (Cobban, Hook, and Kennedy, 1989)

Plate 21, Figures A–C; Plate 22, Figures A–L

Kamerunoceras sp. aff. *puebloense* (Cobban and Scott): Wright and Kennedy, 1981, pl. 14, figs. 3, 11.
Burroceras irregulare Cobban, Hook, and Kennedy, 1989; p. 38, figs. 39, 80S–V.

Diagnosis — A large, evolute species with quadrate whorls generally higher than wide; ornament strong, variable, with spinose primary ribs differentiated early in ontogeny; final quarter whorl of body chamber with dense raised growth lines without spines and strong ribs.

Description — Ammonites at the type locality are preserved in septarian concretions, which during the process of septarization have distorted most of the abundant ammonites contained within. Most specimens have relatively well preserved body chambers. However, sufficient material has survived the process of septarization to describe the species at all growth stages.

The best specimen (MNA N3500, Plate 21) is a complete adult 140 mm in diameter with the innermost whorls obscured. The body chamber extends for approximately the last half whorl, begining at a diameter of approximately 95 mm. There are 12 distant primary ribs on the last whorl of the phragmocone arising from the umbilical seam to give rise to strong, inwardly directed umbilical bullae; ribs strongest on flank, slightly prosiradiate, and weakening at midflank before strengthening and giving rise to outwardly directed inner ventrolateral spine bases; ribs weaken greatly on venter and flex forward slightly to bear strong clavate to nodose ventrolateral tubercles and weaker clavate siphonal tubercles on a weak siphonal ridge. One or two weak secondary ribs are intercalated between each primary and may arise from umbilical shoulder or ventral shoulder, which may or may not bear weak inner ventrolateral tubercles and weak outer ventrolateral and siphonal tubercles. Whorl section of phragmocone nearly quadrate with gently arching venter. Flextures are present in steep umbilical wall to accommodate inner ventrolateral spines. But for the ribbing and tuberculation, the phragmocone is smooth. Rib strength decreases abruptly at base of body chamber with the last primary rib slightly more than a quarter whorl before aperture. The last primary rib has a weak secondary rib looped forward between the umbilical and inner ventrolateral tubercles and looped well forward across the venter between the inner ventrolateral tubercles. Ornament from this point forward to the aperture consists a few very weak ribs without nodes and dense, raised flexuous growth lines. Whorl shape becomes higher and more ovate with more gently sloping umbilical wall, curved flanks and arched venter. The aperture is slightly constricted, recurved on the lower flank and expanded forward on venter.

MNA 3500 has a body chamber similar to most of the many the many adult body chambers examined from MNA loc. #814. Among the largest (diameters of 150–160 mm) specimens examined (e.g., MNA N3505),, while comparable in most details, the body chambers have somewhat stronger ribs bearing subdued nodes extending beyond the last spine-bearing primary rib and fading out well before aperture.

The details of rib density and strength vary considerably between and on individual phragmocones (Plate 22, figs. B–C). Primary ribs number between 12 and 25 per whorl separated by 1–3 intercalated secondary ribs. The inner ventrolateral spines are solid and as much as 100 mm long on later whorls. The spines taper gradually from 4 mm at the base to 3 mm at the invariably broken distal end. They appear twisted at the base and are ornamented by dense striations running parallel to the round shaft of the spine. The secondary ribs never bear inner ventrolateral spines and may arise from umbilical shoulder and may or may not bear a complete compliment of weak umbilical, inner and outer ventrolateral bullae, and siphonal tubercles, arise on the flank bearing inner and outer ventrolateral tubercles and siphonal tubercles, arise on the ventral lateral shoulder bearing outer ventrolateral and siphonal tubercles, or may be represented by outer ventrolateral and siphonal tubercles. Although the spacing of the primary ribs on individual phragmocones is rather constant, because of the variable strength of the secondary ribs, rib spacing appears variable.

Dense, highly flexuous ribs and a siphonal keel appears at a diameter of approximately 3 mm. The ribs number around 30 per whorl at a diameter of 5 mm, are narrower than the interspaces and are sharply recurved at the position of tubercles on later whorls. A full complement of weak umbilical bullae, inner and outer ventrolateral, and siphonal tubercles first appear at a diameter of 6–7 mm with ribs forming chevrons on venter. The inner ventrolateral tubercle on every fourth or fifth rib is strongly developed indicating the position of a small spine on the primary ribs. Weak constrictions may be associated with these primary ribs. From a diameter of 15 mm the primary ribs and spines strengthen and the secondary ribs and their tubercles weaken and the ribs progressively cross the venter less obliquely. By a diameter of 25 mm there are 2–3 secondary ribs for each primary rib and these are only very weakly developed on the flanks strengthening over the venter. At diameters of more than 50 mm the number of secondary ribs tend to be reduced to 1–2 for each primary rib.

The suture is typically acanthoceratid with a broad L lobe wider than E/L saddle.

DIMENSIONS

Specimen	D	U	Wb	Wh	Wb/Wh
MNA N3500	140(100)	52 (37)	37(26.5)	48(34)	0.77
MNA N3501	24(100)	8 (33)	10(41.5)	10(41.5)	1.00
MNA N3502	48(100)	15.5(32)	15(31)	13(37)	1.15
MNA N3503	111(100)	41 (37)	36(32.5)	38(34)	0.95
MNA N3504	10(100)	3 (30)	4(40)	5(50)	0.80
MNA N3505	153(100)	61 (40)	47(31)	49(32)	0.96
MNA N3516	5(100)	1.2(24)	*	*	*

Discussion — *Burroceras irregulare* was described from a couple of fragmentary specimens from southwestern New Mexico (Cobban and others, 1989). Large collections of well preserved material of this taxon at all growth stages were collected from southwestern Black Mesa during this study and had been referred to *Euomphaloceras navahopiensis* n. sp. (Kirkland, 1990). Further study of these specimens, while confirming their inclusion in *Euomphaloceras*, suggests that they are best referred to *Euomphaloceras irregulare*.

Euomphaloceras irregulare is closest to the somewhat older *Euomphaloceras septemseriatum* (Cragin), with which the early whorls might be confused. It differs primarily in its larger adult size, weakly ornamented body chamber, and higher whorl section giving it a somewhat more evolute appearance. It is similar in its suture, ontogeny, pattern and development of ornament. It differs from the older *Euomphaloceras euomphalum* in its larger adult size, weakly ornamented body chamber, higher whorl, and siphonal ridge. *Euomphaloceras irregulare* is close to the slightly younger *Euomphaloceras costatum* (Cobban and others, 1989), differing in its distinctively ribbed inner whorls, more irregular ribbing, and weakly ornate body chamber. These species are similar in their sutures, adult size, whorl shape, and apparently evolute whorls.

Wright and Kennedy (1981) have documented a significant amount of variation in the ornamentation of both *Euomphaloceras euomphalum* and *Euomphaloceras septemseriatum* demonstrating some overlap in the morphology of these two closely related species. The many specimens of *Euomphaloceras irregulare* examined from southwestern Black Mesa indicate a similar range of variation, with a number of specimens (e.g., Plate 22, figs. E, F) closely resembling *Euomphaloceras septemseriatum*, being most readily separated on the basis of their higher whorl section. Poorly preserved juvenile specimens from the shale facies would be very difficult to distinguish. Specimens of this type, but including examples with weakly ornamented body chambers have been collected by Elder (1987b) from the basal late Cenomanian *Neocardioceras juddii* Zone in southern Utah, northeastern Colorado, southeastern Colorado and Montana. In addition, Wright and Kennedy (1981) have illustrated specimens of *Euomphaloceras* as *Kamerunoceras* sp. aff. *K. puebloense* (Cobban and Scott) from between strata containing a typical *Sciponoceras gracile* Zone fauna and strata containing a typical *Neocardioceras juddii* Zone fauna. These specimens, which are believed to be conspecific, are associated with a similar vascoceratid fauna.

Strong dimorphism, as has been recognized in *Euomphaloceras septemseriatum* by Kennedy (1988), is not recognized in *Euomphaloceras irregulare*. However, a more subtle dimorphism appears to be recognizable, with microconchs as exemplified by the holotype adult at from 130–140 mm with smooth body chambers and macroconch adults at from 150–160 mm with weakly ribbed body chambers.

Occurrence — Present abundantly at all sites examined, at Black Mesa restricted to concretionary marker bed BM11 and the shales immediately above and below, *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone (Kirkland, 1990). Elsewhere in the Western Interior this species has been recognized in correlative units in northeastern New Mexico, Utah, eastern Colorado, and Montana. Specimens from this level reported as *Kamerunoceras* sp. cf. *K. puebloense* from southern England are probably conspecific. The type locality is in the Bridge Creek Member of the Mancos Shale in southwestern New Mexico, where it was found associated with a *Neocardioceras juddii* fauna (Cobban and others, 1989).

Illustrated material — MNA N3500-N3516, N3518, from Black Mesa marker bed BM11 on westernmost Coal

Mine Mesa, Coconino County, northeastern Arizona, Navajo Indian Reservation, MNA Loc. #814.

Euomphaloceras costatum Cobban, Hook, and Kennedy, 1989

Description — Poorly preserved compacted examples of *Euomphaloceras* with dense, even ribbing on body chamber are believed to represent to represent this species.

Discussion — Cobban and others (1989) described this species of *Euomphaloceras* from the *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone, southwestern New Mexico. This species is similar to *Euomphaloceras irregulare* but for early growth stages unornamented but for flexuous raised growth lines and constrictions (perhaps foreshadowing the smooth early whorls of *Burroceras* and *Kamerunoceras*) and body chambers characterized by strong regular ribbing.

Occurrence — At Black Mesa the species is uncommon in shales immediately below BM12 along the east side of the mesa in the late Cenomanian *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone (Kirkland, 1990), also observed to be common between BM12 and BM13 in the Tropic Shale in the southern Kaiparowits basin of southern Utah, as well as at this level in southwestern New Mexico and west Texas.

Material — MNA N4956 from MNA loc. #989, above BM13, lower part, lower shale member, Mancos Shale.

Genus *Burroceras* Cobban, Hook, and Kennedy, 1989

Type species — *Burroceras clydense* Cobban, Hook, and Kennedy, 1989.

Diagnosis — Medium sized. moderately evolute ammonites; rounded to quadrate whorls, smooth and constricted during early growth; distant ribs of variable strength on later whorls bear umbilical bullae, inner and outer ventrolateral tubercles and variably developed siphonal tubercles; ribs weaked greatly across venter; inner ventrolateral tubercles larger and fewer than more ventral tubercles. Suture of acanthoceratid type with L lobe much broader than E/L saddle.

Discussion — Cobban and others (1989) erected the genus *Burroceras* for latest Cenomanian euomphaloceratids with features intermediate between *Euomphaloceras* and *Pseudaspidoceras* and *Kamerunoceras*. The nearly smooth inner whorls distinguish the genus from *Euomphaloceras*. The suture and strong inner ventrolateral tubercles distinguish the genus from *Kamerunoceras*. The presence of siphonal tubercles distinguishes the genus from *Pseudaspidoceras*.

Occurrence — The genus is restricted to the latest Cenomanian in west Texas, New Mexico, Arizona, and southern Colorado.

Paleoecology — Batt (1987) places ammonites of this genus in morphotype ECQ(R)P, 12, finding ammonites of this morphotype to be restricted to proximal offshore shales along the southwestern margin of the seaway during the latest Cenomanian and rarely in pelagic limestones of the south-central seaway during the lower Turonian. Its distribution suggests that this genus is restricted to subtropical environments.

Burroceras clydense Cobban, Hook, and Kennedy, 1989
Plate 24, Figures A, B

Burroceras clydense Cobban, Hook, and Kennedy, 1989; p. 38, figs. 38, 79D–J, N–T.

Description — One small internal mold fragment with subquadrate whorl; a whorl height of 12 mm and whorl breadth of 11 mm (MNA N3517; Plate 24, figs. A, B) is nearly smooth with very weak ribs arising from the umbilical shoulder bearing rounded inner ventrolateral tubercles before weakening and inclining forward over rounded venter to a weaker outer ventrolateral tubercle and very weak siphonal tubercle born on a low, weak siphonal ridge.

Discussion — This one small fragment was found with the abundant specimens of *Euomphaloceras irregulare* in BM11 in extreme southwestern Black Mesa. It is readily distinguished from the densely ribbed inner whorls of that species. It compares well with the juvenile specimens of *Burroceras clydense* illustrated by Cobban and others (1989).

Occurrence — One specimen from BM11, *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone extreme southwestern Black Mesa (MNA loc. #814). Described originally from from the possibly slightly older *Burroceras clydense* Zone of southwestern New Mexico.

Illustrated material — MNA N3517 from MNA loc. #814, BM11, lower part, lower shale member, Mancos Shale.

Burroceras transitorium Cobban, Hook, and Kennedy, 1989

Burroceras transitorium Cobban, Hook, and Kennedy, 1989, p. 39, figs. 40, 79A–C, 80D–R.

Description — One partial specimen with a shell adhearing; diameter of approximately 8 cm and umbilical ratio of 34 %; subquadrate whorls 3.3 cm in height and 2.8 cm wide; 6 primary ribs per half-whorl which arise at umbilical shoulder as strong umbilical bullae cross straight across flank to strong inner ventrolateral tubercles and at ventrolateral shoulder bear weaker outer ventrolateral tubercles, where they disappear; one to two (usually two) secondary ribs arise near ventrolateral shoulder between each primary rib, rarely bear weak inner ventrolateral tubercles and always bearing outer ventrolateral tubercles as strong as those on primary ribs; very weak siphonal tubercle on venter for each outer ventraolateral tubercle; poorly preserved inner whorls weakly ornamented.

Discussion — One specimen of *Burroceras* from BM11 in the area of extreme southwestern Black Mesa compares well with *Burroceras transitorium* in its quadrate shape and very weak siphonal ornament.

Occurrence — One specimen from BM11, *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone, extreme southwestern Black Mesa (MNA loc. #814). Described originally from from the slightly younger *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone of southwestern New Mexico.

Material — MNA N3497 from MNA loc. #814, BM11, lower part, lower shale member, Mancos Shale.

Genus *Kamerunoceras* Reyment, 1954

Type species — *Kamerunoceras eschii* (Solger, 1904).

Diagnosis — Small to medium evolute ammonites; rounded to quadrate whorls, smooth and constricted during early growth; distant ribs on later whorls bear umbilical bullae and inner and outer ventrolateral tubercles; in some species umbilical bullae move outward to an inner lateral position and may or may not be replaced by a new umbilical bulla; ribs weaken greatly across venter where there is a variably developed siphonal ridge bearing weak siphonal clavae usually more numerous than ventrolateral tubercles. Species vary from those in which ribs dominate to those in which tubercles dominate ornamentation. Suture of acanthoceratid type with L lobe narrower than E/L saddle.

Discussion — The genus *Kamerunoceras*, first named by Reyment (1954), has recently been reviewed by Kennedy and Wright (1979), who recognized *Kamerunoceras* from the lower and early middle Turonian to be intermediate between *Euomphaloceras* of the late Cenomanian and *Romaniceras* of the late middle and late Turonian.

From the collections in this study, it would appear that *Kamerunoceras* is rare at Black Mesa, although the spinose species *Kamerunoceras puebloense* (Cobban and Scott) appears to be rather common in Colorado.

Occurrence — Widespread in the lower through middle Turonian of Europe, Africa, South America and North America north into Colorado. One specimen described below may represent a latest Cenomanian example from Black Mesa.

Paleoecology — As with *Euomphaloceras* Batt (1987) includes this genus in morphotypes EDQp, 13 and EDCp, 14, and finds that these forms are subtropical to tropical taxa that range from proximal offshore muds to pelagic carbonates. Spines were obviously useful in discouraging predation and also may been used to prop the animal above the substrate. If these ammonites were nekto-benthonic, they would have been tolerant of dysaerobic conditions in the central part of the seaway. Indeed, as with *Euomphaloceras*, they may have have been pelagic taxa, which would explain their intercontinental distribution.

Kamerunoceras turoniense (d'Orbigny, 1850)
Plate 38, Figure I

Kamerunoceras turoniense (d'Orbigny): Kennedy and Wright, 1979, p. 1170, pl. 2, figs. 1–11, pl. 3, figs. 1–2, pl. 4, figs. 1–3, text-figs. 2–3, (with synonymy).
Kamerunoceras turoniense (d'Orbigny): Wright and Kennedy, 1981, p. 57, pl. 14, figs, 1–2, 10, (with synonymy).
Kamerunoceras turoniense (d'Orbigny): Cobban and Hook, 1983, p. 13, pl. 8, figs. 1–5, 9–11, text-fig. 8.

Diagnosis — A large species for genus (up to 200 mm in diameter), very evolute; generally strong, narrow, distant ribs bearing small tubercles; umbilical bullae move outward on flank to form lateral tubercle and are replaced by new umbilical tubercle.

Discussion — One compacted fragment with an estimated whorl height of around 40 mm (MNA N4864; Plate 38, fig. I) displays ribbing with a lateral tubercle typical of *Kamerunoceras turoniense*. Cobban and Hook (1983) have described better material from slightly older strata in west-central New Mexico.

Occurrence — At Black Mesa one specimen has been collected from just above BM35, basal middle Turonian *Collignoniceras woollgari woollgari-Mytiloides hercynicus* subzone of the *Collignoniceras woollgari* Zone at Blue Point, southwestern Black Mesa (MNA loc. #262). It is also known from the upper *Mammites nodosoides* Zone of west-central New Mexico and in Europe, north Africa, the Middle East, and Madagascar.

Illustrated material — MNA N4864 from MNA loc. #262, just below BM36, top middle part, lower shale member, Mancos Shale.

Genus *Pseudaspidoceras* Hyatt, 1903

Type species — *Pseudaspidoceras footeanus* (Stoliczka, 1864).

Diagnosis — Medium to fairly large, moderate to very evolute ammonites with quadrate whorl section; on early whorls distant weak ribs bear umbilical, inner and outer ventrolateral tubercles with secondary intercalated ribs and ventral constrictions; on later whorls primary ribs strengthen and secondary ribs tend to be lost and on mature whorls ribs tend to weaken greatly; siphonal tubercles absent at all growth stages.

Discussion — Historically *Pseudaspidoceras* has been included in the subfamily Mammitinae (e.g., Wright, 1957). Wright and Kennedy (1981) questioned this placement based on the examination of the inner whorls of *Pseudaspidoceras flexuosum* Powell and paratypes of *Pseudaspidoceras footeanus* (Stoliczka), which displayed ventral constrictions, but removed the genus from the subfamily until the type specimen could be examined. On examining the type specimen, it was realized that the inner whorls were improperly reconstructed to resemble an inflated mammitid and *Pseudaspidoceras* was reassigned to the subfamily Euomphaloceratinae (Kennedy and others, 1987).

Occurrence — Latest Cenomanian *Neocardioceras juddii* Zone through lower Turonian *Mammites nodosoides* Zone of the southern Western Interior, Mexico, South America, India, Madagascar, Middle East, north and west Africa, and Europe.

Paleoecology — Batt (1987) places ammonites of this genus in morphotype ECQ(R)P, 12, finding these ammonites to be restricted to proximal offshore shales along the southwestern margin of the seaway during the latest Cenomanian and rarely in pelagic limestones of the south-central seaway during the lower Turonian. Its distribution suggests that this genus is restricted to subtropical environments.

Pseudaspidoceras pseudonodosoides (Choffat, 1898)
Plate 25, Figure L

Pseudaspidoceras cf. *P. pseudonodosoides* (Choffat); Freund and Raab, 1969, p. 14, figs. 10–11, text-fig. 4j–k.
Pseudaspidoceras n. sp. Hook and Cobban, 1981, p. 9. pl. 1, figs. 1–4, 9–11, pl. 2, figs. 6–11, pl. 3.
Pseudaspidoceras pseudonodosoides (Choffat); Kennedy, Wright, and Hancock, 1987, Text-fig. 6A–B, E–F.
Pseudaspidoceras pseudonodosoides (Choffat); Cobban, Hook, and Kennedy, 1989, p. 40, figs. 41, 81–83.

Diagnosis — Medium-sized, evolute ammonite and square whorl section; weak flank ribs bearing prominent umbilical and inner ventrolateral tubercles, and weak outer ventrolateral tubercles on flattened venter and slightly curved, moderate-to-weakly developed flank ribs.

Discussion — One fairly small specimen approximately 35 mm in diameter, which has been moderately compacted obliquely, compares well with other illustrated specimens of this species.

Occurrence — At Black Mesa, only known from concretions associated with bentonite marker bed BM13 at Ha Ho No Geh Canyon (MNA loc. #305), in the southwest in the *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone. Also known from New Mexico, southern Europe, and Israel.

Illustrated material — MNA N4900 from MNA loc. #305, concretion between BM12 and BM13, lower part, lower shale member, Mancos Shale.

Pseudaspidoceras flexuosum Powell, 1963
Plate 32, Figures A, B

Pseudaspidoceras flexuosum Powell, 1963, p. 318, pl. 32, figs. 1, 9–10, text-fig. 2a–c, f–g.
Pseudaspidoceras flexuosum Powell; Kennedy, Wright, and Hancock, 1987, p. 34, figs, 1–4, 8–13, 16–17, text-figs, 3A–C, 6C–D, 7A–C.
Pseudaspidoceras flexuosum Powell; Cobban, Hook, and Kennedy, 1989, p. 41, fig. 91L.

Diagnosis — Fairly large (up to 300 mm), moderately evolute *Pseudaspidoceras* with high rectangular whorl section with arched venter. Adorally-convex ribs arise from low on flank or umbilical bullae on later whorls and join inner ventrolateral tubercles or clavae and are looped across venter to opposite ventrolateral tubercle with a ventral constriction between looped ribs which is lost during ontogeny as are the closely spaced weak outer ventrolateral tubercles born on these ribs.

Discussion — Specimens from Black Mesa consist of compacted shale specimens from near the base of the Turonian and add nothing to our concept of the species. These specimens do display the distinctive flexuous flank ribs connecting the umbilical bullae and inner ventrolateral tubercles.

Kennedy and others (1987) have described this species in detail with numerous new specimens from Powell's (1963) type area in west Texas and followed Wright and Kennedy (1981) in synonymizing the some what younger *Kamerunoceras* (*Ampakabites*) *auriculatum* Collignon (1965) equals ? *Ampakabites collignoni* Cobban and Scott (1972). Whereas *Pseudaspidoceras flexuosum* sometimes displays looped ribs on the flanks, *Pseudaspidoceras auriculatum* has looped ribs between the umbilical bullae and inner ventrolateral tubercles as a dominant feature and in addition has sutures that have narrower elements with numerous folioles. Thus the occurrence of *Pseudaspidoceras flexuosum* in the *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone at Pueblo, Colorado (Cobban, 1985) represents at least a distinct subspecies if not the distinct species *Pseudaspidoceras auriculatum* (Collignon).

Occurrence — Basal Turonian *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone, a short distance above the Cenomanian-Turonian stage boundary to BM16 (Kirkland, 1990). Also in the southern Western Interior of southern Colorado, Arizona, west Texas, as well as, Germany, Nigeria, and Madagascar.

Illustrated material — MNA N4970 from MNA loc. #989, below BM14; MNA N4983 from MNA loc. #262, one meter above BM16; both from lower part, lower shale member, Mancos Shale.

Subfamily Mammitinae Hyatt, 1900
Genus *Metoicoceras* Hyatt, 1903

Type species — *Metoicoceras swallovi* Shumard.

Diagnosis — Medium to moderately large; compressed to square whorled, involute to moderately evolute ammonites; with weak to moderately strong ribs arising in twos or threes from umbilical bullae or with intercalated ribs arising from mid-flank; all ribs bear weak nodose to clavate inner ventrolateral tubercles and clavate outer ventrolateral tubercles, siphonal tubercles present only on earliest whorls of early species; transverse ribs weak or absent on flattened venter; body chamber uncoils slightly with weakening or loss of tubercles, and ribs may flatten or strengthen and cross venter. Suture simplified to pseudoceratitic.

Discussion — Species of *Metoicoceras* are highly variable, as well as dimorphic (Kennedy and Wright, 1981; Kennedy, 1981; Cobban, 1984); leading to a great deal of unwarranted taxonomic splitting. Among the many species described from the *Sciponoceras gracile* Zone of central Texas, Kennedy (1988) recognized a dwarf genus, *Nannometoicoceras*, based on the species *Metoicoceras acceleratum* Hyatt, which is separated on the basis of its much smaller adult size, weak umbilical ornament, and more involute squared whorl section. It has also been recognized that some of the ammonites catalogued into the MNA collections as juvenile *Metoicoceras* are representatives of other dwarf taxa (Kennedy and Cobban, 1990).

Occurrence — Upper Cenomanian North America, South America, Africa, Middle East, western Europe, and central Asia.

Paleoecology — Batt (1987) has placed these ammonites in his morphotypes ICCrn, 40, and ICCr, 41 and indicates that they probably inhabited the lower water column from shoreface sands to pelagic carbonates and were sensitive to reduced oxygen conditions as offshore they are restricted to bioturbated carbonates.

Metoicoceras mosbyense Cobban, 1953
Plate 7, Figures A, B; Plate 8, Figures B–D

Metoicoceras mosbyense Cobban, 1953, p. 48, pl. 6, figs. 1–14, pl. 7, figs. 1–3.
Metoicoceras muelleri Cobban, 1953, p. 49, figs. 15–16, pl. 8, figs. 1–7, pl. 9.
Metoicoceras defordi Young, 1957, p. 1169, pl. 149, figs. 1–8, text-fig. 1a, e, g, i.
Metoicoceras sp. Cobban, 1977, p. 25, pl. 21, figs. 5–6, 10–16.
Metoicoceras mosbyense Cobban; Cobban, Hook, and Kennedy, 1989, p. 43, Figs. 85C–T, 86L, M.

Diagnosis — A *Metoicoceras* with ribs passing over venter on most of body chamber, with loss of ventrolateral tubercles, often becoming rather densely ribbed at this stage.

Discussion — Cobban (1984) has proposed that the concept of *Metoicoceras mosbyense* refers to the microconch and *Metoicoceras muelleri* refers to the macroconch, with *Metoicoceras defordi* representing a more somewhat more densely ribbed southern variant. Examination of large numbers of examples from the east-central Arizona seems to indicate a range of variation that encompasses all these forms, supporting the synonymy of *Metoicoceras defordi*.

Occurrence — At Black Mesa known only from the sandstone facies of the upper sandstone member of the Dakota Formation across Black Mesa, *Metoicoceras mosbyense* Zone (MNA loc. #265, #296, and #963). Also at the same level in southern Utah and southwestern New Mexico, in the Cretaceous undifferentiated of the Mogollon Rim in central Arizona, in the Twowells Sandstone Tongue of the Dakota Formation in east-central Arizona and west-central New Mexico, in the Hartland Shale of Colorado, Frontier Formation of Wyoming, and Mosby Sandstone of Montana.

Illustrated material — MNA N1049, N3538, from MNA loc. #265; MNA N3543, N3544, from MNA loc. #963; all from sandstone facies, upper sandstone member, Dakota Formation.

Metoicoceras geslinianum (d'Orbigny, 1850)
Plate 17, Figures A, B, E, F; Plate 18, Figures A–C

Buchiceras swallovi (Shumard); White, 1877, p. 202, pl. 20, figs. 1a–c.
Buchiceras swallovi (Shumard); Stanton, 1893, p. 168, pl. 37, fig. 1, pl. 38, figs. 1–3.
Metoicoceras gibbosum Hyatt, 1903, p. 121, pl. 15, figs. 5–8.
Metoicoceras whitei Hyatt, 1903, p. 122, pl. 13, figs. 3–5, pl. 14, figs, 1–10, 15.
Metoicoceras kanabense Hyatt, 1903, p. 282, pl. 15, figs. 9–11.
Metoicoceras ornatum Moreman, 1942, p. 211, pl. 32, fig. 4, text-fig. 2c.
Barroisiceras trinodosum Moreman, 1942, p. 212, pl. 33, figs. 1–2, text-fig. 2a.
Barroisiceras brittonensis Moreman, 1942, p. 212, pl. 33, fig. 3, text-fig. 2b.
Metoicoceras whitei (Hyatt); Cobban and Scott, 1972, p. 74, pl. 14, figs. 3–4, 9–11, pl. 16, figs. 1–2, text-fig. 34.
Metoicoceras whitei (Hyatt); Hattin, 1975, p. 32, pl. 6, figs. K, M.
Metoicoceras geslinianum (d'Orbigny); Wright and Kennedy, 1981, p. 62, pl. 17, fig. 2, pl. 18, figs. 1–2, pl. 19, figs. 1–2, pl. 20, figs. 1–3, pl. 21, figs, 1–2, text-figs, 19C–E, 20, 21A–D, (with synonymy).

Metoicoceras geslinianum (d'Orbigny); Kennedy, 1988, p. 58, pl. 9, fig. 8, pl. 10, figs. 25–27, pl. 22, figs. 16–17. text-figs. 20–23, (with additional synonymy).
Metoicoceras geslinianum (d'Orbigny); Cobban, Hook, and Kennedy, 1989, p. 42, fig. 84A–W, AA.

Diagnosis — Large *Metoicoceras* with ventrolateral ornament maintained onto body chamber, with flattening and weakening of ribs across venter until immediately before aperture where tubercles are lost and ribs strengthen and pass uninterrupted across venter.

Discussion — Specimens of *Metoicoceras* from the latest Cenomanian of the Western Interior display a great variability, leading Cobban and Scott (1972) to synonymize many of the species described by Hyatt (1903) and Moreman (1942) with *Metoicoceras whitei* (Hyatt). Subsequently, Wright and Kennedy (1981) demonstrated that, while the type of *Metoicoceras geslinianum* is atypical, it falls within the range of variation found in populations of *Metoicoceras whitei.*

At Black Mesa, as in many other areas, *Metoicoceras geslinianum* is the most common normally coiled ammonite in the rich *Sciponoceras gracile* Zone fauna. It is common in shale and limestone concretions and displays a great deal of variation. Juvenile specimens are by far the most abundant, but adults are present as well. They also display a great deal of variation and display a pattern of dimorphism like that described by Kennedy (1988), with the finely ribbed, compressed macroconchs dominating over the coarsely ornamented microconch to a noticeable degree.

Occurrence — Common in the late Cenomanian *Sciponoceras gracile* Zone, at Black Mesa from just below the base of BM4 in the northeast up through just above BM10 across the area (Kirkland, 1990). Also in central Arizona and throughout the United States Western Interior, Texas, Mexico, Europe, Middle East, and Africa.

Illustrated material — MNA N1064, N4921 from MNA loc. #271, BM10; MNA N1134 from MNA loc. #262, BM10; MNA N4918 from MNA loc. #992, BM8; all from lower part, lower shale member, Mancos Shale.

Genus *Nannometoicoceras* Kennedy, 1988

Type species — *Nannometoicoceras acceleratum* (Hyatt, 1903).

Diagnosis — Small, very involute ammonite, with rectangular whorl section; primary ribs arise on the umbilical shoulder and are separated by two to three intercalated secondary ribs arising at mid-flank; ribbing very weak on early whorls and strengthens with and toward the venter bearing small, conical inner ventrolateral tubercles and aperturally displaced small, conical outer ventrolateral tubercles; on the adult body umbilical bullae may or may not be present and outer ventrolateral tubercles are connected by a strong bar-like rib; suture simple; dimorphic with microconchs maturing at less than 2.5 cm and microconchs maturing at as much as 4 cm in diameter.

Discussion — Kennedy (1988) recognized that of all the described species of *Metoicoceras* from the *Sciponoceras gracile* Zone only *Metoicoceras acceleratum* Hyatt (1903) could not be synonymized with *Metoicoceras geslinianum.* This species represented a dwarf form generically distinct in having small adult size with bar-like ribs crossing the venter and a simplified suture. This genus differs from slightly older *Cryptometoicoceras* in having outer ventrolateral tubercles.

Occurrence — Known only from the late Cenomanian *Metoicoceras mosbyense* Zone of southwestern Montana and *Sciponoceras gracile* Zone of central Texas, western New Mexico, and northeastern Arizona.

Paleoecology — Batt (1987) does not specifically recognize *Nannometoicoceras* in his study, but these ammonites would fit best with his morphotype ICCrn, 40, and this ammonite probable represents a nekto-benthonic form as well. However, its distribution is not well enough known to put much weight on using it to suggest environmental restrictions on its distribution.

Nannometoicoceras acceleratum (Hyatt, 1903)

Plate 17, Figures C, D

Metoicoceras acceleratum Hyatt, 1903, p. 127, pl. 14, figs. 11–14.
Nannometoicoceras acceleratum (Hyatt), Kennedy, 1903, p. 67, pl. 11, figs. 1–24, text-fig. 8A.
Nannometoicoceras acceleratum (Hyatt), Cobban, Hook, and Kennedy, 1989, p. 45, fig. 86N, O.

Diagnosis — Distinguished by its umbilical bullae, strong flank and ventral ribs on body chamber and in having both inner and outer ventrolateral tubercles.

Discussion — Examination of small metoicoceratids from Black Mesa has revealed one slightly crushed specimen of a microconch from BM10 at Blue Canyon on the west side of Black Mesa has the bar-like ventral ribs of *Nannometoicoceras acceleratum.* Further examination of other collections will surely lead to the recognition of many additional examples of this species.

Occurrence — At Black Mesa, one specimen is currently recognized from the Late Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone in BM10 at Blue Canyon on the west side of Black Mesa (MNA loc. #271), elsewhere only known from central Texas and southwestern New Mexico, where ranges down into the *Metoicoceras mosbyensis* Zone.

Illustrated material — MNA N4920 from MNA loc. #271, BM10, lower part, lower shale member, Mancos Shale.

Genus *Spathites* Kummel and Decker, 1954

Type species — *Spathites chispaensis* Kummel and Decker, 1954.

Diagnosis — Medium sized, involute, stout to compressed ammonites, with ribbed and tuberculate (umbilical, inner and outer ventrolateral tubercles) inner whorls that have reduced or loss of ornament on outer whorls, suture simple.

Discussion — *Spathites* was initially placed in the family Vascoceratidae by Kummel and Decker (1954) because of the reduction of ornament on the body chamber. Kennedy and others (1980) subsequently placed the genus in the Mammitinae on the basis of similarities in the early whorls.

Occurrence — Uppermost Cenomanian through Middle Turonian of the southern Western Interior, United States, northern Mexico, Europe, India, and northern Africa.

Paleoecology — Batt places species of this genus in his morphotypes IDQrn, 16 and ICQrn, 17 as juveniles and IDQs, 26 and ICQs, 27 as adults. He indicates that while restricted to shallow water environments, these presumed benthic forms were restricted from more offshore environments by reduced oxygen levels. Their restriction to the southern Western Interior suggests that they were subtropical taxa.

Subgenus *Spathites* Kummel and Decker, 1954

Type species — As for genus.

Diagnosis — Spathites which loses ribs and tubercles in adult.

Occurrence — Late lower through middle Turonian of the southern Western Interior, United States and northern Mexico.

Spathites puercoensis (Herrick and Johnson, 1900)

Plate 47, Figures D, G

Spathites puercoensis (Herrick and Johnson); Kennedy, Wright, and Hancock, 1980, p. 834, pl. 104, figs. 1–5, pl. 106, fig. 3, text-fig. 8c.
Spathites puercoensis (Herrick and Johnson); Kennedy, 1988, p. 70, pl. 2, fig. 15, pl. 12, figs. 4–8, text-figs. 24B–C, 31A.
Spathites puercoensis (Herrick and Johnson); Cobban, 1988b, p. 15, figs. 3A–L, 9A–C, G–M, 10A–L, 11A–F, 14, (with synonymy).

Diagnosis — A variable species of *Spathites* (*Spathites*) that retains ornament into adult stage. Suture is nearly pseudoceratitic.

Discussion — Specimens of *Spathites* the have been positively identified as *Spathites puercoensis* are restricted to a few internal sandstone molds from the lower sandstone member of the Toreva Formation at Blue Point, southwestern Black Mesa and represent a downward range extension for the species. A few poor crushed specimens, with ventrolateral tubercles were found near the top of the upper shale member in the *Prionocyclus hyatti* Zone west of Black Mountain on the east side of Black Mesa.

Occurrence — In the *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone in the lower sandstone member Toreva Formation at Blue Point in southwestern Black Mesa (MNA loc. #342). In the *Prionocyclus hyatti* Zone in eastern Black Mesa (MNA loc. #1158), as well as in this zone in New Mexico, Texas, and northern Mexico.

Illustrated material — MNA N4851, N4852 from MNA loc. #342, lower sandstone member, Toreva Formation.

Spathites sp.

Plate 38, Figure G

Description — Immature crushed specimens of *Spathites* that cannot be assigned to species.

Occurrence — At Black Mesa widely scattered in the *Collignoniceras woollgari* Zone.

Illustrated material — MNA N4861 from MNA loc. #989, 4 m below BM66, middle shale member, Mancos Shale.

Genus *Mammites* Laube and Bruder, 1887

Type species — *Mammites nodosoides* (Schluter).

Diagnosis — Medium to large, moderately evolute ammonites, with quadrate to rectangular whorls; strongly ribbed early whorls with umbilical, inner and outer ventrolateral tubercles; rib strength decreases with increasing size and strengthening of tubercles, with ventrolateral tubercles fusing to form horns on late whorls; broad first lateral saddle and narrow lateral lobe.

Discussion — With the recognition of the genus *Morrowites* by Cobban and Hook (1983) (see below), recognition of the genus *Mammites* among crushed shale specimens was made extremely difficult, if not impossible in most cases. Whereas *Mammites* is generally higher whorled and somewhat more densely ribbed, the lack of preserved sutures in most cases, makes separation of these genera unreliable and thus they are recorded as *Mammites* or *Morrowites* sp. The almost complete overlap in the ranges of these genera allows them to retain their significance in the biostratigraphic zonation developed in this study.

Occurrence — Throughout the Lower Turonian, in the basal Turonian restricted to west Texas and northern Mexico, subsequently common worldwide.

Paleoecology — Batt places species of this genus in morphotypes ECQ(r)n, 3 and ECQn, 7 and found that unlike most heavily ornamented, large, nekto-benthonic ammonites, which are restricted to shallow water settings, these species are distributed from nearshore to offshore pelagic carbonate environments. He proposes that their more deep lobed sutures allowed them to tolerate greater water depths. Their restriction to limestones in these deeper water settings indicates they were not tolerant of reduced oxygen levels.

Mammites nodosoides (Schluter, 1871)

Plate 34, Figure G; Plate 35, Figures A, B

non *Mammites nodosoides* (Schlotheim); Powell, 1963; p. 316, pl. 33, figs. 1, 3, 4, 6, 10. 11; text-fig. 3 m, o, t, u (= *Mammites powelli* Kennedy, Wright, and Hancock, 1987.
Mammites nodosoides (Schlotheim); Cobban and Scott, 1972; p. 78.
Mammites nodosoides (Schluter); Wright and Kennedy, 1981; p. 75, pl. 17, fig. 3; pl. 19, fig. 3; pl. 20, fig. 4; pl. 22, fig. 4; pl. 23, figs. 1?, 2, 3; pl. 24. figs. 2, 3; text-figs. 19B, 23, 24 (with synonymy).
Mammites nodosoides (Schluter); Cobban and Hook, 1983; p. 8, pl. 1, figs. 14, 15; pl. 3, figs. 21, 22; pl. 4, figs. 4–9, 17, 18; pl. 5, figs. 1–3; text-fig. 2.
Mammites nodosoides (Schluter); Cobban, Hook, and Kennedy, 1989, p. 41, figs. 42, 90D–H, M, N.

Discussion — Many crushed mammitids in the *Mammites nodosoides* Zone at Black Mesa probably represent the species *Mammites nodosoides* (Schluter). However, their preservation is such that identification to species is suspect and in many cases their identification to genus, cannot be proved. The few examples identified to species are based on clavate ventrolateral tubercles and preserved fragments of the suture.

Occurrence — Scattered through the *Mammites nodosoides* Zone across the entire Black Mesa area (listed under mammitids, Kirkland, 1990), as well as in Colorado, New Mexico, Europe, Africa, Middle East, and South America.

Illustrated material — MNA N4840, N4867, from MNA loc. #989, BM30; MNA N4873 from MNA loc. #262, below BM36; all from middle part, lower shale member, Mancos Shale.

Genus *Morrowites* Cobban and Hook, 1983

Type species — *Morrowites wingi* (Morrow).

Diagnosis — Medium to large, evolute ammonites with quadrate to depressed rectangular whorls; early whorls smooth with weak constrictions; later whorls with weak ribs bearing umbilical, and inner and outer ventrolateral tubercles which fuse to form horns on late whorls; suture with narrow lateral saddle and broad lateral lobe.

Discussion — Cobban and Hook (1983) established the genus *Morrowites* on several species previously assigned to *Mammites*, which differed from *Mammites* in having weakly ornamented, constricted early whorls and different sutures. At that time they recognized several species, which could be assigned to the genus: *Morrowites wingi* (Morrow), *Morrowites dixeyi* (Reyment), *Morrowites michelobensis* (Laube and Bruder), *Morrowites depressus* (Powell), and *Morrowites subdepressus* Cobban and Hook. In addition, they recognized that *Euomphaloceras* and *Pseudaspidoceras* have a similar suture as well as having constricted whorls. Thus it may be shown that *Morrowites* should be placed in the Euomphaloceratinae and that the similarity of this genus with *Mammites* is purely a case of convergence.

Crushed mammitids are abundant in the *Mammites nodosoides* Zone at Black Mesa. Several of these are juveniles displaying ornament typical of *Morrowites*, and a few show portions of the a suture also typical of this genus.

Occurrence — Widespread in the lower Turonian to basal middle Turonian of North America, Europe, Africa, and Japan.

Paleoecology — Batt places this species of this genus in morphotypes EDD(r)n, 1, EDQ(r)n, 2, ECQ(r)n, 3 ,and ECQn, 7 and found that as in *Mammites* and unlike most heavily ornamented, large, nekto-benthonic ammonites, which are restricted to shallow water settings, these species are distributed from nearshore to offshore pelagic carbonate environments. He proposes that their more deep lobed sutures allowed them to tolerate greater water depths. He did find that the broader, more depressed forms were more common in shallower water settings. Their restriction to limestones in these deeper water settings indicates they were not tolerant of reduced oxygen levels.

Morrowites sp.
Plate 34, Figures H, I; Plate 35, Figure C

Discussion — Many of the crushed mammites from the *Mammites nodosoides* Zone and basal *Collignoniceras woollgari* Zone represent species of *Morrowites*, but the nature of their preservation does not permit identification to species. Specimens identified to genus are based on preserved inner whorls and fragments of the suture. Occurrences in the basal *Collignoniceras woollgari* Zone perhaps represent *Morrowites depressus*, as this is the only species documented as ranging up into the basal middle Turonian.

Occurrence — At Black Mesa throughout the Lower Turonian *Mammites nodosoides* Zone through basal middle Turonian *Collignoniceras woollgari regulare* — *Mytiloides hercynicus* subzone of the *Collignoniceras woollgari* Zone; a short distance below BM21 to a short distance above BM35 (listed under mammitids, Kirkland, 1990).

Illustrated material — MNA N4868 from MNA loc. #296, 2 m below BM27; MNA N4872, below BM32, MNA N4910, below BM28, both from MNA loc. #262; all from middle part, lower shale member, Mancos Shale.

Family Vascoceratidae Douville, 1912
Subfamily Vascoceratinae Douville, 1912
Genus *Nigericeras* Schneegans, 1943

Type species — *Nigericeras gignouxi* Scheenegans, 1943.

Diagnosis — Medium-sized, moderately evolute ammonites with quadrate to somewhat compressed whorls; having early whorls well ribbed with umbilical bullae, inner and outer ventrolateral tubercles, and siphonal tubercles; ornament weakens and disappears during ontogeny. Suture simple.

Discussion — Reyment (1955) suggested that the origins of the Vascoceratidae lie within the genus *Nigericeras*, which has early whorls with acanthoceratid ornament on the early whorls. Wright and Kennedy (1980) suggest that the Vascoceratidae originated earlier from *Protacanthoceras* via *Vascoceras diartianum* as described below. Kennedy (1986, personal communication) reports having examined examples that show derivation from *Pseudocalycoceras*. This suggests that the Vascoceratidae are a polyphyletic group. The examples described below may represent such transitional forms and perhaps indicate that *Nigericeras* should be placed in the Acanthoceratidae.

Occurrence — Known from the uppermost Cenomanian and possibly the lowest Turonian of Colorado, Arizona, west Texas, southern England, the Middle East, and north and central Africa.

Paleoecology — Batt (1987) places juveniles of this ammonite in morphotype ICQr, 25 and adults in his morphotypes ECQr, 9 and ICQs, 27 with their distribution from offshore shales to deep water pelagic carbonates in the southern part of the seaway indicating a subtropical to tropical distribution.

Nigericeras sp. cf. *N. ogojaense* Reyment, 1955
Plate 24, Figures E, F

Nigericeras ogojaense Reyment, 1955, p. 62, pl. XIII, fig. 6, pl. XIV, fig. 3, text-fig. 28.

Diagnosis — Two body chambers, one with parts of the internal whorls preserved (MNA N3496; Plate 24, figs. E, F) and one that preserves the aperture (MNA N3523) are known from the southwestern part of Black Mesa. MNA N3496 is a moderately evolute internal mold with poorly preserved inner whorls with broad rather, distant ribs arising from umbilical bullae. The body chamber is attached to the the last few chamber of the phragmocone and is 108 mm in diameter, with an umbilical ratio of 36% and a whorl width-to-height ratio of 73.5%. The whorl is tabular with a strongly arched venter. Approximately 10 primary ribs on last half whorl arising from weak umbilical bullae extend toward venter, weakening at mid-flank before strengthening at ventrolateral shoulder and bearing weak conical inner ventrolateral tubercles and faint outer ventrolateral and siphonal tubercles. Between each primary rib there is one secondary rib arising near ventrolateral shoulder. Ribs and tubercles weaken greatly toward aperture. The suture is poorly preserved, but can be seen to be little incised with a broad bifid first L lobe and narrow E/L saddle.

MNA N3523 consists of just the body chamber with portions of shell adhering. It differs in having stronger ribbing and tubercles and an abrupt constriction of the shell diameter with loss of ornament, except for dense raised growth lines a couple of centimeters before the aperture. Raised growth lines following the trend of the ribs apparently cover the entire body chamber.

Discussion — The pattern of tuberculation and reduction in ornament on the body chamber indicates that these specimens represent a species of *Nigericeras*. In the persistence of tuberculation on the body chamber these specimens are closest to *Nigericeras ogojaense* Reyment from Nigeria. They apparently differ in having a more compressed whorl section and apparently larger adult size.

Occurrence — At Black Mesa restricted to the Late Cenomanian *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone BM11 in extreme western Coal Mine Mesa, southwestern Black Mesa (MNA loc. #814). The holotype and only described specimen of this species is from Nigeria.

Illustrated material — MNA N3496 from MNA loc #814, BM11, lower part, lower shale member, Mancos Shale.

Genus *Vascoceras* Choffat, 1898

Type species — *Vascoceras gamai* Choffat, 1898.

Diagnosis — Small to fairly large, moderately evolute to somewhat involute ammonites with juveniles with depressed to fairly compressed whorls; with or without constrictions; umbilical tubercles give rise to ribs which cross venter uninterrupted and may develop ventrolateral nodes; adult whorls very variable in shape within and between species, ranging from oval, subquadrate, bluntly triangular to very depressed, with or without ribs across outer flanks and venter and/or umbilical tubercles; suture simple with little incised elements.

Discussion — Kennedy, Wright, and Hancock (1987) have documented the extreme variation in whorl shape and ornament that can be observed in any large population of *Vascoceras* and have noted that this has lead to great numbers of different species, subgenera, and even genera named on the basis of small populations that display an apparently discontinuous range of variation. They found that the least amount of variation in the large population of *Vascoceras proprium* (Reyment, 1954) studied from the basal Turonian of west Texas was in the degree of involution.

The origin of *Vascoceras* out of the dwarf genus *Protacanthoceras* during the late Cenomanian has been well documented by Wright and Kennedy (1980, 1981, 1985). The earliest species *Vascoceras diartianum* is likewise a dwarf species that displays all the features found in the larger, descendent species of *Vascoceras*. Other genera of vascoceratids that have various patterns of tuberculation, such as *Paramammites, Thomasites, Fagesia,* and *Nigericeras,* appear to have ornamentation that is too specialized to have been derived from *Vascoceras diartianum*. In addition these genera lack the constrictions characteristic of early vascoceratids. Further study of the taxa included within the vascoceratid may well lead to the removal of many genera from the Vascoceratidae as has happened to the genus *Spathites* which is now included within the Mammitinae as it is derived from *Metoicoceras* (Wright and Kennedy, 1981, 1985). In fact, it may be found that the Vascoceratidae should be restricted to a specialized subfamily of the Acanthoceratidae.

Occurrence — Uppermost Cenomanian to high in the Turonian, most common in Tethyan sites in southern Europe, north and central Africa, Middle East, Mexico, and northern South America, less common in northern Europe, Madagascar, central South America, and in the Western Interior as far north as Wyoming.

Paleoecology — Batt (1987) created a number of morphotypes — IDDs, 21, EDQs, 22, ECQs, 23, IDQr, 24, ICQr, 25, IDQs, 26, ICQs, 27, ECQs(v), 28, ICQr(v), 29, IDQs(v) 30, ICQs(v), 31 — for the wide range of variation observed in this genus. He found that they were widely distributed from shallow nearshore to deep offshore, where they were restricted to pelagic limestones, indicating an intolerance of lowered oxygen levels. As indicators of tropical water conditions, he used their distribution to trace the temporal and spacial distribution of warm water masses within the Western Interior.

Vascoceras diartianum (d'Orbigny, 1850)
Plate 10, Figures O (a), P

Vascoceras diartianum (d'Orbigny); Wright and Kennedy, 1981; p. 86, pl. 17, fig. 1, text-figs. 29A–F (with synonymy).
Vascoceras diartianum (d'Orbigny); Cobban, Hook, and Kennedy, 1989, p. 47, figs, 48, 88T–AA.

Diagnosis — Small, moderately evolute ammonites with whorl section widest at umbilical shoulder broadly arching across venter; pinched umbilical tubercles retained onto body chamber; ribs on early whorls rise in groups of 3–5 from umbilical tubercles and intercalated, lost on smooth body chamber.

Discussion — The holotype from France is nearly adult at 30 mm. The specimens from Black Mesa range from 20–25 mm in diameter and consist of compacted specimens in lateral view displaying 4–5 pinched umbilical tubercles per half whorl and essentially smooth outer whorl. Although slightly smaller, the Black Mesa specimens seem to compare well with the holotype. Cobban has collected this species from Wyoming and west Texas (Wright and Kennedy, 1981; Cobban, 1984a), and specimens have beed illustrated from southwestern New Mexico (Cobban and others, 1989).

Occurrence — At Black Mesa in the upper Cenomanian *Vascoceras diartianum* subzone of the *Sciponoceras gracile* Zone below and within BM4 in the area of northeastern Black Mesa (MNA loc. #296, #989, #990, and #992). Elsewhere in the Western Interior in Wyoming, southwestern New Mexico, west Texas, and Europe.

Vascoceras sp.
Plate 32, Figures H, I

Diagnosis — Mostly small- to medium-sized, compacted ammonites displaying moderate evolution, constrictions and broad low ribs arising from umbilical bullae.

Discussion — Ammonites identified as *Vascoceras* sp. are all considered to represent juvenile specimens displaying features shared by *Vascoceras proprium* (Reyment, 1954) and *Vascoceras birchbyi* Cobban and Scott (1972), among others, and as such are not taken to species. Large possibly adult specimens of *Vascoceras* are represented by mostly poorly preserved fragmentary material display broad curved flanks. Much of this material may represent the remains of other adult vascoceratid genera.

Occurrence — At Black Mesa from a short distance below BM16 to BM26, lower Turonian from the upper part of the *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone into the lower *Mammites nodosoides* Zone (Kirkland, 1990). Elsewhere as for genus.

Illustrated material — MNA N4680, 2 m above BM15; MNA N4982, one meter below BM17; both from MNA loc. #262, lower part, lower shale member, Mancos Shale.

Genus *Fagesia* Pervinquiere, 1907

Type species — *Fagesia superstes* (Kossmat, 1897).

Diagnosis — Medium to large, moderately involute to evolute, globose, cadicone, to coronate ammonites; umbilical bullae giving rise to 2–3 ribs which weaken across venter, where on early whorls there are rather closely spaced bullate ventrolateral tubercles; umbilical tubercles and ribs may persist onto adult body chamber or not; suture generally with deeply incised elements and trifid L lobe.

Discussion — As with the *Vascoceras, Fagesia* has been shown to be variable leading to large numbers of species being described for single variable species. Large poorly preserved specimens from Black Mesa may be included under *Vascoceras* sp.

Occurrence — Lower through low middle Turonian in the Western Interior from Montana south into Mexico, California, South America, Japan, India, Madagascar, Africa, Middle East, and Europe.

Paleoecology — Batt (1987) placed ammonites in this genus in his morphotypes EDDr, 18; EDDs, 19; IDDr, 20; and IDDs, 21 and found them to be distributed from shoreface sands to offshore shales, in addition they are less common in the pelagic limestone facies (Cobban and Scott, 1972; Cobban, 1985). He found this genus to be subtropical in habit with less restriction by temperature than other vascoceratids.

Fagesia catinus (Mantell, 1822)

Plate 32, Figures C, F

Fagesia haarmanni Böse, 1920; p. 211, pl. 14, figs. 1, 2; pl. 15, fig. 2.
Vascoceras mohovanense Böse 1920; p. 219, pl. 18, figs. 1, 2.
Vascoceras thomi Reeside, 1923; p. 29, pl. 11, figs. 1, 2; pl. 12, figs. 1, 2; pl. 13, figs. 1, 2; pl. 14. figs. 1, 2; pl. 15, figs. 1–7; pl. 16, figs. 1–6.
Vascoceras moultoni Reeside, 1923; p. 30, pl. 17, figs. 1, 2; pl. 18, figs. 1, 2.
Vascoceras stantoni Reeside, 1923; p.30, pl. 19, figs. 1, 2; pl. 20, figs. 1–3, pl. 21, figs. 1–3.
Fagesia haarmanni Böse; Kummel and Decker, 1954; p. 313, text-fig. 3.
Fagesia californica Anderson; Anderson, 1958; p. 248, pl. 39, figs. 1, 2.
Vascoceras shastense (Anderson); Anderson, 1958; p. 248.
Fagesia haarmanni Böse; Powell, 1963; p. 320, pl. 33, fig. 2; pl. 34, figs. 1–5, text-figs 2 h–k.
Fagesia sp. Cobban and Scott, 1972; p. 88, pl. 34, figs. 1, 2; pl. 38, fig. 4.
Fagesia catinus (Mantell); Wright and Kennedy, 1981; p. 88, pl. 26, fig. 2, text-figs. 31–36 (with synonymy).
Fagesia catinus (Mantell); Kennedy, Wright, and Hancock, 1987; p. 51–56. pl. 7, figs. 1–13; pl. 8, figs. 1–4, 6–9; text-figs. 2j, k, m, n, 10 (with additional synonymy).
Fagesia catinus (Mantell); Cobban, Hook, and Kennedy, 1989, p. 50, figs. 50, 92L–KK, 96S, T.

Diagnosis — Large, moderate to very evolute species of *Fagesia*, which in early whorls is moderately evolute; generally 2 ribs looped over venter from umbilical tubercles and intercalated rib bearing closely spaced ventrolateral bullae; ribs and ventrolateral tubercles disappear at maturity while retaining umbilical bullae; variation in the size of mature specimens indicates dimorphism with microconchs moderately involute, adult at less than 100 mm and ribbing lost early and weak umbilical tubercles retained on depressed body chamber and with macroconch very evolute, adult at around 200 mm with strongly inclined umbilical walls and umbilical tubercles becoming very strong moving into a lateral position on the depressed body chamber.

Discussion — Studies of large numbers of *Fagesia catinus* from narrow horizons (Wright and Kennedy, 1981; Kennedy and others, 1987) has revealed a both a great deal of variation in whorl shape and ornament, but also distinct dimorphism as described above. This permitted many of the described species of *Fagesia* to synonymized with this species. *Fagesia superstes* differs in being more involute and having more umbilical tubercles and ribs per whorl. A few moderately evolute compacted ammonites are interpreted as representing *Fagesia catinus* (perhaps microconchs).

Occurrence — At Black Mesa uncommon throughout the entire *Watinoceras coloradoense* Zone (Kirkland, 1990). Also throughout Western Interior from Montana south in Mexico, California, Europe, and northern South America.

Illustrated material — MNA N4895 from MNA loc. #989, associated with disconformity at base of Turonian below BM14, lower part, lower shale member; MNA N5017 from MNA loc. #262, below BM21, middle part, lower shale member; both from Mancos Shale.

Fagesia ? sp. cf. *Fagesia superstes* (Kossmat, 1895)

Fagesia superstes var. *tunisiensis* Pervinquiere, 1907; p. 323, pl. 20, figs. 1a–c, 2a, b.
Fagesia superstes var. *spheroidalis* Pervinquiere, 1907; p. 324, pl. 20, figs. 3a, b, 4a; text-fig. 122.
? *Fagesia lenticularis elliptica* Freund and Raab, 1969; p. 36. pl. 7, figs. 1, 2; text-figs. 7h, 8a–c.
? *Fagesia lenticularis asymmetrica* Freud and Raab, 1969; p. 38, pl. 6, figs. 3–7, text-figs. 7i–k, 8d–g, 9a.
? *Fagesia lenticularis lenticularis* Freund and Raab, 1969; p. 39, pl. 7, fig. 3; pl. 8, figs. 1, 2; text-figs, 8h, i, 9b, c.
Fagesia superstes (Kossmat); Wright and Kennedy, 1981; p. 87, text-fig. 30.
Fagesia superstes (Kossmat); Cobban and Hook, 1983; p. 16, pl. 3, figs. 1, 2; pl. 13, figs. 6–11; text-fig. 12 (with synonymy).

Diagnosis — A medium-sized, rather involute species of *Fagesia* with a depressed whorl section; numerous umbilical tubercles giving rise to 2–3 ribs which with the single intercalated ribs bear closely spaced umbilical tubercles only on earliest whorls.

Discussion — *Fagesia superstes* has not been described from large populations and if dimorphic, as in *Fagesia catinus*, has only had microconchs attributed to it. Kennedy and others (1987) suggest that *Fagesia lenticularis* Freud and Raab (1969), which is adult at 380 mm in diameter and loses its umbilical tubercles at a rather early ontogenetic stage, may represent the macroconch of *Fagesia superstes*.

Rare large ammonite fragments from the upper *Mammites nodosoides* Zone at Black Mesa that display dense ribbing, may represent examples of *Fagesia superstes*. None of these fragments are suitable for illustration.

Occurrence — At Black Mesa rare in upper part of lower Turonian *Mammites nodosoides* Zone (Kirkland, 1990). Elsewhere in New Mexico, Germany, North Africa, the Middle East, and Japan.

Genus *Neoptychites* Kossmat, 1895

Type species — *Neoptychites cephalotus* (Courtiller, 1860).

Diagnosis — Medium-sized, very involute ammonite with constricted early whorls; middle growth with numerous low ribs; body chamber largely smooth with constricted aperture; dimorphic; microconch smaller with ribs extending onto body chamber; macroconch larger with smooth body chamber.

Discussion — Cobban and Hook (1983), from examining large collections of the type species from west-central New Mexico, recognized that *Neoptychites xetriformis* Pervinquiere represented the microconch of the more abundant macroconch, *Neoptychites cephalotus* (Courtiller). This species is quite variable in regard to whorl shape; from compressed to inflated, and in regard to the strength and density of the ribbing. It would thus seem that *Neoptychites* is a widespread, long-ranging monospecific genus.

Occurrence — Throughout the lower Turonian into middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone of Colorado, Arizona, New Mexico, west Texas, northern Mexico, southern Europe, north and central Africa, Middle East, Madagascar, India, and Japan.

Paleoecology — Batt (1987) places ammonites of this genus in his morphotypes IDQs, 26, IDQs(v), 30, and ICCs(v), 42, finding little evidence of water depth control with examples ranging from shallow water shales to pelagic limestones. Their restriction to pelagic limestones indicates a possible intolerance of reduced oxygen and their restriction to the southern seaway and northern Tethys indicates the ammonite is a good sensor of tropical to subtropical water masses.

Neoptychites cephalotus (Courtiller, 1860)

Plate 32, Figure J

Neoptychites xetriformis Pervinquiere, 1907, p. 389, pl. 27, figs. 5–7, text-figs. 153–154.
Neoptychites cephalotus (Courtiller); Pervinquiere, 1907, p. 393, pl. 27, figs. 1–4, text-fig. 152.
Neoptychites cephalotus (Courtiller); Cobban and Scott, 1972, p. 90, pl. 30, fig. 9, text-figs. 49–50.

Neoptychites cephalotus (Courtiller); Kennedy and Wright, 1979b, p. 670, pl. 82, figs. 3–5, pl. 83, pl. 84, fig. 3, pl. 85, pl. 86, figs. 4–5, text-fig. 2, (with synonymy).
Neoptychites xetriformis Pervinquiere, 1907; Kennedy and Wright, 1979b, p. 679, pl. 84, figs. 1–2, pl. 86, figs. 1–3, (with synonymy).
Neoptychites cephalotus (Courtiller); Cobban and Hook, 1983, p. 14, pl. 3, figs. 9–11, pls. 9–12, text-figs. 9–11.
Neoptychites xetriformis Pervinquiere; Kennedy and Cobban, 1988, p. 604, Fig. 3.3–4, 8–9, (with additional synonymy).
Neoptychites cephalotus (Courtiller); Cobban, Hook, and Kennedy, 1989, p. 52, figs. 54, 88BB–FF.

Diagnosis — As for genus.

Discussion — A number of crushed vascoceratids from the lower shale member of the Mancos Shale are very involute with ribbing and constrictions like that found in *Neoptychites* and these specimens surely represent *Neoptychites cephalotus*.

Occurrence — Across Black Mesa in the lower Turonian *Vascoceras birchbyi* subzone through *Mammites nodosoides* Zone from BM18 to a short distance below BM27 (Kirkland, 1990), elsewhere as for genus.

Illustrated material — MNA N5010 from MNA loc. #262, above BM18, middle part, lower shale member, Mancos Shale.

Subfamily Pseudotissotiinae Hyatt, 1903
Genus *Thomasites* Pervinquiere, 1907

Type species — *Thomasites rollandi* (Peron, 1889).

Diagnosis — Medium sized, involute ammonites with globose to compressed tabulate whorl section; umbilical bullae give rise to two to four ribs which cross flank to weak ventrolateral tubercles, siphonal tubercles may be on low keel at some stage in growth; ornament reduced on nearly smooth body chamber which may retain umbilical bullae and have a constricted aperture; suture simplified.

Discussion — Reyment (1979) maintained that *Gombeoceras* Reyment, 1954 was distinct from *Thomasites* Pervinquiere, 1907 in developing a low siphonal keel a some some stage in ontogeny. Barber (1957) had demonstrated that *Gombeoceras gongilense* Woods was a very variable species and erected numerous subspecies. Wright and Kennedy (1981) synonymized this genus on the basis that the development of siphonal ornament was highly variable and some of the specimens of *Thomasites* illustrated by Pervinquiere (1907) display a low siphonal ridge.

Occurrence — A Tethyan ammonite from the uppermost Cenomanian through lower Turonian of Arizona, New Mexico, west Texas, northern Mexico, Europe (most common in southern Europe), north and central Africa, Middle East, and Turkestan.

Paleoecology — Batt (1987) has not not assigned *Thomasites* from Black Mesa to his morphotypes. *Thomasites* sp. cf. *T. gongilense* (Woods) would best fit his morphotypes IDQs, 26 and ICQs, 27. Species of this genus as with other vascoceratid appear to be good indicators of subtropical to tropical conditions.

Thomasites sp. cf. *T. gongilensis* (Woods, 1911)
Plate 23, Figures A–E, H

Gombeoceras gongilense (Woods): Reyment, 1955, p. 63, pl. 14, fig. 5, pl. 21, fig. 4.
Gombeoceras gongilense (Woods): Barber, 1957, p. 39, pl. 17, figs. 1–6, pl. 18, figs. 1–4. pl. 19, figs. 1–6, pl. 20, fig. 3, pl. 33, figs. 1–20.
Thomasites gongilensis (Woods): Wright and Kennedy, 1981, p. 100, pl. 24, fig. 1, pl. 25, fig. 1.
Thomasites gongilensis (Woods): Zaborski, 1987, p. 47, figs. 29, 34–35, (with synonymy).

Diagnosis — Medium-sized, involute ammonites with somewhat compressed, flattened flanks and distinct ventrolateral shoulder to inflated with broadly rounded ventrolateral shoulder; umbilical bullae give rise to low ribs, with one to two secondary ribs arising at mid-flank, all bearing one pair of ventrolateral tubercles, venter with weak siphonal ridge bearing one clavate tubercle corresponding to each flank rib; ventral tubercles weaken greatly on the body chamber; suture simple and little incised.

DIMENSIONS

Specimen	D	U	Wb	Wh	Wb/Wh
MNA N3504	80(100)	26(32.5)	"29"(36)	35(44)	.79
MNA N3499	70(100)	19(27)	34(48.5)	28(40)	1.21
MNA N3520	87(100)	20(23)	32(37)	36(41)	.89

Discussion — The specimens from Black Mesa, while variable, display many consistent features. Specimens are widest at the umbilical shoulder with moderately flattened flanks and arched venter. Phragmocone with 5–6 primary ribs per half-whorl arising from moderate to strong umbilical bullae, broad and weak on crossing flank to distinct ventrolateral tubercle on prominent ventrolateral shoulder, weak or absent on venter. Two very weak intercalated secondary ribs arise high on flank and give rise to ventrolateral tubercles of equal strength with those of primary ribs. There is one weak clavate siphonal tubercle for each ventrolateral tubercle. On the adult body chamber the venter becomes more broadly arched and the ribs and ventral tubercles greatly weakened, with umbilical bullae retained or sometimes reduced.

The broad range of variation documented for *Thomasites gongilensis* in Africa by Barber seems to extend to the forms from Black Mesa as well. Specimens range from nearly smooth inflated adults with strong umbilical bullae (MNA N3499, Plate 23, figs. C, E) to compressed specimens maintaining ventrolateral and siphonal tubercles without strong umbilical tubercles to the base of body chamber (MNA N3520, Plate 23, figs. B, D). None of the specimens display any sign of a siphonal keel visible on many specimens of *Thomasites gongilensis* illustrated in the literature. Kennedy (1988, personal communication) has noted that overall, this population has stronger umbilical bullae than is typical in the species.

Occurrence — At Black Mesa known only from a few specimens from the late Cenomanian *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone from septarian concretion marker bed BM11 on the westernmost side of Coal Mine Mesa in the southwest (MNA loc. #814). Elsewhere, from southern England and Africa.

Illustrated material — MNA N3494, N3499, N3520, N3521 from MNA loc #814, BM11, lower part, lower shale member, Mancos Shale.

Genus *Rubroceras* Cobban, Hook, and Kennedy, 1989

Type Species — *Rubroceras alatum* Cobban, Hook, and Kennedy, 1989.

Diagnosis — Small to medium sized; moderately evolute to moderately involute ammonites; inflated inner whorls with large umbilical tubercles, rouded venter crossed by transverse ribs bearing ventrolateral and siphonal tubercles; adult body chamber ornamented by strong rectiradiate ribs, accentuated at the ventrolateral shoulder; suture moderately incised with narrow, symetrical to asymetrical bifid L lobe.

Discussion — *Rubroceras* was described for ammonites with inflated inner whorls like those of inflated forms of *Thomasites* and *Nigericeras*, but differing in retaining flange-like primary ribs on body chamber (Cobban and others, 1989). The genus is superficially very similar to *Thomasites koulabicus* from central Asia (Atabekyan, 1966; Stankievich, 1969). Cobban and others (1989) report that Russian ammonite workers believe that *Thomasites koulabicus* is better assigned to *Nigericeras*.

Occurrence — The genus was described from the latest Cenomanian of southwestern New Mexico, where several species occur in the *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone. All other occurrences known to the author are from this zone but different subzones. Material from Black Mesa is from the slightly older *Euomphaloceras irregulare* subzone, and a possible specimen from southeastern Colorado is from the slightly younger *Nigericeras scotti* subzone.

Paleoecology — Batt assigned the species from Black Mesa (listed as *Koulibiceras* sp. cf. *K. koulibicus* (Kler) to his morphotype IDDr, 20 and noted it had a subtropical to tropical distribution.

Rubroceras rotundum Cobban, Hook, and Kennedy, 1989
Plate 23, Figures F, G

Rubroceras rotundum Cobban, Hook, and Kennedy, 1989, p. 56, figs. 58, 94, Z–CC.

Diagnosis — Medium-sized, moderately involute species, with inflated whorls and inflated whorl section; strong ribs as wide as interspaces arising in pairs from strong umbilical bullae, with two or more secondary ribs arising on flank between each pair of umbilical tubercles bearing closely spaced ventrolateral and siphonal tubercles.

Discussion — One moderately distorted ammonite from the *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone in extreme southwestern Black Mesa compares well with *Rubroceras rotundum*. It has a diameter of 63 mm and umbilical diameter of 18 mm (umbilical ratio of 28.5%). At this diameter the whorl breadth is 42 mm and height is 23 mm (Wb/Wh of 1.82) and the shell has an overall globose appearance, with an overhanging umbilical wall. Only the outer half whorl is well enough preserved to described. There are 4 pairs of primary ribs arising from strong twined umbilical tubercles. These ribs are pass up very strongly to bullate lateral tubercles and weaken somewhat across the venter where they bear closely spaced weak ventrolateral and siphonal tubercles as do the secondary ribs. The secondary ribs are intercalated arising on the flank. There are two between the pair of primary ribs closest to and furthest away from the aperture, while there are five in the intervening position, possibly as a pathologic feature.

This specimen most noticeably differs from *Rubroceras rotundum* in its twinned umbilical bullae. The pattern of tuberculation and inflated whorls make this specimen reminiscent of *Calycoceras*, with which it had initially been confused.

Occurrence — At Black Mesa only known from one specimen from the septarian concretion horizon BM11, late Cenomanian *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone in extreme southwestern Black Mesa at western Coal Mine Mesa (MNA loc. #814). The species is reported from the slightly younger *Neocardioceras juddii* subzone insouthwestern New Mexico.

Illustrated material — MNA N3495 from MNA loc. #814, BM11, lower part, lower shale member, Mancos Shale.

Family Collignoniceratidae Wright and Wright, 1951
Subfamily Collignoniceratinae Wright and Wright, 1951
Genus *Cibolaites* Cobban and Hook, 1983

Type species — *Cibolaites molenaari* Cobban and Hook, 1983.

Diagnosis — Small to medium sized, moderately involute ammonites; bullate umbilical tubercles giving rise to low ribs branching and/or intercalated, bearing clavate ventrolateral tubercles and arching forward to clavate siphonal tubercle.

Discussion — Cobban and Hook (1983) included *Cibolaites* within the subfamily Barroisiceratinae Basse, as the genus lacks inner ventrolateral tubercles. As the superficially similar Barroisiceratinae of the Coniacian arose from the collignoniceratid *Reesidites* Wright and Matsumoto (1954) of the late Turonian, and *Cibolaites* is the earliest genus of Collignoniceratidae and most probably gave rise to *Collignoniceras* at the base of the middle Turonian by the addition of an inner ventrolateral tubercle, it is felt that *Cibolaites* should be included within the Collignoniceratinae (Kennedy and others, 1986)

Occurrence — High in the lower Turonian *Mammites nodosoides* Zone of Arizona (Plates 51, 52) and New Mexico. Kennedy and others (1986) report an undescribed species of the genus from the late Cenomanian *Neocardioceras juddii* Zone of southern England and northern France.

Paleoecology — Batt (1987) places *Cibolaites molenaari* in his morphotype ICQrn, 17 and found this taxon to be restricted to proximal offshore muds. *Cibolaites* ? sp. would best fit morphotype ECCf(sk), 37 and in this case would seem to have a similar distribution.

Cibolaites molenaari Cobban and Hook, 1983
Plate 35, Figures D, I

Cibolaites molenaari Cobban and Hook, 1983; p. 16–18, pl. 2, figs. 1–9; pl. 3, figs. 3–8; pl. 8, figs. 6–8; pl. 13, figs. 1–5, pl. 14; text-fig. 14
Cibolaites molenaari Cobban and Hook; Cobban and Hook, 1989, p. 252, fig. 8C, D.

Diagnosis — Medium-sized, moderately involute species with whorls with steep umbilical slope, broadest at umbilical shoulder, flattened flanks tapering to ventrolateral shoulder, and sharply angled venter; broad ribs arise in pairs from umbilical bullae with 1–2 intercalated ribs arising on flank pass across flank to clavate ventrolateral tubercles, angle forward across venter to give rise to high clavate siphonal tubercles; umbilical bullae tend to be lost on adult body chamber, while retaining ribs and ventral tubercles.

Discussion — The specimens from Black Mesa all consist of compacted shale specimens displaying features of species.

Occurrence — At Black Mesa scattered across the region from BM32 to BM36 highest lower Turonian *Mammites nodosoides* Zone (Kirkland, 1990). Elsewhere only known from west-central New Mexico.

Illustrated material — MNA N4887 from MNA loc. #989, below BM34; MNA N4897 from MNA loc. #262, one meter below BM33; both from middle part, lower shale member, Mancos Shale.

Cibolaites ? sp.
Plate 35, Figures E–H, J

Diagnosis — Small, moderately evolute to moderately involute ammonites, apparently high whorls with flattened flanks; dense flexuous ribs (15–20 ribs per half-whorl) arising from weak umbilical bullae or not, ribs weak to strong across flanks as wide as interspaces, flex forward at ventrolateral shoulder, where there may or may not be a very weak inner ventrolateral tubercle and weak outer ventrolateral tubercle, pass forward to join siphonal keel which may or may not have small siphonal clavae equal to ribs. Appears adult at around 30 mm with weakening of ribbing and loss of umbilical bullae.

Discussion — These small ammonites from Black Mesa consist of compacted shale specimens that have the same distribution as *Cibolaites molenaari* and, other than the fact that Cobban and Hook (1983) have documented that juvenile *Cibolaites molenaari* has weak, coarse ornament on early whorls, would have been interpreted as juveniles. The presence of weak inner ventrolateral tubercles on some specimens, a siphonal keel, and in many cases more evolute whorls, suggest that these ammonites may be better assigned to *Collignoniceras* and at least would appear to represent a transitional form between these two genera. *Collignoniceras woollgari* is distinct in displaying strong inner ventrolateral tubercles from an early stage of development. This interesting ammonite represents a new species which seems to hold an important position within the Collignoniceratidae, and final assignment to genus most await better material.

Occurrence — At Black Mesa scattered across the region from BM32 to BM36 highest lower Turonian *Mammites nodosoides* Zone (Kirkland, 1990).

Illustrated material — MNA N4870 from MNA loc. #262, above BM32; MNA N4901 from MNA loc. #262, 2 m below BM32; MNA N4904 from MNA loc. #262, one meter above BM32; MNA N5045 from MNA loc. #262, 2 m above BM32; MNA N4893 from MNA loc. #989, one meter above BM32: all from middle part, lower shale member, Mancos Shale.

Genus *Collignoniceras* Breistroffer, 1947

Type species — *Collignoniceras woollgari* (Mantell, 1822).

Diagnosis — Medium to large, evolute ammonites; compressed whorls during early growth with rather dense strong ribs arising from umbilical bullae or intercalated at mid-flank bearing inner and outer ventrolateral tubercles, with siphonal clavae; whorls become more quadrate on mature whorls with ribs weakening and becoming more widely spaced, with inner and outer ventrolateral tubercles enlarging and fusing to form ventrolateral horns, which may even absorb umbilical tubercle on body chamber.

Occurrence — Worldwide, is common in the middle Turonian, and rarely in the upper Turonian of Europe.

Paleoecology — Batt (1987) has recognized that this genus ranges from morphotypes ECCrn (sk), 36 and ECCf (sk), 37 for early and middle growth stages to morphotype to ECQ(R)N, 3 for adults. He found that specimens in early to middle growth stages are abundant in all facies across the seaway and that adults were restricted to shallow water facies on the margins of the seaway, indicating a change in life habits through ontogeny, with juveniles living in the upper water column and becoming more benthonic in habit with increasing size, with exclusion from the central seaway due to intolerance of reduced oxygen conditions. The geographic distribution of these ammonites indicates they were temperate forms.

Collignoniceras woollgari (Mantell, 1822)

Diagnosis — Medium to large *Collignoniceras* with ribs strongly projecting on venter to form chevrons on venter with clavate siphonal tubercles usually forming siphonal keel, adult ventrolateral horns formed primarily by the enlargement of the inner ventrolateral tubercles, which absorb the clavate outer ventrolateral tubercles.

Discussion — Cobban and Hook (1979) have documented that most of the North American illustrated forms of *Collignoniceras woollgari* represent a distinct late variety. The type specimen of *Collignoniceras woollgari* is from the middle Turonian of southern England and shares with other examples of the highly variable population: persistence of secondary ribs into middle growth stages, more siphonal clavae than ventrolateral tubercles, and looped ribs connecting opposite ventrolateral horns in the adult stage (Kennedy and others, 1980). North American forms of this type are restricted to the lower part of the middle Turonian and thus represent only a portion of the range of early forms which occurs throughout the middle Turonian in other regions. The late North American variety is also highly variable (i.e., Hass, 1946), but is distinctive in the early loss of secondary ribs leading to whorls at middle growth with more widely-spaced primary ribs and siphonal clavae equal in number to the ventrolateral tubercles.

Most of the material from Black Mesa consists of crushed shale specimens in early growth stages, making confident identifications to subspecies impossible. However, specimens in middle-to-adult growth stages occur as both crushed shale specimens and uncompacted specimens at critical intervals, permitting the stratigraphic distribution of these forms at Black Mesa to be fairly accurately determined.

Occurrence — In North America restricted to approximately the lower half of the middle Turonian, elsewhere throughout the middle Turonian of the the Northern Hemisphere and northern Australia, rare in the upper Turonian of Europe.

Collignoniceras woollgari woollgari (Mantell, 1822)
Plate 39, Figures A, C, D, F, G

Prionotropis woollgari var. *mexicana* Böse, 1927, p. 262, pl. 11, figs. 11–12.
Selwynoceras mexicanum (Böse); Powell, 1963, p. 1225, pl. 166, figs. 2–7, pl. 167, figs. 1, 3–8, pl. 168, fig. 4, text-figs. 2a–e, 3a–h, 4a–g.
Collignoniceras woollgari (Mantell); Cobban and Scott, 1972, p. 94, pl. 14, fig. 5, pl. 30, fig. 1, pl. 37, figs. 9–10.
Collignoniceras woollgari woollgari (Mantell); Cobban and Hook, 1979, pl. 1, figs. 1–11, pl. 2, figs. 5–22, pl. 4, figs. 11–12, pl. 5, figs. 13, (non? 14–16), pl. 12, figs. 1–2, text-fig. 12, (with synonymy).
Collignoniceras woollgari (Mantell); Kennedy, Wright, and Hancock, 1980, p. 560, pls. 62–67, pl. 69, figs. 3–4, pl. 71, figs. 1–3, text-figs. 1A, 2–4.
Collignoniceras woollgari (Mantell); Wright and Kennedy, 1981, p. 103, pl. 28, figs. 1–3, pl. 29, figs. 1–7, pl. 30, figs. 1–3.
Collignoniceras woollgari woollgari (Mantell); Kennedy and Cobban, 1988, p. 604, fig. 7.14–15.

Diagnosis — Variety of *Collignoniceras woollgari* with secondary ribs persisting well into middle growth stages; siphonal tubercles outnumbering ventrolateral tubercles, and looped ribs connecting opposite ventrolateral horns on adult.

Discussion — Most specimens consist of crushed shale specimens not positively identifiable to subspecies. Well preserved specimens of middle and adult growth stages are preserved near the top of the middle shale member at Blue Point in septarian concretion horizon, unit 124. Fragments of adult body chambers were also observed in the base of the Hopi Sandy Member at several sites around Black Mesa.

Occurrence — At Black Mesa common to abundant in the middle Turonian *Collignoniceras woollgari woollgari*-*Mytiloides hercynicus* subzone through *Collignoniceras* *woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone, BM35 through lower Hopi Sandy Member (Kirkland, 1990). Elsewhere throughout the Western Interior, west Texas and Mexico, throughout the middle Turonian of Europe, Russia, Japan, west coast of North America, and northern Australia.

Illustrated material — MNA N4860 from MNA loc. #989, 3 m below BM66; MNA N3554, N4834, N3555 from MNA loc. #262, concretions one meter below BM70; all from middle shale member, Mancos Shale.

Collignoniceras woollgari regulare (Haas, 1946)

Plate 39, Figure B; Plate 40, Figure A (c); Plate 45, Figure J; Plate 46, Figures B–G; Plate 47, Figures B, E, F

Prionotropis woollgari Mantell; Stanton, 1893, p. 174, pl. 42, figs. 1–4.
Prionotropis woollgari (Mantell) and varieties; Haas, 1946, p. 150, pls. 11–12, pl. 13, figs. 1–3, 5–18, (non 4, 19), pl. 14, figs. 1–10, 12–16, (non 7–8), pls. 16–17, pl. 18, figs. 1–2, 7–9, pl. 24, text-figs. 1–4, 6–44, 46–91.
Collignoniceras woollgari regulare (Haas); Cobban and Hook, 1979, p. 22, pl. 3, pl. 12, fig. 3.
Collignoniceras woollgari regulare (Haas); Cobban, 1983, p. 16, pl. 15, figs. 2–4, 7–11.
Collignoniceras woollgari regulare (Haas); Kennedy, 1988, p. 74, pl. 14, figs. 1–2, 4–5, 10–11, (with synonymy).
Collignoniceras woollgari regulare (Haas); Kennedy and Cobban, 1988, p. 606, fig. 7.9–12.

Diagnosis — Variety of *Collignoniceras woollgari* with intercalated ribs only on early whorls with middle and later growth stages characterized by strong, progressively more distant primary ribs with siphonal clavae for each rib.

Discussion — As with the subspecies described above, many of the specimens of *Collignoniceras woollgari regulare* consist of crushed juvenile shale specimens, however, there are relatively more examples of middle to adult stages present, perhaps reflecting shallowing of water depth during the range of this subspecies at Black Mesa. Specimens that can be placed in this subspecies have been found near the middle of the Hopi Sandy Member, and there is an interval of several meters between these occurrences and the highest occurrence of *Collignoniceras woollgari woollgari*, making the lower limits of its range imprecisely known within the Hopi Sandy Member at Black Mesa. *Collignoniceras* is only recorded from the lower few meters of the upper shale member overlying the Hopi Sandy Member, but well preserved specimens are common at the Top of the Blue Point Tongue of the Toreva Formation and are present in the lower sandstone member of the Toreva Formation at Blue Point in southwestern Black Mesa.

Occurrence — At Black Mesa common to abundant in the middle Turonian, *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone from middle Hopi Sandy through the lower few meters of the upper shale member throughout the region (Kirkland, 1990), common at the the top of the Blue Point Sandstone Tongue (MNA loc. #1150) and present in the lower sandstone member of the Toreva Formation at Blue Point in the southwest (MNA loc. #342). Elsewhere apparently restricted to the Western Interior, central Texas, and northern Mexico.

Illustrated material — MNA N1169 from MNA loc. #812, Hopi Sandy Member, Mancos Shale; MNA N3590 from MNA loc. #989, 13 m above base of Hopi Sandy Member, Mancos Shale; MNA N3552, N4845, N4846, N4847, N4848, N5396 from MNA loc. #1150. caprock, Blue Point Sandstone Tongue, Toreva Formation; MNA N4848 from MNA loc. #342, lower sandstone member, Toreva Formation.

Collignoniceras n. sp. ? aff *C. carolinum* (d'Orbigny)

Plate 45, Figures G, I; Plate 46, Figure A

Collignoniceras carolinum (d'Orbigny); Kennedy, Wright, and Hancock, 1980; p. 574, pl. 68, figs. 1–11, pl. 76, figs. 1–2, text-figs. 1b, 5.
? *Collignoniceras woollgari woollgari* (Mantell); Cobban and Hook, 1979, pl. 5, figs. 14–16.

Diagnosis — A medium-sized species of *Collignoniceras* that has early growth stages like that of *Collignoniceras woollgari*, but apparently matures at a much smaller diameter as indicated by a great reduction in rib strength and reduction and loss of the inner ventrolateral tubercles, clavate outer ventrolateral tubercles and siphonal tubercles that may give the tabulate venter of the compressed body chamber a tricarinate appearance.

Discussion — This species appears distinct from *Collignoniceras woollgari* in its smaller adult size and in the reduction of the inner ventrolateral tubercles on maturity, as opposed to their strengthening to form ventrolateral horns.

Two specimens of this type have been recovered from the top of the Blue Point Tongue of the Toreva Formation at Blue Point. The best preserved specimen (MNA N4850, Plate 45, figs. G, I) is a medium-sized, evolute phragmocone 86 mm in diameter, has an umbilical ratio of 36%, width of 22mm, and whorl breadth to height ratio of 0.67. To a diameter of around 54 mm the ribbing is dense (15 ribs per half-whorl) with ribs inclined forward from umbilical tubercles to inner ventrolateral tubercles and clavate outer ventrolateral tubercles from which the ribs weaken greatly and angle forward to give rise to strong clavate umbilical tubercles. Beyond a diameter of 54 mm, ribs broaden and weaken (14 ribs on final visible half-whorl), and umbilical and inner ventrolateral are greatly reduced, with venter flattening and with clavate outer ventrolateral and siphonal tubercles has a tricarinate appearance. The other specimen (MNA N4894, Plate 45, fig. A) is 79.5 mm in diameter, umbilical ratio of 36.5 % and, while ribbing on final half-whorl is somewhat stronger, displays the same features and ontogenetic trends.

Cobban and Hook (1979) illustrated a very similar ammonite as *Collignoniceras woollgari woollgari* (Mantell) from a sandstone concretion 34 meters above the base of the Mancos Shale in Mesa County, western Colorado (*Collignoniceras woollgari woollgari* subzone). As interpreted from their illustration, the specimen (USNM 252799) has a diameter of 106 mm, an umbilical ratio of 40%, and width of approximately 23 mm. The ribs are strong and regularly spaced to a diameter 72 mm, at which point rib strength markedly declines and the inner ventrolateral tubercles decrease in strength. Although older, this ammonite is likely conspecific with the Black Mesa examples, which occur in the *Collignoniceras woollgari regulare* subzone.

Collignoniceras vermilionense (Meek and Hayden) from the *Prionocyclus percarinatus* Zone of Cobban (1984a) of northeastern Nebraska, is somewhat similar in having single outer ventrolateral tubercles in mature specimens, but apparently loses the inner ventrolateral tubercle at a much earlier diameter and develops ventrolateral horns on the adult (Cobban, 1983). The Black Mesa specimens may represent an intermediate species between *Collignoniceras woollgari* and *Collignoniceras vermilionense*.

Cobban (1989, personal communication) has suggested these ammonites may represent the microconch of *Collignoniceras woollgari regulare* comparable to the gracile form of *Prionocyclus* described below, but it would seem to be extremely rare in comparison to specimens of typical *Collignoniceras woollgari regulare*. It differs from this new species in having more distant ribs at a comparable size, a squarer whorl section, much larger adult size, and increasing the size the inner ventrolateral tubercles to the point where they absorb the outer ventrolateral tubercles to form horns.

Occurrence — At Black Mesa uncommon in the *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone at the top of the Blue Point Tongue of the Toreva Formation at Blue Point, southwestern Black Mesa (MNA loc. #1150), with an additional possible example from the older *Collignoniceras woollgari woollgari* subzone in western Colorado.

Illustrated material — MNA N4850, N4894 from MNA loc. #1150, caprock, Blue Point Sandstone Tongue, Toreva Formation.

Genus *Prionocyclus* Meek, 1876

Type species — *Prionocyclus wyomingensis* (Meek, 1876).

Diagnosis — Medium to large, evolute ammonites with compressed whorls during early growth; densely ribbed with ribs arise from umbilical bullae, branching or are intercalated, straight to flexuous across flank, giving rise to nodate to spinose inner ventrolateral tubercles and generally to clavate outer ventrolateral tubercles, ribs fade prior to reaching serrate keel; late growth involves decrease in rib density, increase in the strength of ventrolateral tubercles, often with loss of outer ventrolateral tubercles with or most often without the moderate development of ventrolateral horns; keel may become entire in some species.

Discussion — Kennedy (1988) has recognized dimorphism in *Prionocyclus* with a gracile form having more compressed whorls and denser ribbing and a robust form having more rectangular whorls and coarser ribbing.

Occurrence — Widespread in the Western Interior of Canada and the United States, as well as northern Mexico during the late middle through late Turonian. Also in the late Turonian of Japan and the North Pacific realm.

Paleoecology — Batt (1987) has recognized that this genus, like *Collignoniceras*, ranges from morphotypes ECCrn (sk), 36 and ECCf (sk), 37 for early and middle growth stages to morphotype to ECQ(R)N, 3 for adults, indicating a change in life habits through ontogeny, with juveniles living in the upper water column and becoming more benthonic in habit. He found them to have a much wider geographic distribution than that seen for *Collignoniceras*, reflecting decreased water depth across the seaway during peak regression. The geographic distribution of these ammonites also indicates they were temperate forms.

Prionocyclus percarinatus (Hall and Meek, 1856)
Plate 40, Figures B–F, I

Ammonites percarinatus Hall and Meek, 1856, p. 396, pl. 4, fig. 2a–b.
Collignoniceras woollgari (Mantell); Stephenson, pl. 12, fig. 3.
Subprionocyclus percarinatus (Hall and Meek); Cobban, 1983, pl. 5, figs. 26–37.
Prionocyclus percarinatus (Hall and Meek); Cobban, 1984a, p. 84.

Description — Small, moderately evolute prionocyclids with compressed, densely ribbed whorls; ribs flexuous with primary ribs begining at fine umbilical bullae and from one to five intercalated ribs arising low on flank, ribs bend forward at the ventrolateral shoulder a disappear at the base of the keel; ventrolateral tubercles variable ranging from rarely stronger ventrolateral tubercles, inner and outer ventrolateral of equal strength, outer ventrolateral tubercles stronger with inner ventrolateral tubercles sometimes lost, to no ventrolateral tubercles; inner ventrolateral tubercles nodate, outer ventrolateral tubercles nodate to clavate, serrate with each serration corresponding to a rib or less commonly continuous.

Discussion — Cobban (1983) has described a number of well preserved specimens of this small species (largest specimen 3.2 cm) from the type locality in northeastern Nebraska. The author was able to visit the site and secured additional material to compare with specimens from Black Mesa.

Most of the specimens from Black Mesa came from a single fossiliferous concretion from the Hopi Sandy Member of the Mancos Shale at Lohali Point and compare well to the material from northeastern Nebraska. A number of the Black Mesa specimens appear to have a complete keel as opposed to the serrated keel described by Cobban (1983), however, several specimens illustrated by him appear to have a continuous keel (pl. 5, figs. 27, 31, 32) demonstrating the subdued nature of the serrations on many specimens.

In addition to the specimens from the Hopi Sandy Member, an apparently adult body chamber was recovered from the Blue Point Tongue at Blue Point. This specimen (MNA N3582, Plate 40, figs. E, F) is atypical in its even ribbing. Other specimens were most likely overlooked among the many crushed specimens of *Collignoniceras woollgari* encountered during this study.

While the material from northeastern Nebraska could not be placed in stratigraphic context in relationship with other better known ammonites, specimens from the Black Hills occur in concretions overlying concretions with *Collignoniceras woollgari regulare*, leading Cobban (1983, 1984a) to erect a distinct zone of *Prionocyclus percarinatus* between the zones of *Collignoniceras woollgari* and *Prionocyclus hyatti*. Specimens from Black Mesa range throughout the *Collignoniceras woollgari regulare* subzone, indicating overlap of these zones at least in the southwestern United States. Hattin (1975b) has recognized *Collignoniceras woollgari* and *Mytiloides latus* from very near the top of the Carlile Shale in northeastern Nebraska. A visit by the author to these sites indicates that *Collignoniceras woollgari regulare* occurs near the top of this sequence and suggests strongly that the *Prionocyclus percarinatus* Zone should be included in the *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990, 1991).

Occurrence — At Black Mesa uncommon in the middle Turonian *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone in the Hopi Sandy Member of the Mancos Shale (locally abundant at MNA loc. #989) and at the top of the Blue Point Tongue of the Toreva Formation at Blue Point in the southwest (MNA loc. #1150). Else where in the *Prionocyclus percarinatus* Zone? in Nebraska, South Dakota, Minnesota.

Illustrated material — MNA N3587, N3583, N3590 from MNA loc. #989, 13 m above base of Hopi Sandy Member, Mancos Shale; MNA N5400 from MNA loc. #989, 15 m above base of Hopi Sandy Member, Mancos Shale; MNA N3582 from MNA loc. #1150, caprock, Blue Point Sandstone Tongue, Toreva Formation.

Prionocyclus hyatti Stanton, 1893
Plate 50, Figures L, M

Prionocyclus hyatti Stanton, 1893, p. 176, pl. 42, figs. 5–8.
Prionocyclus hyatti Stanton, Hattin, 1962, p. 79, pl. 24, figs. A–E.
Prionocyclus hyatti Stanton; Kennedy and Cobban, 1976, pl. 8, fig. 3.
Prionocyclus hyatti Stanton, Kennedy, 1988, p. 75, pl. 15–17, text-figs. 24D–F, 25–27, 31B, (with synonymy).
Prionocyclus hyatti Stanton, Kennedy and Cobban, 1988, p. 606, fig. 7.1–8, 11.

Diagnosis — Large, variable prionocyclid; densely ribbed with inner and aperturally displaced outer ventrolateral tubercles closely spaced and finely serrate keel on flattened venter; inner ventrolateral tubercles represent septate bases of long spines.

Discussion — Kennedy (1988), studying many hundred specimens from central Texas, recognized a remarkable level of intraspecific variation and was able to demonstrate that the genus *Prionocyclus* was dimorphic (see above).

The Black Mesa material is represented by few specimens, all of which are either flattened to various degrees or fragmentary. The best preserved material is from a horizon of siderite concretions, unit 212 near the top of the upper shale member at Lohali Point in northeastern Black Mesa. The specimens are laterally compacted and the venter is not visible, most specimens apparently represent the densely ribbed gracile form and the largest very poorly preserved specimen had indications of ventrolateral spines at a diameter of approximately 150 mm. Much larger specimens are common in large septarian concretions in the Blue Hill Shale from central Kansas (Hattin, 1962), but have poorly preserved inner whorls.

Small poorly preserved specimens are also present in the transition zone of the Mancos Shale with the overlying Toreva Formation at the Coal Chute section in northwestern Black Mesa.

Occurrence — At Black Mesa uncommon in the middle Turonian *Prionocyclus hyatti* Zone in the upper shale member of the Mancos Shale above BM76 in the northern part of the basin (Kirkland, 1990) and uncommon in the basal lower sandstone member of the Toreva Formation at the Coal Chute section (MNA loc. #988); elsewhere throughout the United States Western Interior, Texas, and northern Mexico.

Illustrated material — MNA N4829, N4830 from MNA loc. #989, siderite concretions 19 m below base of Toreva Formation, upper shale member, Mancos Shale.

Family Tissotiidae Hyatt, 1900
Genus *Choffaticeras* Hyatt, 1903

Type species — *Choffaticeras meslei*, Peron, 1897.

Diagnosis — Medium-sized, very to moderately involute ammonites; lanceolate whorls widest near umbilical shoulder; very weakly ribbed; prominent siphonal keel closely bounded by low ventrolateral ridges with low dense clavate tubercles.

Occurrence — Lower Turonian of southern Europe, Africa, Middle East, Madagascar, and the southern Western Interior.

Paleoecology — Batt (1987) includes ammonites of this genus in his morphotype ICCs(k), 44. This type is restricted to the distal offshore pelagic carbonate facies. The occurrences at Black Mesa would extend the range toward shore into the offshore calcareous shale facies. This ammonites' equatorial distribution would indicate that this genus is a good indicator of tropical to subtropical water masses.

Choffaticeras cf. *C. pavillieri* (Pervinquiere), 1907
Plate 34, Figure F

Pseudotissotia (*Choffaticeras*) *pavillieri* Pervinquiere, 1907, p. 353, pl. 23, figs. 4–6, text-fig. 134.
Choffaticeras pavillieri (Pervinquiere); Freund and Raab, 1969, p. 56, pl. 9, figs. 3, 4; text-figs. 11b–d.
Choffaticeras cf. *C. pavillieri* (Pervinquiere); Cobban and Scott, 1972; p. 92, pl. 34, figs. 3–6, 8–9, pl. 35, figs. 1–3, text-fig. 52 (with synonymy).

Diagnosis — Very evolute species with slender cross section.

Discussion — All the Black Mesa specimens consist of very compacted shale specimens up to around 150 mm in diameter, which are very evolute with keel visible only in lateral view. Because of the state of preservation, these specimens in large part would be easy to confuse with compacted specimens of *Placenticeras*, but for their exceedingly narrow umbilicus.

Occurrence — At Black Mesa scattered throughout lower Turonian *Mammites nodosoides* Zone from BM21 to BM32. Elsewhere at this level in Colorado, southern Europe, North Africa, Madagascar, and the Middle East.

Illustrated material — MNA N4876 from MNA loc. #989, one meter below BM27, middle part, lower shale member, Mancos Shale.

SUBORDER ANCYLOCERATINA WIEDMANN, 1960
Superfamily Turrilitaceae Gill, 1871
Family Hamitidae Gill, 1871
Genus *Hamites* Parkinson, 1811

Type species — *Hamites attenuatus* J. Sowerby, 1814.

Diagnosis — Two to three, well-separated shafts, but early helical coiling may persist; whorl section circular, compressed, or depressed, nontuberculate ribbing fine and dense to coarse and distant.

Discussion — *Stomohamites* was initially separated from *Hamites* on the basis of its finer, denser ribbing, somewhat flattened venter, and strongly collared, constricted aperture on some species.

Occurrence — Upper Aptian to middle Turonian, North America, Europe, Africa, India, and Australia.

Paleoecology — Batt (1987) places hamitids in morphotype OU, 48 and found them to be a very widespread, dominantly offshore form not restricted by facies. He interpreted these ammonites as pelagic taxa.

Hamites simplex d'Orbigny, 1840
Plate 25, Figures O. P; Plate 38, Figure F

Stomohamites simplex (d'Orbigny); Kennedy, 1971, p. 6, pl. 1, figs. 1–8.
Stomohamites cf. *S. simplex* (d'Orbigny); Cobban and Scott, 1972, p. 44, pl. 13, figs. 5–10, pl. 17, figs. 3–4.
Hammites (*Stomohamites*) *simplex* (d'Orbigny); Cobban, 1984b, p. 16, pl. 3, figs. 9, 13, pl.4, figs. 8, 13, pl. 5, figs. 4–5.
Hamites cf. *simplex* d'Orbigny; Cobban, Hook, and Kennedy, 1989, p. 56, figs. 59, 92A–K.

Diagnosis — Small species with open spire followed by two fairly straight shafts, rib index of about 4 1/2, aperture constricted.

Discussion — Cobban (1984b) found that, while apparently restricted to middle Cenomanian in Europe, the species extends upward into the upper Cenomanian in the United States. A few very compacted hamitid fragments from the middle Turonian at Black Mesa are questionably referred to this species (e.g., Plate 38, fig. F). The species is represented by a number of fragments from the latest Cenomanian *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone in the area of southwestern Black Mesa. Similar specimens were observed at the same level in the Cretaceous "undifferentiated" of the Mogollon Rim of central Arizona.

Hamites cimarronensis (Kauffman and Powell, 1977) from the *Calycoceras canitaurinum* Zone and *Hamites salebrosus* (Cobban and others, 1989) from the *Metoicoceras mosbyensis* Zone differs primarily in their much larger size.

Hamites pygmaeus (Cobban and others, 1989) from the *Neocardioceras juddii* Zone differs in its very small adult size.

Occurrence — At Black Mesa in concretions associated with BM13, latest Cenomanian, *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone at Ha Ho No Geh Canyon in the southwest (MNA loc. #305), also questionable specimens are widely scattered in the middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone (Kirkland, 1990). Elsewhere, in the middle Cenomanian of Europe, Africa, Australia, and North America, where it is also known from throughout the upper Cenomanian.

Illustrated material — MNA N4966 from MNA loc. #305, concretions associated with BM12 and BM13, lower part, lower shale member, Mancos Shale; MNA N4890 from MNA loc. #989, above BM62, middle shale member, Mancos Shale.

Genus *Metaptychoceras* Spath, 1926

Type species — *Metaptychoceras smithi* (Woods, 1896).

Diagnosis — Very small, irregularly coiled ammonites with 3 tightly appressed straight shafts; first shaft, smooth with weak constrictions; penultimate shaft ribbed; final shaft densely ribbed without constrictions or tubercles.

Discussion — Wright (1979), on reviewing the validity of the genus, found that while similar to *Hemiptychoceras* Spath, *Metaptychoceras* was smaller and more finely ribbed, with constrictions on smooth, first shaft only, Cobban (1984) added that *Metaptychoceras* had simpler sutures as well. Described from upper Turonian of central Texas, *Metaptychoceras annulatum* Kennedy (1988) is a nearly smooth form with widely spaced constrictions, flanked by ribs on the final shaft, that should perhaps be assigned to a new genus.

Occurrence — Upper Cenomanian through upper Turonian of the Western Interior, Texas, and Europe.

Paleoecology — Batt (1987) places *Metoptychoceras* in morphotype HU, 47 and found them to be a widespread, dominantly offshore form not restricted by facies. He interpreted these ammonites as pelagic taxa.

Metaptychoceras reesidei (Cobban and Scott, 1972)

Plate 10, Figure C (a); Plate 18, Figure D

Hemiptychoceras reesidei Cobban and Scott, 1972, p. 45, pl. 2, figs. 1–2.
Hemiptychoceras reesidei Cobban and Scott; Hattin, 1975, pl. 5, fig. D.
Metaptychoceras reesidei (Cobban and Scott); Cobban, 1984b, p. 18, pl. 4, fig. 7.
Metaptychoceras reesidei (Cobban and Scott); Kennedy, 1988, p. 96, pl. 19, fig. 13.

Diagnosis — Species with densely ribbed second shaft and hook, becoming suddenly more coarsely ribbed at begining of final shaft.

Discussion — One specimen (MNA N3556, Plate 18, fig. D) recovered from BM10 at Black Mesa is well preserved and consists of much of the penultimate and final shafts connected by the final bend. It compares well with the type specimen from central Colorado. The other specimen (MNA N4939, Plate 10, fig. C(a)) is a compacted specimen from BM4 that also seems to compare fairly well with the type specimen.

Occurrence — At Black Mesa one well preserved specimen was recovered from the *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone in BM10 on the west side of Black Mesa at Blue Canyon (MNA loc. #271), in addition one crushed specimen was recovered from BM4 in the underlying *Vascoceras diartianum* subzone on the north side of Black Mesa (MNA loc. #990). Elsewhere in Wyoming, Colorado, Kansas, and central Texas.

Illustrated material — MNA N4939 from MNA loc. #990, BM4; MNA N3556 from MNA loc. #271, BM10; both from lower part, lower shale member, Mancos Shale.

Genus *Puebloites* Cobban and Scott, 1972

Type species — *Puebloites corragatum*. (Stanton, 1893).

Diagnosis — Medium sized, irregularly coiled ammonites with shallow helical spire, tending to be elliptical; oblique dense ribbing without tubercles, flared ribs, or constrictions.

Discussion — *Puebloites* is best known from Colorado and has only been rarely reported from other areas.

Occurrence — Upper Cenomanian through lower Turonian of Colorado, Kansas, New Mexico, Arizona, and France.

Paleoecology — Batt (1987) includes these ammonites in his morphotype L, 46 and reports that they range from proximal offshore muds to pelagic environments, where they are most common. He interprets them as benthic taxa or if pelagic living in the middle to lower water column, where they would be excluded by anoxic water conditions.

Puebloites spiralis Cobban and Scott, 1972

Plate 33, Figure J (b)

Puebloites spiralis Cobban and Scott, 1972, p. 46, pl. 18, figs. 1–5, pl. 19, figs. 1–6.

Diagnosis — Species with low, open, symmetrical spire; ribbing variable with rib index ranging from 4–8.

Occurrence — At Black Mesa known only from Blue Point (MNA loc. #262) in the lower Turonian *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone just above BM17, also in Colorado, New Mexico, and Kansas.

Illustrated material — MNA N4997 from MNA loc. #262, BM18, base of middle part, lower shale member, Mancos Shale.

Puebloites greenhornensis Cobban and Scott, 1972

Plate 35, Figures K, L

Puebloites greenhornensis Cobban and Scott, 1972, p. 46, pl. 19, figs. 7–28.

Diagnosis — Species with densely ribbed inner whorls and more coarsely ribbed very elliptical outer whorls.

Discussion — One compacted specimen (MNA N4866, Plate 35, fig. L) seems to display the adult aperture and would seem to indicate that the spire straightens before the aperture and becomes densely ribbed with constricted aperture.

Occurrence — At Black Mesa in the lower Turonian *Mammites nodosoides* Zone from about a meter above BM26 to BM30 (Kirkland, 1990) and in central Colorado.

Illustrated material — MNA N4866 from MNA loc. #262, above BM30; MNA N4875 from MNA loc. #989, below BM27; both from middle part, lower shale member, Mancos Shale.

Family Anisoceratidae Hyatt, 1900
Genus *Anisoceras* Pictet, 1854

Type species — *Anisoceras saussureanus* (Pictet, 1847).

Diagnosis — Medium-sized, irregularly coiled ammonite with open helical spire extending into a long hook prior to aperture; ornamented by numerous ribs periodically bearing ventral and lateral tubercles connected by looped rib.

Occurrence — Albian to late Turonian of Europe, Africa, Madagascar, Pakistan, India, Mexico, and southern Western Interior.

Paleoecology — Batt (1987) places *Anisoceras* in morphotype OU, 48 and found them to be a very widespread, dominantly offshore form not restricted by facies. He interpreted these ammonites as pelagic taxa, in which the long spines would be a useful defensive adaptation.

Anisoceras coloradoense Cobban, Hook, and Kennedy, 1989

Plate 25, Figures P, T, V

Anisoceras plicatile (J. Sowerby); Cobban, 1972, p. 4, pl. 1, figs. 4–7, text-fig. 2.
Anisoceras sp. nov. aff. *plicatile* (J. Sowerby); Kennedy, 1988, p. 103, pl. 19, figs. 1, 2.
Anisoceras coloradoense Cobban, Hook, and Kennedy, 1989, p. 58, figs. 61, 94C–M, 95U–Y.

Diagnosis — A large compressed species with lateral tubercles high on flank.

Description — All specimens from Black Mesa are compacted to varying degrees. Open coiled apparently in one plane to at least 30 mm, whorl oval, expanding rapidly, densely ribbed from early stage, lateral tubercles appear at less than 10 mm connected by pair of looped ribs to ventrolateral spines which in turn are connected across venter by looped ribs. The pairs of looped, spine-bearing ribs are separated by 2–3 nontuberculate ribs. One slightly curved adult body chamber (MNA N4899: Plate 25, fig. V) was collected on which the tubercles are lost, ribbing becomes dense, and whorl section becomes constricted for the last 20 mm before aperture.

Discussion — The specimens from Black Mesa seem to demonstrate that that at least the ventrolateral tubercles on other species of *Anisoceras* represent the septate bases of spines.

The specimens of *Anisoceras coloradoense* described by Cobban (1971) and Kennedy (1988) from the *Sciponoceras gracile* Zone differ in primarily in having tubercles connected by three looped ribs. Kennedy (1988) reports that the *Sciponoceras gracile* Zone specimens, as does the present material, differs from *Anisoceras plicatile* (J. Sowerby, 1819) in their larger size, rounder nonclavate tubercles, and apparently planar spiral coiling. In defining the present species, Cobban and others (1989) note that the number of looped ribs varies between 2 and 3 and so the latest Cenomanian falls within the species concept.

Occurrence — At Black Mesa known only from the sediments associated with BM12 and BM13, latest Cenomanian *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone across Black Mesa (Kirkland, 1990) and at this level in southwestern New Mexico. Present in the *Sciponoceras gracile* Zone in Colorado and Texas.

Illustrated material — MNA N239, N4899 from MNA loc. #305, concretions associated with BM12 and BM13; MNA N4962 from MNA loc. #989, below BM12; all from lower part, lower shale member, Mancos Shale.

Genus *Allocrioceras* Spath, 1926

Type species — *Allocrioceras woodsi* Spath, 1939.

Diagnosis — Generally small, open coiled aberrant ammonites; whorls compressed to subcircular, slowly expanding, coiling in one plane or forming open spire; single ribs encircle shell, strongest on venter, some or all bearing ventrolateral tubercles.

Occurrence — Known from the latest Cenomanian *Sciponoceras gracile* Zone into the lower Coniacian of North America, Europe, Africa, and Japan.

Paleoecology — Batt (1987) places these aberrant ammonites in his morphotype OU, 48 and are found to be widely distributed across the seaway, suggesting these were pelagic forms.

Allocrioceras annulatum (Shumard, 1860)

Plate 18, Figures E–G, I

Helicoceras pariense White; Stanton, 1993, p. 164, pl. 35, figs. 2–4.
Allocrioceras annulatum (Shumard); Cobban and Scott, 1972, p. 51, pl. 20, figs. 1–14.
Allocrioceras annulatum (Shumard); Hattin, 1975, p. 32, pl. 5, figs. B–C.
Allocrioceras annulatum (Shumard); Wright and Kennedy, 1981, p. 111, pl. 32, figs. 3–7, (with synonymy).
Allocrioceras annulatum (Shumard); Kennedy, 1988, p. 104. pl. 19, figs. 3–12, 14, pl. 22, figs. 1–2, pl. 24, fig. 2, text-fig. 36.
Allocrioceras annulatum (Shumard); Cobban, Hook, and Kennedy, 1989, p. 59, fig. 96P.

Diagnosis — After initial whorl, smooth curved shaft becomes ribbed at about 2 mm in diameter and forms an open elliptical coil, that forms low helix; whorls are generally subcircular with 3 to 5 ribs per whorl diameter; each rib has ventrolateral tubercles and may be depressed across venter; ribs become more crowded toward adult aperture.

Discussion — Close to *Allocrioceras dentonense*, which may represent a more compressed variant (Kennedy, 1988) However, while the type of *Allocrioceras dentonense* is from the *Sciponoceras gracile* Zone, this form is recognized in the is recognized in the basal Turonian of west Texas above the known range of *Allocrioceras annulatum*. Other species are known to co-occur with *Allocrioceras annulatum*. *Allocrioceras larvatum* is separated on having tubercles only on alternating ribs. *Allocrioceras conlini* is distinguished by having distinct constrictions.

Occurrence — Common in the *Sciponoceras gracile* Zone at all sites at Black Mesa (Kirkland, 1990) and throughout the central United States Western Interior south into Mexico, and in northern Europe.

Illustrated material — MNA N1201 from MNA loc. #303, BM8; MNA N4924, N4925 from MNA loc. #306; all from lower part, lower shale member, Mancos Shale.

Allocrioceras sp.

Plate 25, Figure U (b)

Discussion — A small fragment of *Allocrioceras* was recovered from near the Cenomanian-Turonian stage boundary. It is a compacted specimen not assignable to species. Similar specimens have been observed at this level in the Bridge Creek Limestone Member of the Greenhorn Limestone north of Boulder Colorado (Elder, 1987b). Kennedy and others (1987) described both *Allocrioceras dentonense* Moreman, 1942 and *Allocrioceras larvatum* (Conrad, 1855) from the basal Turonian of west Texas, ranging across the Cenomanian-Turonian stage boundary.

Occurrence — Latest Cenomanian ? *Nigericeras scotti* subzone of the *Neocardioceras juddii* Zone at Ha Ho No Geh Canyon, southwestern Black Mesa (MNA loc. #305).

Illustrated material — MNA N4960 from MNA loc. #305, 2–3 m above BM13, lower part, lower shale member, Mancos Shale.

Family Baculitidae Gill, 1871
Genus *Sciponoceras* Hyatt, 1894

Type species — *Sciponoceras baculoides* (Mantell, 1822).

Diagnosis — Small to medium sized, slowly expanding baculitids distinguished by periodic constrictions of shell; prosiradiate ribs and constrictions strongest on venter.

Discussion — *Sciponoceras* can be most readily distinguished from the all other baculitids by its prominent constrictions. Species are best determined by form, strength, and spacing of ribs and constrictions and whorl shape (Kennedy, 1971). Dimorphism has been recognized, with macroconchs generally larger and microconchs developing a hooded aperture at around 10 mm in diameter (Kennedy, 1988).

Occurrence — Nearly worldwide from the upper Albian to upper Turonian. Within the Western Interior, restricted to the upper Cenomanian.

Paleoecology — Batt (1987) places the baculitids in his morphotype EB, 51, and interprets them as pelagic forms ranging from offshore muds to pelagic carbonates.

Sciponoceras gracile (Shumard, 1860)
Plate 18, Figure H; Plate 25, Figure W

Baculites gracilis Shumard?; Stanton, 1893, p. 166, pl. 36, figs. 1–3.
Sciponoceras gracile (Shumard); Cobban and Scott, 1972, p. 47, pl. 17, figs. 9–29, text-fig. 18.
Sciponoceras gracile (Shumard); Hattin, 1975, pl. 6, figs. A–B, N.
Sciponoceras gracile (Shumard); Wright and Kennedy, 1981, p. 112, pl. 31, figs. 1–3, pl. 32, figs. 8, 11, text-figs. 38A–Q, (with synonymy).
Sciponoceras gracile (Shumard); Kennedy, 1988, p. 108, pl. 20, figs. 1–14, 17–20, text-fig. 38.
Sciponoceras gracile (Shumard); Cobban, Hook, and Kennedy, 1989, p. 61, figs. 94A, B, 95G–N, 96 A, B.

Diagnosis — Small to medium sized *Sciponoceras*; oval to circular cross-section; constrictions spaced every one to one and one half diameters, with 5 to 7 ribs between each constriction, ribs weak across dorsum, are concave on inner flank and convex on outer flank, where they strengthen on curving forward across venter.

Discussion — *Sciponoceras baculoides* from the middle Cenomanian has stronger asymmetric ribs that do not recurve on the inner flank. *Sciponoceras bohemicum* from the Turonian has flattened flanks, stronger constrictions and fewer ribs, which are have much lower relief and tend to cross the venter transversely. Wright and Kennedy (1981) described *Sciponoceras bohemicum anterius* from the latest Cenomanian of southern England. Material from this level at Black Mesa is generally poorly preserved, but is tentatively identified as *Sciponoceras gracile* as specimens have distinct rather dense ventral ribbing as well as typical constrictions of the genus. It is interesting that at Black Mesa *Sciponoceras gracile* does not occur in the *Vascoceras diartianum* subzone of the *Sciponoceras gracile* Zone, although it is abundant in the overlying *Euomphaloceras septemseriatum* subzone as is typical across the United States Western Interior.

Occurrence — At Black Mesa abundant in the late Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone from BM5 to just above BM10. Elsewhere at this level known from throughout the United States Western Interior and Europe and possibly in west Africa and the north Pacific region. Also likely specimens known at Black Mesa up through the *Neocardioceras juddii* subzone of the *Neocardioceras juddii* Zone to a short distance above BM13 (Kirkland, 1990). Similar specimens at this level are present in Utah and Colorado.

Illustrated material — MNA N4923 from MNA loc. #813, BM8; MNA N4963 from MNA loc. #305, concretions associated with BM12 and BM13; both from lower part, lower shale member, Mancos Shale.

Genus *Baculites* Lamark, 1799

Type species — *Baculites vertebralis* Lamark, 1801.

Diagnosis — Small to very large baculitids, oval whorl section, lacking constrictions, variable lateral and ventral ornament.

Discussion — Early forms may have ventral hood on aperture, whereas later forms have a long straight rostrum.

Occurrence — Worldwide, lower Turonian through upper Maestrichtian.

Paleoecology — Batt (1987) places the baculitids in his morphotype; EB, 51, and interprets them as pelagic forms ranging from offshore muds to pelagic carbonates.

Baculites yokoyamai Tokunaga and Shimizu, 1926
Plate 38, Figure K

Baculites yokoyamai Tokunaga and Shimizu; Matsumoto and Obata, 1963, p. 30, pl. 8, fig. 5, pl. 10, figs. 1–6, pl. 11, figs. 1, 4–5, pl. 12, fig. 3, pl. 14, fig. 4, text-figs. 72–87.
Baculites cf. *B. yokoyamai* Tokunaga and Shimizu; Cobban and Scott, 1972, p. 48, pl. 20, figs. 15–21.
Baculites cf. *B. yokoyamai* Tokunaga and Shimizu; Hattin, 1975, pl. 8, figs. F, H.
Baculites yokoyamai Tokunaga and Shimizu; Cobban and Hook, 1979, p. 13, pl. 4, figs. 9–10.
Baculites yokoyamai Tokunaga and Shimizu; Cobban and Hook, 1983, p. 7, pl. 1, figs. 1–7.
Baculites yokoyamai Tokunaga and Shimizu; Kennedy, 1988, p. 110, pl. 23, figs, 8–10, text-fig. 29C, (with synonymy).

Diagnosis — Small, very weakly ornamented baculitids with ovate whorl section and low expansion rate, smooth or with growth lines raised into fine ribs that are strongest across venter. Growth line convex dorsal, flexing concave on the lower flank before flexing strongly forward and crossing the venter convexly. Ventral hood formed on aperture in some specimens.

Discussion — The type specimens are from the Coniacian of Japan and are comparable to small, weakly ornamented baculites from the Turonian of the Western Interior for which this name has been applied. Within the Western Interior specimens assignable to this species as used here, are known from the lower Turonian *Vascoceras birchbyi* subzone of the *Watinoceras coloradoense* Zone through the middle Turonian *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone and in the upper Turonian *Prionocyclus wyomingensis* Zone through *Prionocyclus quadratus* Zone.

Occurrence — At Black Mesa ranges from the BM26, lower Turonian, *Mammites nodosoides* Zone up through the middle shale member, middle Turonian, *Collignoniceras woollgari woollgari* subzone of the *Collignoniceras woollgari* Zone. The species was observed to occur significantly higher in the section in the southwest as compared to the northeast (Kirkland, 1990). Within the Western Interior the species ranges through the entire Turonian. In the type area of Hokkaido, ranges from the upper Turonian up into the Coniacian and is also reported from the Coniacian of Madagascar.

Illustrated material — MNA N4835 from MNA N262, above BM50, upper part, lower shale member, Mancos Shale.

Baculites calamus Morrow, 1935
Plate 38, Figure J

Baculites calamus Morrow, 1935, p. 473, pl. 49, figs. 8a–b.
Baculites calamus Morrow; Cobban and Scott, 1972, p. 49, pl. 34, fig. 7.

Diagnosis — Small baculitid with weak, broad flank ribs and simple suture.

Discussion — *Baculites calamus* is known from the upper part of the Bridge Creek Limestone Member (correlative to Pfeifer Member of central Kansas) of the Greenhorn Limestone in southwestern Kansas (Morrow, 1935; Cobban and Scott, 1972). Poorly preserved crushed baculitids with broad weak flank ribs are rare in correlative strata in the upper part of the lower shale member of the Mancos Shale at both Blue Point and Lohali Point. These baculitids can best be compared with *Baculites calamus*. This species is the earliest known baculitid with broad flank ribs. It apparently is a rare species restricted to the southern Western Interior.

Occurrence — The *Collignoniceras woollgari woollgari* — *Mytiloides hercynicus* subzone of the *Collignoniceras woollgari* Zone between BM35 and BM50 at Black Mesa (Kirkland, 1990) and at the same level in southwestern Kansas.

Illustrated material — MNA N4865 from MNA loc. #262, below BM41, upper part, lower shale member, Mancos Shale.

Superfamily Scaphitaceae Gill, 1871
Family Scaphitidae Gill, 1871
Subfamily Scaphitinae Gill, 1871
Genus *Scaphites* Parkinson, 1811

Type species — *Scaphites equalis* Sowerby, 1813.

Diagnosis — Moderately small, compressed to inflated scaphitid ammonite, with increasing involution of phragmocone during growth; rib strength variable, commonly branching and/or intercalated; the straight shaft hook of body chamber variably ribbed, often with ventrolateral tubercles and sometimes umbilical bullae on shaft; hook not overlapping phragmocone, with constricted, often thickened rim around aperture, which may expand forward at venter. Dimorphic with microconchs distinguished by smaller, more compressed shell, and macroconchs distinguished by larger size and base of body chamber largely overlapping umbilicus.

Discussion — Cobban (1951) described in detail the mid-Cretaceous species of *Scaphites* from the Western Interior, permitting the development of a precise biostratigraphy based on this group. With the recognition of a remarkable degree of variation in shell size within species, Cobban (1969) hypothosized that dimorphism such as recognized in the *Scaphites hippocrepis* group would most likely be found in all scaphitids. Many of the dimorphs in Cobban's (1951) study are separated as different subspecies.

Occurrence — Cenomanian through Campanian worldwide. Rare at Black Mesa.

Paleoecology — North American scaphitid lineages are largely endemic (Cobban, 1951). In addition, endemic species of this genus are most common in the more north-central seaway of Kansas, Wyoming and Montana — largely Kauffman's (1984) mid-temperate, Western Interior endemic center. However, abundant scaphites are found as far south as northern New Mexico during the late Turonian. Batt (1987) has placed these taxa in his morphotype IU, 49 and found them to be largely restricted to shallow water facies. Interpreted as pelagic, lower water column forms restricted from the deepest parts of the seaway. The frequency of endemic species and their exclusion from deeper parts of the seaway suggests they may be nekto-benthonic taxa.

Scaphites larvaeformis Meek and Hayden, 1859
Plate 40, Figure H

Scaphites larvaeformis Meek and Hayden; Cobban, 1951, p. 19, pl. 1, figs. 4–15, (with synonymy).
Scaphites larvaeformis Meek and Hayden var. *obesus* Cobban, 1951, p. 20, pl. 1, figs. 16–22.
Scaphites larvaeformis Meek and Hayden; Kennedy, 1988, p. 119, (with additional synonymy).

Diagnosis — Well rounded and ribbed scaphitid, with ribs on straight body chamber branching from transversely elongate, lateral bullae and intercalated.

Discussion — The one specimen on hand from Black Mesa represents a microconch and has approximately 7 pairs of primary ribs separated by 1–2 intercalated secondary ribs on its slender body chamber. It is close to the holotype (U.S.N.M. 229). The macroconchs (Kennedy, 1988) are referred to *Scaphites larvaeformis* var. *obesus* Cobban and have more inflated body chambers. The specimen from the Hopi Sandy Member on the south side of Black Mesa is about the same size as the Blue Point Tongue specimen but is more inflated and may represent a small macroconch.

Kennedy (1988) has recently synonymized many of the scaphitid species of the *Prionocyclus hyatti* Zone with *Scaphites carlilensis*; including the species of *Scaphites* described from Kansas by Crick (1978) and the species described from Texas by Moreman (1942). He refers as co-occurring macroconchs and microconchs, respectively, *Scaphites arcadiensis* and *Scaphites minutus* in texas and *Scaphites carlilensis* and *Scaphites morrowi* in the Western Interior. Cobban (1952) recognized both *Scaphites arcadiensis* and *Scaphites carlilensis* as distinct species separated primarily on the basis of stronger tubercles on the more depressed shaft of the body chamber in *Scaphites arcadiensis*. Both taxa appear to be dimorphic based on his material. Furthermore, Cobban has *Scaphites arcadiensis* descending from *Scaphites patulus*. If these forms are co-occurring variations of the same species, then it must be assumed that *Scaphites patulus* represents a strongly noded, depressed variant of *Scaphites larvaeformis*. As scaphitid material is so rare at Black Mesa and specimens of the two species do not overlap at any one locality, traditional nomenclature is followed and they are described as distinct species.

Occurrence — At Black Mesa restricted to the *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone with one specimen known from the Hopi Sandy Member on the south side of Black Mesa (MNA collections) and one specimen collected by the author from the top of the Blue Point Tongue on the southwest side of Black Mesa (MNA loc. #1150). Elsewhere at this level in Montana, Kansas, South Dakota, Nebraska, northeastern Wyoming and central Texas.

Illustrated material — MNA N4843 from MNA loc. #1150, caprock, Blue Point Sandstone Tongue, Toreva Formation.

Scaphites patulus Cobban, 1951
Plate 40, Figure G

Scaphites patulus Cobban, 1951, p. 20, pl. 1, figs. 23–32.
Scaphites patulus Cobban; Cobban, 1983, p. 9, pl. 1, fig. 2 (in part).

Diagnosis — Scaphitid with depressed body chamber, sparse ribbing and rather strong lateral nodes on shaft of body chamber.

Discussion — Specimens of *Scaphites patulus* are readily distinguished from *Scaphites larvaeformis*, in having coarser ornament with strong lateral tubercles.

Occurrence — *Scaphites patulus* is represented by two specimens from near the base of the *Collignoniceras woollgari regulare* subzone in the Hopi Sandy Member at the Lohali Point section on the northeast side of Black Mesa (MNA loc. #989). Elsewhere at this level in Kansas and in the Black Hills area. It has a also been recorded in the overlying *Prionocyclus percarinatus* Zone in the Black Hills area and northeastern Nebraska.

Illustrated material — MNA N3593 from MNA loc. #989, 13 m above base of Hopi Sandy Member, Mancos Shale.

Subfamily Otoscaphitinae Wright, 1953
Genus *Yezoites* Yabe, 1910

Type species — *Yezoites perrini* (Anderson, 1902).

Diagnosis — Strongly dimorphic, finely ribbed scaphitids, with rather densely ribbed, involute, depressed phragmocone; microconchs small to very small; straight shaft of body chamber weakly ribbed, often with ventrolateral tubercles, hook rather sharply recurved, not overlapping body chamber with strong lateral lappets bounding aperture; medium sized macroconchs with base of body chamber partially overlapping umbilicus, straight shaft of body chamber inflated with weak primary ribs giving rise to ventrolateral tubercles from which ribs branch and cross venter or are intercalated, hook does not overlap body chamber and aperture is constricted.

Discussion — Kennedy (1988) reported that all scaphitid specimens identified as *Scaphites delicatulus* and *Scaphites brittonensis* are macroconchs, that these often occur with small lappeted specimens referred to the genus *Otoscaphites* and that these small forms represent the microconchs. The earliest available name for this distinctively dimorphic genus is *Yezoites*.

Scaphitids identifiable as *Scaphites delicatulus* are uncommonly found weathered free from limestone concretions of the *Sciponoceras gracile* Zone on the east side of Black Mesa. No microconchs have been recognized at Black Mesa, but may easily have been overlooked due to their small size and rarity. Thus the Black Mesa material does not provide support or dispute Kennedy's (1988) view of this genus.

Occurrence — Late Cenomanian through middle Turonian of Western Interior, Texas, Alaska, California, and Japan.

Paleoecology — Batt (1987) grouped *Yezoites* with *Scaphites* in his morphotype IU, 49 and as these genera do not overlap temporally in the Western Interior and display similar distribution patterns, they are also interpreted as pelagic forms living in the lower water column, restricted from deeper parts of the basin and alternatively may also be interpreted as benthic forms.

Yezoites delicatulus (Warren, 1930)

Plate 18, Figures J, K

Scaphites delicatulus Warren, 1930, p.66, pl. 3, fig. 3, pl. 4, figs. 7–8.
Scaphites brittonensis Moreman, 1942, p. 215, pl. 34, figs. 1–2, text-fig. 2r.
Scaphites minutus Moreman, 1942, p. 216, pl. 34, figs. 9–10, text-fig. 2s.
Otoscaphites minutus (Moreman, 1942); Clark, 1965, p. 63, pl. 4, figs. 5–7, text-fig. 22c.
Yezoites delicatulus (Warren, 1930); Kennedy, 1988, p. 120. pl. 24, figs. 1, 3–5, 7–21, (with-synonymy).

Diagnosis — Macroconchs, moderately small scaphitids with densely ribbed depressed phragmocone, stout body chamber, with primary ribs branch high on flank from variably developed tubercles and are intercalated, resulting in a finely ribbed venter. Microconchs, small to very small, densely ribbed, scaphites with well developed lateral lappets, lacking distinct tubercles on body chamber.

Discussion — Kennedy (1988) reports that microconchs are much rarer than macroconchs in the large collection from central Texas. No microconchs have been collected from Black Mesa, perhaps reflecting the rarity , as well as small size of the macroconchs, which are only rarely found as float from weathering concretions at the top of the *Sciponoceras gracile* on the east side of the mesa.

Kennedy (1988) remarks that the species from Turonian, described from the central Western Interior (Cobban, 1951, 1983) and northern Alaska (Cobban and Gyrc, 1961) differ primarily in details of ornament on the body chamber and represent a distinct lineage of *Yezoites*.

Occurrence — At Black Mesa rare in the Late Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone (MNA loc. #236, #306). Elsewhere at this level, it is common in central Texas and is rare to the north in Western Interior.

Illustrated material — MNA N1150 from MNA loc. #236, BM8; MNA N4930 from MNA loc. #306, BM10; both from lower part, lower shale member, Mancos Shale.

Genus *Worthoceras* Adkins, 1928

Type species — *Worthoceras platydorsus* Scott, 1924.

Diagnosis — Small to very small, very evolute, largely smooth scaphitids; small to very small microconchs with slender body chamber bearing lateral lappets on aperture and somewhat larger, small macroconch with inflated shaft of body chamber overlapping umbilicus and a simple constricted aperture.

Discussion — Kennedy (1988) is uncertain as to the validity of the subfamily Otoscaphitidae for scaphitids with lappeted microconchs, as there are possible links of *Worthoceras* to the Ptychoceratidae.

Occurrence — Albian through lowest Turonian of North America and Europe.

Paleoecology — Batt assigns this scaphitid to morphotype EU, 50, and it is widespread in all offshore environments across the seaway, indicating that it is a pelagic form. This genus is only present in the United States Western Interior during the latest Cenomanian to basal Turonian. Early occurrences are found in Texas and Europe, suggesting that *Worthoceras* is a warm water form.

Worthoceras vermiculus (Shumard, 1860)

Plate 18, Figures L–N; Plate 25, Figure U (a)

Worthoceras vermiculus (Shumard, 1860); Moreman, 1942, p. 214, pl. 34, figs. 12–13. text-fig. 2p.
Worthoceras gibbosum Moreman, 1942, p. 215, pl. 34, figs. 7–8, text-fig. 2q.
Worthoceras vermiculus (Shumard, 1860); Clark, 1965, p. 62, pl. 4, figs. 9–11, (with synonymy).
Worthoceras gibbosum Moreman, 1942; Clark, 1965, p. 63, pl. 4, figs. 13–15, text-fig. 22b.
Worthoceras vermiculus (Shumard, 1860); Cobban and Scott, 1972, p. 43.
Worthoceras gibbosum Moreman, 1942; Cobban and Scott, 1972, p. 43, pl. 17, fig. 2.
Worthoceras vermiculus (Shumard, 1860); Hattin, 1975, p. 44, pl. 5, figs. A, F, K.

Worthoceras vermiculus (Shumard, 1860); Kennedy, 1988, p. 114, pl. 22, figs. 5, 10–15, pl. 24, figs. 22–33, text-fig. 39, (with additional synonymy).
Worthoceras vermiculus (Shumard, 1860); Cobban, Hook, and Kennedy, 1989, p. 62, figs. 93D–F, 96E–N.

Diagnosis — Small smooth scaphites with straight shaft of body chamber having flattened flanks and occasionally weak undulating flank ribs.

Discussion — *Worthoceras vermiculus* is common across much of the Western Interior, as it is at Black Mesa, where microconchs have historically been referred to as *Worthoceras vermiculus* and macroconchs have historically been referred to as *Worthoceras gibbosum*. Microconchs are more common than are macroconchs.

Specimens of *Worthoceras* from the latest Cenomanian *Neocardioceras juddii* Zone and the basal Turonian have not been assigned to species as they are thought to perhaps represent a new species with phragmocones slightly smaller than typical *Worthoceras vermiculus* (Kennedy and others, 1987; Cobban and others, 1989). Specimens of this age from Black Mesa are comparable, but do not seem to differ significantly from small microconchs of *Worthoceras vermiculus* and so are considered here.

Occurrence — At Black Mesa in the *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone, BM8 to the Cenomanian-Turonian boundary, between BM13 and BM16 (Kirkland, 1990). Elsewhere in this interval throughout the United States Western Interior and Europe. Similar specimens range up into the basal Turonian *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone in west.

Illustrated material — MNA N1201 from MNA loc. #303, BM8; MNA N4912 from MNA loc. #989, BM8; MNA N4913 from MNA loc. #271; MNA N4960 from MNA loc. #305, 2–3 m above BM13; all from lower part, lower shale member, Mancos Shale.

PHYLUM ANNELIDA
CLASS POLYCHAETIA
ORDER SEDENTARIA
Family Serpulidae
Genus *Serpula* Linne, 1768
Serpula sp.
Plate 41, Figure A (a)

Diagnosis — Round, comparatively large (8–10 mm in diameter), somewhat flexuous tube ornamented by fine growth lines.

Discussion — Fragments of this large serpulid are found meandering through shell beds.

Occurrence — Present near top of Blue Point Tongue of the Toreva Formation at Blue Point; MNA loc. #1150.

Illustrated material — MNA N5396 from MNA loc. #1150, caprock of Blue Point Tongue.

Paleoecology — Encrusting filter-feeder in open marine environments.

Subgenus *Cycloserpula* Parsch, 1956
Serpula (*Cycloserpula*) *intrica* White, 1876
Plate 15, Figures J, K

Serpula intrica White: Stanton, 1893; p. 53, pl. I, fig. 1.

Diagnosis — Round, thin (1.5 mm), long tubes highly contorted; shell wall nearly as thick as space within tube (0.5 mm) with fine concentric growth lines; attached to shells and each other.

Discussion — At a number of localities (MNA loc. #298, #989, #990, #992) this species binds shell material on the substrate together to form biostromal accumulations. It also occurs as extensive intertwined mats 1–2 cm thick.

Occurrence — Holotype from southeast of Paria, Utah, possibly from *Sciponoceras gracile* Zone; common and widespread in the southwestern part of the seaway. At Black Mesa common to abundant at all sections in the *Sciponoceras gracile* Zone, also present in the *Euomphaloceras irregulare* subzone of the *Neocardioceras juddii* Zone (Kirkland, 1990).

Illustrated material — MNA N236 from MNA loc. #236, BM8; MNA N5375 from MNA loc. 813, BM8.

Paleoecology — Encrusting gregareous filter-feeders, which require firm substrates in open marine environments.

Serpula (*Cycloserpula*) sp.

Diagnosis — Thin (1 mm) convolute tubes, attached to shells and meandering through shell beds; shell wall thin and ornamented by very fine growth lines.

Discussion — This species is similar to *S.* (*Cycloserpula*) *intrica*, but tubes are consistently thinner.

Occurrence — At Black Mesa, restricted to the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #264, #265, #308, and #540.

Paleoecology — The distribution of this species indicates a preference for brackish water.

Subgenus *Dorsoserpula* Parsch, 1956
Serpula (*Dorsoserpula*) *implicata* (Stephenson), 1952
Plate 2, Figures B, C

Serpula implicata Stephenson, 1952; p. 52, pl. 8, figs. 7–9.

Description — Thin, slowly expanding tubes, 1–5 cm long, encrusting for their entire length on shells of *Flemingostrea prudentia*; ornament consisting of strong dorsal ridge and fine concentric growth lines which bend sharply forward over dorsal ridge.

Discussion — Specimens in Texas commonly are found encrusting specimens of *Crassostrea soliniscus* (Stephenson, 1952). This oyster is a good indicator of brackish water conditions (Kauffman, 1967, 1969).

Occurrence — Holotype from middle Cenomanian Lewisville Member of Woodbine Formation in central Texas. At Black Mesa in shelly shale facies of upper sandstone member of Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #264, #265, #308, and #540.

Illustrated material — MNA N1230 from MNA loc. #265, shale facies, upper sandstone member Dakota Formation.

Paleoecology — A brackish water species, which is cemented to the substrate throughout life.

Genus *Hamulus* Morton, 1834
Hamulus sp.
Plate 25, Figure A

Description — Crushed specimens in shale; tubes curved into open semicircle up to one centimeter long, expanding fairly rapidly to a maximum diameter of 4 mm; ornament consists of strong longitudinal ribs (5?) and fine concentric growth lines.

Occurrence — Widely scattered through the lower shale member, uppermost Cenomanian *Nigericeras scotti* subzone of the *Neocardioceras juddii* Zone through Hopi Sandy Member, middle Turonian, basal *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone of the Mancos Shale, locally common above near the Cenomanian-Turonian boundary (Kirkland, 1990).

Illustrated material — MNA N5370 from MNA loc. #305, 2–3 m above BM13.

Paleoecology — Free living, reclining filter feeder.

Genus *Longitubus* Howell, 1943
***Longitubus* sp.**
Plate, 15, Figures F, G

Diagnosis — Long, nearly straight tubes, averaging 3 mm in diameter, with ornament of strong concentric growth lines. Fragments recovered unattached.

Discussion — It is believed that this form is attached to shells during early growth. Specimens of this genus similar to those from Black Mesa have been described from the Cretaceous of New Jersey by Howell (1943).

Occurrence — Present in concretions of the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone, most common along the east side of Black Mesa associated with BM8 (Kirkland, 1990).

Illustrated material — MNA N5372, N5373, from MNA loc. #989, BM8.

Paleoecology — Attached semi-erect filter feeder in open marine environments.

Genus *Spirorbis* Daudin, 1800
***Spirorbis* sp.**

Diagnosis — Very small (average of 0.2 cm in diameter), spiral tube encrusting shells.

Discussion — These serpulids are very rare at Black Mesa, but many specimens may have been overlooked due to their small size.

Occurrence — Rare in the shale facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #264, #265, #540.

Paleoecology — Cemented epifaunal filter feeder. Restricted to brackish water at Black Mesa.

Family Spionidae
Genus *Polydora*
***Polydora* ? sp.**
Plate 6, Figure A

Diagnosis — Very small (up to 0.5 cm long), U-shaped passages in the margins of oyster shells, tubes slightly less than 1 mm across.

Discussion — These tubes all face the margins of their host oyster shell and look superficially much like borings. Bromley (1970) has discussed the differences between borings and embedding structures. Borings should be randomly distributed over the shell and cut across growth lines, while embedding structures should be oriented along growth lines with the U of the boring directed away from margin of shell. Following these criteria, the U-tubes in the margins of oyster shells seem to represent embedding. Polydorid worms produce both types of structures.

Occurrence — Uncommon in the margins of oyster shells in the sandstone facies of the upper sandstone member of the Dakota Formation, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #305.

Illustrated material — MNA N1503 from MNA loc. #305, sandstone facies, upper sandstone member, Dakota Formation.

Paleoecology — These worms have a pair of long ciliated palps, which they use to gather food from the sediment or the water column (Brusca, 1980).

Miscellaneous Worms

Discussion — The presence of a diverse fauna of infaunal worms is indicated by a great abundance of trace fossils of various types. The presence of worms is important in ventilating the sediment and in providing a food source for a variety of small carnivores (many of the small carnivorous gastropods). In addition, the density and diversity of their traces has been used as a means of tracking oxygen levels at the sea floor (Ekdale and others, 1984). They are particularly important in facies where few or no body fossils are found, as they may indicate by their presence if the absence of a shelly macrobiota is due to environmental restrictions or to preservational factors.

Trace fossils attributed to worms probably include those made by worm-like taxa belonging to a variety of phyla. Some traces are not well understood as to what organism might have made them, but it is likely that in most cases those discussed herein were made by worm-like taxa.

The most widespread trace fossil attributed to worms is *Planolites*. This trace includes all meandering horizontal structures formed within the sediment. They have been recognized in nearly all facies studied at Black Mesa, from nearshore sandstones to offshore carbonate-rich strata. Apparently they are produced by both carnivorous worms and by deposit-feeding worms with simple foraging behavior. In some cases other taxa may produce *Planolites*, such as burrowing gastropods, particularly where the sediments are soft.

Another widespread trace fossil is *Crossopodia*. This trace is characterized by two rows of inclined lobes separated by a medial furrow. It is only found on the surfaces of thin, resistant beds such as thin layers of calcarenite and fine sandstone. Hattin and Frey (1969), in their study of this trace fossil on the eastern side of the seaway, found it to be widely distributed from nearshore to offshore sediments and interpret it to have been formed on the seafloor by a nektonic organism, as the trace only travels across the substrate for a short distance. In actuality, the trace appears to have been formed within the sediment — when the burrowing organism moving through soft, clay-rich sediment encounters a coarser-grained bed it would travel along it for a short distance before either penetrating the coarser layer or moving back up into the finer soft overlying sediment. The nature of the trace suggests that it may have been formed by a polychaete worm, which pushed the sediment aside with its paired parapodia. Its preservation at the interface between fine sandstones or calcarenites and the surrounding shale is determined by the selective cementation of the coarser sediment. Within sediment of uniform consistency the resulting trace is probably *Planolites*. This trace may represent an actively hunting, carnivorous polychaete. *Crossopodia* is found in association with thin calcarenites in the lower and basal middle shale member of the Mancos Shale and in association with thin sandstone beds in the upper middle, lower upper and throughout the Hopi Sandy Members of the Mancos Shale.

The vertical U-shaped trace fossil *Arenicolites* has a much more limited distribution, being recognized only in the sandstone facies of the upper sandstone member of the Dakota Formation, in the Blue Point Tongue, in the lower sandstone member of the Toreva Formation and its transition with the underlying Mancos Shale, and in the Hopi Sandy Member of the Mancos Shale at Blue Point. These trace fossils are probably constructed by a variety of organisms that lived within the open burrow, suspension-feeding. Such dwelling burrows tend to be most abundant in shallow marine environments (Seilacher, 1967; Frey and Howard, 1970; Ekdale and others, 1984), although care must be taken as no trace fossil is a perfect environmental indicator (Frey and Howard, 1970; Ekdale, 1988). Nondescript vertical and subvertical burrows have much the same distribution as *Arenicolites*.

The deposit-feeding traces *Diplocriterion, Rhizocorallium, Teichichnus*, and *Zoophycus* are not represented by clearly recognizable traces at Black Mesa. These traces are characterized by spritae following the lateral or vertical movement of the burrow, as the trace producing organism mines for food. The only indications of spritae with burrows are found in bioturbated argillaceous sands and sandy mudstones found in the transition zone between the Mancos Shale and Toreva Formation and in the Hopi Sandy Member of the Mancos Shale in the southwest. The recognition of these traces at other levels in the Mancos Shale may have been limited by the soupy nature of the sediment.

The problematic trace fossil *Chondrites* is widespread in the Mancos Shale at Black Mesa. It is characterized by fine downward branching tubes, which were made by an organism systematically searching for food in the sediment. *Chondrites* has been found to be one of the last trace fossils to drop out of a sequence with reducing oxygen levels (Bromley and Ekdale, 1984; Ekdale and others, 1984; Savrda and others, 1984; Savrda and Bottjer, 1986). *Chondrites* is recognized from the lower shale member up through the Hopi Sandy Member of the Mancos Shale, where it is found penetrating the tops of marker bentonites, concretionary marker beds, calcarenites, and thin fine sandstone beds.

PHYLUM ARTHROPODA
CLASS OSTRACODA
ORDER PODOCOPIDA

Discussion — Ostracodes were not studied during the coarse of this study. They have been reported from Black Mesa by Hazenbush (1972, 1973), Olesen (1987), and Fursich and Kirkland (1986). All specimens reported are from the late Cenomanian. An unidentified ostracod is locally common in the shale facies of the upper sandstone member of the Dakota Formation (Fursich and Kirkland, 1986). It is a simple, brackish water form with a smooth, punctate shell.

Olesen (1987) reports that three species of ostracod are present in the basal 6 m of the Mancos Shale. *Protocythere* sp. is generally uncommon through the interval. *Cythereis eaglefordensis* is most common in the *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone and *Cytheropteron eximium* is most common in the *Euomphaloceras navahopiensis* subzone of the *Neocardioceras juddii* Zone. Ostracods have not been observed higher in the section at Black Mesa.

CLASS CIRRIPEDIA
ORDER THORACICA
Family Lepadidae
Genus *Scalpellum* Leach, 1817
Scalpellum ? sp.
Plate 2, Figures D, E

Description — Isolated plates of a small goose-neck barnacle.

Discussion — The material compares well with isolated plates illustrated and referred to *Scalpellum* ? sp. by Stephenson (1952) from the Lewisville Member of the Woodbine Formation.

Occurrence — At Black Mesa, uncommon in shelly shale facies of upper sandstone member of Dakota Formation along north side of Coal Mine Mesa, southwestern Black Mesa; MNA loc. #264, #265 and #540.

Illustrated material — MNA N4519, N4520 from MNA loc. #540, shale facies, upper sandstone member, Dakota Formation.

Paleoecology — Low level, epifaunal filter feeders firmly attached to hard substrates by a flexible stalk. Occurrences at Black Mesa and in central Texas indicate a tolerance if not a preference for brackish water settings for this species.

ORDER ACROTHORACIA

Discussion — Borings of acrothoracid barnacles are present at a number of levels at Black Mesa. They occur as tiny cuneate openings in original shell material and as tiny sack-like structures on the surface of internal molds. Many occurrences of these borings may have been overlooked due to their small size. The significance of these borings has been discussed by Seilacher (1969) and by Bromley (1970), among others.

Occurrence — Rare borings in shells of the free-living oysters *Pycnodonte, Rhynchostreon*, and *Costagyra* from the sandstone facies of the upper sandstone member of the Dakota Formation; MNA loc. #265, and #305 and at base of Mancos Shale, upper Cenomanian *Metoicoceras mosbyensis* Zone; MNA loc. #296 and *Sciponoceras gracile* Zone; MNA loc. #262 and in shells of the inoceramid *Mytiloides* in the middle part of the lower shale member of the Mancos Shale, lower Turonian *Watinoceras coloradoense* through *Mammites nodosoides* Zones: MNA loc. #262, BM18 and BM28; MNA loc. #989, two meters above BM26, BM28, and BM30.

Paleoecology — These borings are made by barnacles that are endolithic filter feeders. Their presence indicates that the substrate was exposed at the sediment surface. No preferred orientations were found on the relatively few samples examined.

CLASS MALACOSTRACA

Discussion — Fossil arthropods are noticeably absent from the vast majority of collections made at Black Mesa. In large part this is probably due to nonpreservation and not original absence from the fauna. Dissolution appears to have been a primary reason for their absence. Molted and mortality skeletons in aquaria in the University of Colorado paleontologic laboratory were observed to be completely dissolved in a few days, whereas molluscan material was observed to survive largely unaltered for more than a year. In addition, Tshudy and others (1989) have proposed that observations of modern *Nautilus* scavenging molts of lobsters indicate that cephalopods may in scavenging arthropod remains may be an important source or biasing against the preservation of arthropods in the rock record.

Large burrows (around 4 cm in diameter), that are inclined in a seaward direction, have been recognized in the upper part of the lower sandstone member of the Toreva Formation at Blue Point; MNA loc. #342. These burrows are possibly the result of a large burrowing crab living in the upper shoreface.

ORDER STOMATOPODA
Family Squillidae
Genus *Squilla* Fabricius, 1787
cf. *Squilla* sp.

Diagnosis — Relatively small (4–5 cm total length) crustacean preserved as compacted chitonous films, cephlothorax with two free somites, appendages poorly preserved, abdomen approximately 3–4 times length of cephalothorax.

Discussion — The poor state of preservation of this material does not permit a positive classification of these specimens beyond the recognition that they do represent stomatopods. The fact, that they are preserved at all, suggests the material was buried rapidly.

Occurrence — At Black Mesa, rare in the upper part of the middle shale member and in the Hopi Sandy Member of the Mancos Shale, middle Turonian, upper *Collignoniceras woollgari woollgari* subzone; Lohali Point, MNA loc. #989, unit 153, 1 m above BM65, through basal *Collignoniceras woollgari regulare* subzone of the *Collignoniceras woollgari* Zone; Blue Point, MNA loc. #262, unit 149.

Paleoecology — Modern stomatopods dwell in burrows or crevices in shallow temperate to tropical marine waters, where they are predators on a wide variety of marine organisms (Scott, 1970).

ORDER DECAPODA
Family Callianassidae
Genus *Callianassa* Leach, 1814
Callianassa ? sp.

Discussion — Callianassid shrimp have not been recognized as body fossils from Black Mesa, but burrows attributed to this group (*Ophiomorpha* and *Thalassinoides*) are abundant at a number of levels. Large branching burrow systems lined by fecal pellets are referred to the ichnogenus *Ophiomorpha,* whereas smooth forms are referred to the ichnogenus *Thalassinoides.* In some cases burrows attributed to *Thalassinoides* may have been produced by some other crustacean, such as *Squilla* or *Palaeohomarus.*

Occurrence — *Ophiomorpha* is recognized throughout the sandstone facies of the upper sandstone member of the Dakota Formation, in the Hopi Sandy Member of the Mancos Shale at Blue Point; MNA loc. #262, and in the uppermost few meters of the Mancos Shale and in the lower sandstone member of the Toreva Formation across the basin. Across all of Black Mesa, *Thalassinoides* is recognized in many of the thicker bentonites (BM6, BM7, BM13, BM15, BM17, BM54) and marker concretionary horizons (BM8 and BM10) in the lower shale member, also recognized widely in the Hopi Sandy Member and in the transition zone of the Mancos Shale with the overlying Toreva Formation.

Paleoecology — Modern examples of callianassid shrimps live in open burrow systems, often with a large number of commensal organisms. Both suspension-feeding and deposit-feeding is undertaken by most species, with most species specializing in one mode of feeding (Brusca, 1980).

There is a tendency for the genus *Ophiomorpha* to be found in shallow marine sandstones. This is because packing the burrow with fecal pellets is an adaption to loose, unconsolidated sediment. These burrow systems tend to be dominated by vertical elements in the intertidal and to be dominated by horizontal elements in shallow subtidal environments (Ekdale and others, 1984). This may be due to two factors; first, in the intertidal environment callianassid burrow systems become horizontal below the marine water table, and thus may be crossing facies as observed in the rock record; second, in shallow marine environments the vertical component of the burrow systems may be reworked during erosional events. Unlined burrows of the *Thalassinoides* type are formed in more cohesive clay-rich substrates and tend to be most common in shallow marine environments and, as with *Ophiomorpha* in these environments, tend to be dominated by horizontal components.

Family Nephropidae
Genus *Homarus* Weber, 1795
Subgenus *Palaeohomarus* Mertin, 1941
Homarus (*Palaeohomarus*) sp.

Description — One relatively small specimen (estimated length from tip of cephlothorax to end of telson 9 cm) preserved as compacted chitinous film in lateral view; cephalothorax about 4 cm long; claws serrate and about two thirds length of cephalothorax; other appendages poorly preserved; abdomen preserved with telson curved below cephalothorax.

Discussion — The one specimen from Black Mesa is rather poorly preserved. The serrate claw suggests assignment to *Homarus* (*Palaeohomarus*).

Occurrence — One specimen from just below marker bed BM15 in the lower shale member of the Mancos Shale at the Coal Chute section, lower Turonian *Pseudaspidoceras flexuosum* subzone of the *Watinoceras coloradoense* Zone; MNA loc. #298, 50 cm below BM16.

Paleoecology — Modern lobsters are active scavenger predators that actively burrow to produce their dwellings.

PHYLUM ECHINODERMATA
CLASS CRINOIDEA

Description — Isolated chalky plates 2–3 mm in diameter.

Discussion — These small crinoid plates are poorly preserved, but the remains may represent arm plates from a pelagic species. The preservation does not suggest that this is reworked material, although this is always possible.

Occurrence — At Black Mesa two small specimens were recovered from an ant hill resting on the upper Cenomanian *Euomphaloceras septemseriatum* subzone of the *Sciponoceras gracile* Zone at Balakai Point (MNA 306) in the southeast.

CLASS ECHINOIDEA
ORDER SPATANGOIDA
Family Hemiasteridae
Genus *Hemiaster* Desor, 1847
Hemiaster sp. cf. *H. jacksoni* Maury, 1925
Plate 15, Figures L–Q

Hemiaster jacksoni Maury; Cooke, 1953, p. 33, pl. 12, figs. 5–11.

Description — Test of medium size, suboval, heart shaped, upper surface inflated, lower surface flattened, posterior margin truncated; largest specimens are 2.6 cm long, 2.4 cm wide, and 1.9 cm high. The apex is central, the ambulacra are subequal in size, set in depressions, with numerous elongate pore-pairs.

Discussion — The specimens from Black Mesa compare well in size and most features with specimens illustrated from

Brazil and Texas (Cooke, 1953). However, the Arizona specimens are noticeably more heart shaped, leaving the specific identification questionable. This echinoid is commonly found clustered in large numbers, suggesting it was gregarious. These accumulations usually consist of specimens in the same size range, i.e., all large or all small, suggesting that these accumulations are controlled by age class and are not gatherings solely for reproduction.

Occurrence — The holotype is from the lower Turonian of Sergipe province, Brazil. Also reported from Coahuila, Mexico, Texas, and New Mexico in the upper Cenomanian. Apparently widespread in the southern Western Interior in the *Sciponoceras gracile* Zone, at Black Mesa restricted to concretion zones BM8 and BM10 on the east side of Black Mesa; MNA loc #236, #254, #306, #387, #989.

Illustrated material — MNA N5379, N5380 from MNA loc. #306, concretionary marker bed BM10, lower part of lower shale member, Mancos Shale.

Paleoecology — Mobile infaunal deposit feeder, modern examples of this family live in deep water. Cretaceous species can be divided into two groups: those from the tropical-subtropical region with long petals containing many ambulacral pores and those from the boreal-temperate region with short petals, especially the posterior pair, containing few ambulacral pores. The high metabolic rate of warm water species requires a higher density of respiratory tube feet (Smith, 1984). The specimens from Black Mesa would be a warm water species.

PHYLUM CHORDATA
SUBPHYLUM VERTEBRATA

Discussion — A detailed systematics of the vertebrate fauna from the Greenhorn cyclothem at Black Mesa is beyond the scope of the present study. Many of the specimens are currently under study by various researchers with the results pending. Detailed locality data will be presented in these reports. The vertebrate fauna represents the top of the food chain and in some cases interacts directly with the invertebrate fauna (e.g., Kauffman, 1972b), thus a annotated faunal list will be presented below.

CLASS CHONDRICHTHYES
SUBCLASS HOLOCEPHALI
ORDER CHIMERIFORMES
unidentified chimaerid

Discussion — One isolated tooth plate of one of these invertebrate-eating cartilaginous fish was recovered as float from near the base of the middle shale member of the Mancos Shale; MNA loc. #262.

SUBCLASS ELASMOBRANCHIA

Discussion — Isolated elasmobranch teeth are common throughout the study interval at Black Mesa. In a few cases, associated dentitions have been recovered. A complete report on this material is currently in press (Williamson and others, 1993). One of the most important results is the realization that most of the elasmobranch taxa present at Black Mesa have an intercontinental distribution.

Both nearshore and pelagic faunas can be recognized and compare well with those recognized on the Gulf Coast by Meyer (1975). Nearshore and pelagic taxa tend to be mixed in the transgressive lag at the base of the Mancos Shale, whereas the nearshore fauna from the lower sandstone member does not show this mixing. The classification presented here is after Cappetta (1987).

ORDER HYBODONTEA
Hybodus sp.

Discussion — Isolated teeth that can be assigned to the genus *Hybodus* are found in the transgressive lag at the base of the Mancos Shale and in the lower sandstone member of the Toreva Formation. The distribution of this shark indicates that it is nearshore. Many collections that have recently been made from the Cretaceous of southern Utah indicate that at least some species ranged well inland.

Ptychodus sp. cf. *P. mammillaris* Agassiz

Discussion — This common species is restricted to the Turonian and ranges from about BM15 upward to the Hopi Sandy Member. As with the other species of *Ptychodus*, this species is interpreted to have fed on inoceramid bivalves as the distribution of these sharks follows that of the inoceramids very closely. The only report of predation on an inoceramid by *Ptychodus* is that of Kauffman (1972b). The lack of documentation may be a result of the efficiency with which *Ptychodus* preyed on inoceramids. Hattin (1975a) suggests that the source of inoceramid prisms making up the bulk of many calcarenites are inoceramids processed by *Ptychodus*.

Ptychodus decurrens Agassiz

Discussion — This common species is restricted to the transgressive lag at the base of Mancos Shale up through the basal few meters of the Mancos Shale, late Cenomanian up into the basal Turonian (Williamson and others, 1991).

Ptychodus whipplei Marcou

Discussion — This species, while common in the middle and upper Turonian elsewhere in the Western Interior, is relatively uncommon at Black Mesa, where it ranges from the Hopi Sandy Member up into the lower sandstone member of the Toreva Formation.

ORDER LAMNIFORMES

Discussion — The sharks of this order are all carnivores feeding mostly on fish which are swallowed nearly whole and are characterized by long slender (grasping) and triangular (tearing) teeth (Cappetta, 1987). An exception is *Squalicorax*, whose serrated teeth are adapted to cutting large prey items.

Cretodus semiplicata (Munster)

Discussion — This shark is a nearshore taxon and is perhaps the largest shark found at Black Mesa, with anterior teeth as much as 6 cm high. At Black Mesa, it is restricted to the lower Turonian and is found in the Blue Point Tongue, in the upper 20 meters of the Mancos Shale, and in the lower sandstone member of the Toreva Formation. Elsewhere, the species is also known from nearshore sediments of Cenomanian age.

Cretolamna appendiculata (Agassiz)

Discussion — This species of shark ranges from the late Albian through the Maestrichtian and is reported to be the ancestor of the modern lamnid groups. It ranges throughout the section at Black Mesa, but is much more common in the transgressive lag at the base of the Mancos Shale and in the lower sandstone member of the Toreva Formation. Its distribution appears to indicate a distinct preference for shallow water environments.

Cretolamna woodwardi Herman

Discussion — This shark is a pelagic taxon that differs from the superficially similar *Cretolamna appendiculata* in its more robust teeth, which are inclined relative to the base of the massive root. It is common in the lower through middle shale members of the Mancos Shale.

Cretoxyrhina mantelli (Agassiz)

Discussion — *Cretoxyrhina* is one of the best guides to recognizing pelagic shark faunas. It is readily recognized by its large teeth which generally (except for posterior lateral teeth) lack lateral cusps. While specimens from both the Niobrara and Greenhorn cyclothems are included in the same species, specimens from the Niobrara have noticeably larger and relatively broader teeth. This is the only shark from Black Mesa to be known from an articulated set of jaws and vertebral column collected from Black Mesa. It is rare in the transgressive lag at the base of the Mancos Shale and is relatively common in the lower and middle shale members of the Mancos Shale.

cf. *Leptostryax* sp.

Discussion — Specimens tentatively assigned to the sand tiger shark are recognized from the transgressive lag at the base of the Mancos Shale and in the lower sandstone member of the Toreva Formation.

Scapanorhynchus rhaphiodon (Agassiz)

Discussion — The distinct teeth of this extinct goblin shark are readily identified by their long slender form and fine striations. While occurring throughout the section, it is only common from the transgressive lag at the base of the Mancos Shale and in the lower sandstone member of the Toreva Formation, indicating a preference for shallow water environments. Sharks of this type were abundant in shallow water environments throughout the late Cretaceous and were thought to have gone extinct at the end of the Cretaceous until discovered living in deep water off Japan during the last century.

Squalicorax falcatus (Agassiz)

Discussion — The recurved, serrated teeth of this distinctive Cretaceous version of the tiger shark are the most common fossil shark teeth in all facies at Black Mesa. They occur in the shale facies of the upper sandstone member of the Dakota Formation and range upward into the lower sandstone member of the Toreva Formation. This distribution indicates that this shark ranges from brackish water lagoons offshore into pelagic environments.

ORDER BATOIDEA

Discussion — The ray-like fish from Black Mesa probably interacted on a regular basis with the invertebrate fauna, although as with the modern advanced rays their diet probably included fish as well as invertebrates. Most of the batoids are recovered from the nearshore environments where the highest diversity of invertebrates are found. The sclerorhynchid sawfish (*Ischyrhiza, Onchopristes, Ptychotrygon,* and *Sclerorhynchus*) may have used their rostrum to probe the sediment for invertebrates as well as to incapacitate fish. The rhinobatoids (*Protoplatyrhina, Pseudohypolophus,* and *Rhinobatis*) were well adapted for feeding on invertebrates as well.

Family Rhinobatidae

Rhinobatis sp.

Discussion — Guitarfish teeth are very small (generally 1–2 mm across) and are therefore rarely recovered during the normal course of sampling. A few teeth were recovered from a thin lag deposit at the Cenomanian-Turonian boundary in the area of Lohali Point.

Protoplatyrhina hopii Williamson, Kirkland, and Lucas

Discussion — The low flat teeth of this specialized guitarfish are well adapted to crushing invertebrate shell material. It is present in the lower sandstone member of the Toreva Formation.

Pseudohypolophus mcnultyi (Thurmond)

Discussion — The low flat teeth of this close relative of the guitarfish are also well adapted to crushing shellfish. A closely related form present in freshwater environments in southern Utah may be distinguished by a low crest which runs along the midline of the tooth. The lineage to which this ray belongs is one of the very few major groups of elasmobranchs to be strictly endemic to North America. At Black Mesa common, restricted to the transgressive lag at the base of the Mancos Shale. Elsewhere known to range from the late Albian upward into the basal Campanian in shallow marine sandstones.

Family Sclerorhynchidae

Ischyrhiza sp. cf. *I. avonicola* Estes

Discussion — This small to very small sawfish is present in the transgressive lag at the base of the Mancos Shale and in the lower sandstone member of the Toreva Formation. It has also been found in a thin lag deposit at the Cenomanian-Turonian boundary in the area of Lohali Point.

Ischyrhiza schneideri Slaughter and Steiner

Discussion — This is a much larger species of *Ischyrhiza* and is only known from the lower sandstone member of the Toreva Formation, where it is relatively uncommon.

Onchopristis dunklei McNulty and Slaughter

Discussion — This distinctive sawfish is readily distinguished by the recurved barbs on the rostral teeth. It is present in the transgressive lag at the base of the Mancos

Shale and is rare in the shales of the basal Mancos Shale up to the Cenomanian-Turonian boundary.

Ptychotrygon triangularis **(Reuss)**

Discussion — This species is readily identified by its small but massive oral teeth with three transverse crests. Rostral teeth are not positively known for this genus, but may have been much like those of *Ischyrhiza*. The massive teeth of this species are well adapted to processing shellfish. Common in the lower sandstone member of the Toreva Formation.

Ptychotrygon rubyae **Williamson, Kirkland, and Lucas**

Discussion — This very small species is identified a crown with only one crest and labial ornament with a central cusp and row of isolated tubercles along margin. Known only from the thin shark tooth lag (unit 33, MNA loc. #989; Kirkland, 1990, 1991) near the base of the Turonian on the east side of Black Mesa.

CLASS OSTEICHTHYES
ORDER SEMIONOTIFORMES
Lepidotes **sp.**

Discussion — Isolated teeth and scales of *Lepidotes* are common in the transgressive lag at the base the Mancos Shale. While generally considered exclusively a marine form, teeth and scales of this genus are common in the fluvial sediments of the middle carbonaceous member of the Dakota Formation on the north side of Black Mesa (MNA loc. #924), as well as across southern Utah. This distribution indicates that the genus could tolerate fresh water during at least the Cenomanian. The round crushing teeth of this large fish are readily distinguished by their consistent shape and small extension at the center of the tooth. These crushing teeth indicate that these extinct fish may have fed on shelled invertebrates as part of their diet.

ORDER PYCNODONTIFORMES
indeterminant pycnodontids

Discussion — Isolated pycnodont teeth and jaws are found throughout the marine strata at Black Mesa, ranging from the shallow marine sandstones to the pelagic marlstones. The crushing teeth of this group are distinguished by their more varied shape and generally smooth crown. Quite a number of different species appear to have been present at Black Mesa. These fish are interpreted to have included shelled invertebrates in their diet.

ORDER AMIIFORMES
indeterminant amioid

Discussion — Some isolated teeth from the lower sandstone member of the Toreva Formation seem to belong to some form of amioid.

ORDER OSTEOGLOSSIFORMES
Xiphactinus audax **Leidy**

Discussion — *Xiphactinus* is known from two skulls and isolated postcranial material from the lower Turonian at Black Mesa. This extremely large carnivorous fish is a typical element of pelagic faunas during the Late Cretaceous.

indeterminant icthyodectids

Discussion — The presence of other icthyodectid fish is indicated by the presence of large transversely elongate scales typical of these forms. They have been recognized throughout the lower shale member and range up into the middle shale member.

ORDER SALMONIFORMES
Enchodus **sp.**

Discussion — The characteristic striated recurved teeth of this genus are common throughout the marine strata at Black Mesa, ranging from the transgressive lag at the base of the Mancos Shale up into the lower sandstone member of the Toreva Formation.

Indeterminant Teleost Remains

Discussion — Isolated bones, teeth, and scales of a wide variety of teleosts are present at Black Mesa. They have been recognized in every interval sampled, including the largely barren upper shale member of the Mancos Shale. The presence of this wealth of indeterminant material indicates that a healthy fauna existed in the upper water column throughout the Greenhorn marine cycle at Black Mesa.

CLASS REPTILIA
ORDER CHELONIA
Desmatochelys **sp.**

Discussion — A well preserved skull and partial skeleton of this large sea turtle was recovered from near the Cenomanian-Turonian boundary at Blue Point. Dr. David Elliot of Northern Arizona University is currently studying the material.

indeterminant turtle material

Discussion — Isolated vertebrae and shell material of unidentified turtles have been found at a number of localities at Black Mesa. Material probably pertaining to various sea turtles has been uncovered in the lower shale member of the Mancos Shale. Material pertaining to freshwater aquatic turtles is rare from the shale facies of the upper sandstone member of the Dakota Formation and lower sandstone member of the Toreva Formation. Fragmentary turtle material is commonly associated with fluvial deposits of the middle carbonaceous member of the Dakota Formation on the north side of Black Mesa (MNA loc. #924).

ORDER SAUROPTERYGIA
Trinacomerium **sp.**

Discussion — Plesiosaur remains are known from a few partial skeletons from the lower and middle shale members of the Mancos Shale. The only material so far identified is *Trinacomerium*. This is a short necked plesiosaur with a long narrow snout, which was well adapted to catching small fish. The material from Black Mesa was described by Lucas (1994).

ORDER CROCODILIA
unidentified crocodilian remains

Discussion — Isolated crocodilian teeth and scutes are rarely found in the shale facies of the upper sandstone member of the Dakota Formation and lower sandstone member of the Toreva Formation and is commonly associated with fluvial deposits of the middle carbonaceous member of the Dakota Formation on the north side of Black Mesa (MNA loc. #924).

ORDER SAURISCHIA
unidentified theropod teeth

Discussion — A few isolated theropod teeth have been recovered from fluvial deposits of the middle carbonaceous member of the Dakota Formation on the north side of Black Mesa (MNA loc. #924).

ORDER ORNITHISCHIA
unidentified ornithopod tracks

Discussion — Tracks of a large unidentified ornithopod have been recognized in the middle carbonaceous member of the Dakota Formation at a few localities on the southwestern side of Black Mesa (MNA loc. #344, #964).

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Table 1. Listing of Museum of Northern Arizona (MNA) localities at Black Mesa referred to in this report. *measured section in Kirkland (1990, 1991).

MNA Loc.	Map #	Formation	Latitude	Longitude
236	14	MANCOS	36* 08'40"	109* 49'00"
254	16	MANCOS	36* 07'00"	109* 54'40"
*262	BP	MANCOS	35* 44'00"	110* 49'30"
264	2	DAKOTA	36* 01'00"	111* 02'45"
265	3	DAKOTA	36* 00"05"	111* 00'05"
*271	9	MANCOS	36* 11'00"	110* 52'30"
*296	13	MANCOS	36* 20'00"	109* 49'08"
*298	CS	MANCOS	36* 33'10"	110* 29'04"
303	7	MANCOS	35* 57'55"	110* 50'25"
304	5	DAKOTA	35* 54'40"	110* 55'20"
*305	8	MANCOS	35* 57'35"	110* 53'20"
*306	19	MANCOS	35* 50'42"	109* 49'49"
*307	6	MANCOS	35* 52'00"	110* 45'00"
*308	1	DAKOTA	36* 02'25"	111* O2'10"
324	10	MANCOS	36* 14'37"	110* 53'40"
337	21	DAKOTA	35* 27'05"	110* 30'10"
*338	20	MANCOS	35* 37'15"	110* 17'30"
*342	BP	TOREVA	35* 44'40"	110* 49'08"
*344	BP	DAKOTA	35* 43'58"	110* 49'49"
*387	18	MANCOS	35* 02'58"	110* 05'51"
540	4	DAKOTA	35* 59'30"	111* 56'15"
812	3	MANCOS	36* 00'00"	111* 00'05"
*813	1	MANCOS	36* 02'25"	111* 02'10"
814	0	MANCOS	36* 04'30"	111* 04'00"
878	16	TOREVA	36* 07'00"	109* 57'00"
924	12	DAKOTA	36* 31'37"	110* 05'00"
926	11	DAKOTA	36* 24'40"	110* 49'20"
962	5	MANCOS	35* 54'40"	110* 55'20"
*963	CS	DAKOTA	36* 33'13"	110* 29'08"
*964	8	DAKOTA	35* 57'35"	110* 53'20"
*988	CS	TOREVA	36* 33'06"	110* 29'00"
*989	LP	MANCOS	36* 11'01"	109* 52'48"
*990	12	MANCOS	36* 31'30"	110* 05'40"
*992	15	MANCOS	36* 09'50"	109* 50'30"
*1150	BP	BLUE POINT TONGUE	35* 44'42"	110* 49'10"
1158	17	MANCOS	36* 02'58"	110* 05'51"

Table 2. Black Mesa marker bed types and correlative terminology used elsewhere in the Western Interior. ^indicates that a Black Mesa marker bed is interpreted to immediately overlie a marker bed recognized in the central Western Interior basin.

Black Mesa Marker Beds	Type	Cobban 1985	Hattin 1962 1985	Elder 1985	Pratt et al. 1985
BM1	Bentonite				
BM2	Bentonite				
BM3	Bentonite				
BM4	Marlstone	63	HL-1	LS1	PBC-1
BM5	Bentonite	64			
BM6	Bentonite				PBC-4
BM7	Bentonite	69		A	PBC-5
BM8	Concretion	73	HL-2	LS3	PBC-6
BM9	Bentonite				
BM10	Concretion	77		LS4	PBC-7
BM11	Concretion			LS5	PBC-9
BM12	Bentonite				
BM13	Bentonite	80	^HL-3	B	PBC-11
BM14	Bentonite				
BM15	Bentonite	88	HL-4	C	PBC-17
BM16	Bentonite	91			PBC-19
BM17	Bentonite	96	HL-5	D	PBC-20
BM18	Calcisilt				
BM19	Marlstone	97	JT-1		PBC-21
BM20	Calcisilt				
BM21	Calcisilt				
BM22	Marlstone	101	JT-3		PBC-23
BM23	Calcisilt				
BM24	Calcisilt				
BM25	Marlstone	105	JT-6		PBC-26
BM26	Calcisilt				
BM27	Bentonite		^JT-9		PBC-30
BM28	Calcisilt				
BM29	Bentonite	114	^JT-10		PBC-32
BM30	Calcisilt				
BM31	Bentonite				
BM32	Bentonite				
BM33	Concretion				
BM34	Bentonite				
BM35	Bentonite	^118	^JT-12		^PBC-34
BM36	Bentonite				
BM37	Bentonite				
BM38	Bentonite				
BM39	Bentonite				
BM40	Bentonite				
BM41	Bentonite				
BM42	Bentonite				
BM43	Bentonite				
BM44	Bentonite				
BM45	Bentonite	126			PBC-44
BM46	Bentonite		PF-2		PBC-45
BM47	Bentonite				PBC-46
BM48	Bentonite				
BM49	Bentonite				
BM50	Bentonite				
BM51	Bentonite				
BM52	Bentonite				
BM53	Bentonite				
BM54	Bentonite		F-1		PF-5
BM55	Bentonite				
BM56	Bentonite				
BM57	Bentonite				
BM58	Bentonite				
BM59	Calcisilt				
BM60	Calcisilt				
BM61	Calcisilt				
BM62	Bentonite				
BM63	Bentonite				
BM64	Bentonite				
BM65	Bentonite				
BM66	Bentonite				
BM67	Bentonite				
BM68	Bentonite				
BM69	Bentonite				
BM70	Bentonite				
BM71	Bentonite				
BM72	Bentonite				
BM73	Bentonite				
BM74	Bentonite				
BM75	Bentonite				
BM76	Bentonite				
BM77	Bentonite				

Table 3. Upper Cenomanian - middle Turonian biozones used in this report with symbols used in Figures 2 and 3.

Substage	Zone	Subzone	Key
Middle Turonian	*Prionocyclus hyatti*		7
	Collignoniceras woollgari	*C. woollgari regulare*	6c
		C. woollgari woollgari	6b
		C. woollgari woollgari- *Mytiloides hercynicus*	6a
Lower Turonian	*Mammites nodosoides*		5
	Watinoceras coloradoense	*Vascoceras birchbyi*	4b
		Pseudaspidoceras flexuosum	4a
Upper Cenomanian	*Neocardioceras juddii*	*Nigericeras scotti*	3c
		Neocardioceras juddii	3b
		Euomphaloceras irregulare	3a
	Sciponoceras gracile	*Euomphaloceras septemseriatum*	2b
		Vascoceras diartianum	2a
	Metoicoceras mosbyense		1
	Calycoceras canitaurinum		

PLATE CAPTIONS

All specimens whitened unless indicated. SCALES: x1/2 = 1cm; x1 = 2 cm; x2 = 4 cm; x3 = 6 cm; x4 = 8 cm; x5 = 10 cm.

PLATE 1 — SHALE FACIES, UPPER SANDSTONE MEMBER, DAKOTA FORMATION

Figure A. *Entobia* sp. clionid sponge borings in *Flemingostrea prudentia*. Epoxy cast. x2 MNA N3765, loc. #265. Figure B. Oyster spat (indet.) on *Flemingostrea prudentia* with *Membranipora* sp. x2 MNA N4493, loc. #540. Figure C. Shell bed with *Carycorbula nematophora* and *Fulpia pinguis*. x1 MNA N4480, loc. #540. Figure D. Algal borings in *Flemingostrea prudentia*. Epoxy cast. x2 MNA N3766, loc. #265. Figure E. *Brachiodonte filisculptus* shell bed. x1 MNA N4535, loc. #265.

PLATE 2 — SHALE FACIES, UPPER SANDSTONE MEMBER, DAKOTA FORMATION

Figure A. *Membranipora* sp. x1 MNA N4493, loc. #540. Figures B, C. *Dorsoserpula implicata* (Stephenson). B. x3 MNA N1230, loc. #265. C. x1 MNA N1230, loc. #265. Figures D, E. *Scalpellum* sp. isolated plates. D. x3 MNA N4520, loc. #540. E. x3 MNA N4519, loc. #540. Figures F, G. *Neritina* sp. SEM x10 MNA N1034, loc. #265. Figures H, I, J. *Levicerithium basicostata* Stephenson. x2 MNA N901, loc. #265. I. x2 MNA N4525, loc. #265. J. SEM x8 MNA N1035, loc. #265. Figures K, P, Q, R. *Voysa varia* Stephenson. K. SEM x5 MNA N900, loc. #265. P. SEM x4 MNA N900, loc. #265. Q. x3 MNA N900, loc. #265. R. SEM x4 MNA N900, loc. #265. Figures L, M. *Levicerithium micronema* (Meek). L. x2 MNA N4523, loc. #265. M. x2 MNA N4524, loc. #265. Figure N. *Craginia coalvillensis* (Meek). x1 MNA N822, loc. #264. Figure O. *Pyrgulifera ornata* Stephenson. x2 MNA N925, loc. #265. Figure S. *Vascellum* sp. compacted specimen x2 MNA N4527, loc. #264. Figures T, U, V. *Admetopsis subfusiformis* (Meek). T. x2 MNA N4529, loc. #265. U. x3 MNA N4530, loc. #265. V. x2 MNA N4531, loc. #265. Figures W, X. *Ambrosea nitida* Stephenson. x3 MNA N4526, loc. #265. Figure Y. *Pirslia* sp. x3 MNA N1039, loc. #265.

PLATE 3 — SHALE FACIES, UPPER SANDSTONE MEMBER, DAKOTA FORMATION

Figures A, B. *Nuculana mutuata* Stephenson. A. internal mold of right valve x3 MNA N4505, loc. #540. B. internal mold of left valve x3 MNA N4506, loc. #540. Figure C. *Nucula* sp. internal mold of left valve x2 MNA N4504, loc. #264. Figures D, F. *Barbatia tramitensis* (Cragin). D. right valve x1 MNA N4513, loc. #265. F. right valve x1 MNA N4514, loc. #540. Figure E. *Opis* sp. left valve x2 MNA N4499, loc. #540. Figures G, H. *Brachidontes filisculptus* (Cragin). G. latex peel of right valve x1 MNA N892, loc. #265. H. latex peel of right valve x1 MNA N894, loc. #265. Figures I, J, K, L. *Anomia ponticulana* Stephenson. I. upper valve x2 MNA N4537, loc. #540. J. upper valve x2 MNA N4497, loc. #540. K. upper valve x2 MNA N4496, loc. #265. L. calcified byssus on *Flemingostrea prudentia* (White) x3 MNA N4495, loc #540. Figure M. *Senis elongatus* Stephenson. latex peel of attached valves x1 MNA N4532, loc. #540. Figures N, O, Q, R. *Fulpia pinguis* Stephenson. N. left valve x1 MNA N4512, loc. #540. O. right valve x2 MNA N4509, loc. #540. Q. left valve x2 MNA N 4510, loc. #540. R. internal view of left valve x3 MNA 4512, loc. #540. Figures P, S, T, U. *Parvilucina juvensis* (Stanton). P. right valve x2 MNA N4511, loc. #540. S. internal mold of left valve with shell adhearing x2 MNA N4502, loc. #264. T. left valve x2 MNA N4503, loc. #264. U. internal mold of right valve x2 MNA N4501, loc. #264. Figures V, W. *Cuspidaria alaeformis* (Shumard). V. left valve x1.5 MNA N4500, loc. #264. W. right valve x1.5 MNA N4499, loc. #540.

PLATE 4 — SHALE FACIES, UPPER SANDSTONE MEMBER, DAKOTA FORMATION

Figures A, C. *Flemingostrea prudentia* (White). A. left valve x1 MNA N4494, loc. #540. C. internal view of right valve x1 MNA N4493, loc. #540. Figure B. *Crassostrea soleniscus* (Meek) left valves attached to left valve of *Flemingostrea prudentia* (White) x1 MNA N4481, loc. #540. Figures D, E, F, G, L, M, N, O. *Carycorbula nematophora* (Meek). D. right valve x2.5 MNA N4515, loc. #540. E. dorsal view x2.5 MNA N4515, loc. #540. F. anterior view internal mold x2 MNA N4486, loc. #264. G. internal mold right valve x2 MNA N4486, loc. #264. L. right valve SEM x4 MNA N4483, loc. #540. M. left valve SEM x4 MNA N4484, loc. #540. N. internal view of right valve SEM x8 MNA N4483, loc. #540. O. internal view of right valve SEM x8 MNA N4485, loc. #540. Figures H, I, J, K, R, S. *Dakotaorbula senecta* (Stephenson). H. right valve x2 MNA N4489, loc. #540. I. dorsal view x2 MNA N4489, loc. #540. J. left valve x2 MNA N4490, loc. #540. K. right valve x2 MNA N4490, loc. #540. R. internal of view right valve SEM x9 MNA N4488, loc. #540. S. internal view of left valve SEM x7 MNA N4487, loc. #540. Figures P, Q. *Cymbophora* ? sp. P. internal mold of right valve x2 MNA N4517, loc. #540. Q. internal mold of right valve x4 MNA N4516, loc. #264. Figure T. *Anatimya virgata* (Stephenson). right valve x1 MNA N4491, loc. #265.

PLATE 5 — SANDSTONE FACIES, UPPER SANDSTONE MEMBER, DAKOTA FORMATION

Figure A. *Exogyra (Costagyra) olisiponensis* Sharp. left valve x1 MNA N1046, loc. #265. Figures B, C. *Lopha staufferi* Bergquist. B. right valve x1 MNA N6378, loc. #926. C. ventral view x1 MNA N6378, loc. #926. Figures D, F. *Rhynchostreon levis* (Stephenson) (smooth form). D. left valve x1 MNA N1505, loc. #265. E. left valve lateral view x1 MNA N1504, loc #265. Figures E, G, I. *Rhynchostreon levis* (Stephenson) (costate form). E. right valve x1 MNA N1503, loc. #305. G. left valve lateral view x1 MNA N1502, loc. #305. I. left valve lateral view uncoated to show color bands near umbo x1 MNA N1471, loc. #305. Figures H, J, K. *Pycnodonte* sp. aff. *P. kellumi* (Jones). H. left valve with clionid sponge and barnicle borings x1 MNA N5068, loc. #296. J. right valve x1 MNA N5064, loc. #296. K. left valve x1 MNA N 5070, loc. #296.

PLATE 6 — SANDSTONE FACIES, UPPER SANDSTONE MEMBER, DAKOTA FORMATION

Figure A. *Caulostrepsis* sp. polydorid worm borings in margin of right valve of *Rhynchostreon levis* Stephenson. x2 MNA N1503, loc. #305. Figure B. *Phelopteria dalli* Stephenson (a) left valve with b. *Plicatula hydroyheca* White and c. *Granocardium trite* (White) x1 MNA N227, loc. #265. Figure C. *Plicatula hydrotheca* White. x1 MNA N1042, loc. #265. Figures D, E. *Camptonectes platessa* White D. left valve x2 MNA N1056, loc. #265. E. interior right valve x1 MNA N5077, loc. #963. Figure F. *Plicatula* sp. cf. *P. ferryi* Coquand. latex peel right valve x1 MNA N3558, loc. #963. Figure G. *Idonearca depressa* (White) right valve x1 MNA N1057, loc. #265. Figure H. *Arca* n. sp. left valve x1 MNA N1058, loc. #265. Figure I. *Aphrodina* cf. *A. munda* Stephenson right valve x1 MNA N5521, loc. #963. Figure J. *Pholadomya* sp. right valve x1 MNA N5519, loc. #963.

PLATE 7 — SANDSTONE FACIES, UPPER SANDSTONE MEMBER, DAKOTA FORMATION

Figures A, B. *Metoicoceras mosbyensis* Cobban A. lateral view x1 MNA N1049, loc. #265. B. lateral view microconch x1 MNA N3544, loc. #963. Figure C. *Turritella* sp. A. compacted specimen x1 MNA N5076, loc. #296.

PLATE 8 — SANDSTONE FACIES, UPPER SANDSTONE MEMBER, DAKOTA FORMATION

Figures A, E. *Kummeloceras* sp. A. lateral view x1/2 MNA N3540, loc. #963. ventral view x1/2 MNA N3540, loc. #963. Figures B, C, D. *Metoicoceras mosbyensis* Cobban. B. ventral view macroconch body chamber x1/2 MNA N3538, loc. #265. C. lateral view macroconch body chamber x1/2 MNA N3538, loc. #265. D. lateral view macroconch phragmocone x1 MNA N3543, loc. 963.

PLATE 9 — SANDSTONE FACIES, UPPER SANDSTONE MEMBER, DAKOTA FORMATION

Figures A, B. *Calycoceras obrieni* Young A. lateral view x1/2 MNA N3539, loc. #265. B. ventral view x1/2 MNA N1074, loc. #265. Figures C, D. *Cunningtoniceras novimexicanum* Cobban, Hook, and Kennedy. C. lateral view x1 MNA N3542, loc. #963. D. ventral view x1 MNA N3542, loc. #963.

PLATE 10 — LOWER SHALE MEMBER, MANCOS SHALE *VASCOCERAS DIARTIANUM* SUBZONE, *SCIPONOCERAS GRACILE* ZONE

Figure A. *Placenticeras cumminsi* Craigin compacted specimen lateral view x1 MNA N4935, loc. #296, BM4. Figure B. *Moremanoceras scotti* (Moreman) latex peel compacted specimen lateral view x1 MNA N4942, loc. #990, BM4. Figures C, D, E. *Pseudocalycoceras angolaense* (Spath). C. compacted specimen lateral view (b) with *Metaptychoceras* sp. (a) x1 MNA N4939, loc. #990, BM4. D. compacted specimen lateral view x1 MNA N4955, loc. #992, below BM4. E. compacted specimen lateral view x1 MNA N4955, loc. #992, below BM4. Figure F. *Neocardioceras minutum* Cobban. compacted specimen lateral view x2 MNA N4945, loc. #990, BM4. Figures G, H, I, J, K, N. *Eucalycoceras pentagonum* (Jukes-Browne). G. compacted specimen ventral view x1 MNA N4936, loc. #296, BM4. H. compacted specimen lateral view x1 MNA N4948, loc. #992, below BM4. I. compacted specimens lateral view MNA N4950, loc. #992, below BM4. J. compacted specimen lateral view x1 MNA N4950, loc. #992, below BM4. K. fragment of compacted specimen lateral view x1 MNA N4949, loc. #992, below BM4. N. compacted specimen lateral view x1 MNA N4952, loc. #992, below BM4. Figures L, M. *Calycoceras naviculare* (Mantell). L. compacted specimen ventral view x1 MNA N4937, loc. #990, BM4. M. latex peel compacted specimen lateral view x1 MNA N4938, loc. #990, BM4. Figures O, P. *Vascoceras diartianum* (d'Orbigny). O. compacted specimen lateral view (a) with *Neocardioceras minutum* Cobban. (b). x1 MNA N4941, loc. #990, BM4. P. latex peel compacted specimen lateral view x1 MNA N4940, loc. #990, BM4. Figure Q. *Nemodon* sp. x4 MNA N5184, loc. #992, below BM4. Figure R. *Psilomya* n. sp. cf. *P. concentrica* Stanton. right valve x1 MNA N5175, loc. 992, BM4.

PLATE 11 — TOP UPPER SANDSTONE MEMBER, DAKOTA FORMATION and LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS SEPTEMSERIATUM* SUBZONE, *SCIPONOCERAS GRACILE* ZONE

Figures A, B. *Gryphaeostrea nationsi* n. sp. A. Paratype, left valve x2 MNA N5549, loc. #344, top of Dakota equivalent. B. Holotype, left valve x1 MNA N1240, loc. #344, top of Dakota equivalent. Figure C. *Pycnodonte newberryi* (Stanton) left valve x1 MNA N1048, loc. #265, upper sandstone member, Dakota Formation. Figures D, V, W, *Modiolus perryi* n. sp. D. Lectotype, dorsal view x1 MNA N1079, loc. #344, top of Dakota equivalent. V. Lectotype, right valve x1 MNA N1061, loc. #271, BM10. W. Holotype, right valve x2 MNA N5066, loc. #306, BM10. Figure E. *"Mytilus"* sp. right valve x1 MNA N1245, loc. #344, top of Dakota equivalent. Figure F. *Lima* sp. left valve x1 MNA N1245, loc. #344, top of Dakota equivalent. Figure G, N. *Pseudopteria* n. sp. cf. *P. serrata* Stephenson. G. compacted left valve x2 MNA N3545, loc. #344, top of Dakota equivalent. N. internal mold left valve with part of inner shell layer adhearing x2 MNA N5178, loc. #989, BM8. Figure H. *Modiolus* sp. cf. *M. attenuatus* (Meek and Hayden) left valve (b) with *Turritella whitei* Stanton x1 MNA N1239, loc. #344, top of Dakota equivalent. Figure I. *Cyclorisma orbiculata* (Hall and Meek) left valve x2 MNA N5179, loc. #344, top of Dakota equivalent. Figure J, K. *Gryphaeostrea elderi* n. sp. J. Paratype, internal mold right valve x2 MNA N5163, loc. #306, BM10. K. Holotype, right valve x2 MNA N5148, loc. #989, BM8. Figure L. *Rhynchostreon* sp. (small and smooth) lateral view left valve x2 MNA N5161, loc. #262, NM8. Figure M, *Phelopteria minuta* Kauffman and Powell. M. left valve x4 MNA N1214 loc. #303, BM8. Figure O. *Plicatula* sp. cf. *P. ferryi* Coquand latex peel left valve x2 MNA N5154, loc. #989, BM8. Figure P. *Plicatula hydrotheca* White internal mold left valve x2 MNA N1159, loc. #262, BM8. Figure Q. *Ostrea anomiodes* Meek internal mold right valve x2 MNA N5174, loc. #989, BM8. Figure R. *Phelopteria* sp. A right valve x2 MNA N3605, loc. #306, BM10. Figure S, X. *Camptonectes* sp. A. S. right valve x2 MNA N4816, loc. #306, BM10. X. right valve x2 MNA N4825, loc. #262, BM8. Figure T, U. *Gervillea navajovus* n. sp. T. Holotype, displaced pair of valves x1 MNA N5072, loc. #306, BM10. U. Paratype right valve x2 MNA N5073, loc. #306, BM10. Figure Y. *Camptonectes* sp. B. internal view left valve x2 MNA N4824, loc. #989, BM8. Figure Z. *Limatula kochi* n. sp. Holotype, right valve x4 MNA N5155, loc. #306, BM10. Figure AA. *Lima utahensis* Stanton left valve x2 MNA N5151, loc. #298, BM8.

PLATE 12 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS SEPTEMSERIATUM* SUBZONE, *SCIPONOCERAS GRACILE* ZONE

Figure A. *Inoceramus nodai* Matsumoto and Tanaka internal mold right valve x1 MNA N3568, loc. #324, BM10. Figures B, E, F, G, H, I, J, *Inoceramus pictus* Sowerby s.l. B. left valve x2 MNA N5518, loc. #306, BM10. E. internal mold right valve x1 MNA N3563, loc. #254, BM10. F. right valve x1 MNA N3569, loc. #989, BM8. G. right valve x1 MNA N3567, loc. #989, BM8. H. internal mold left valve x1 MNA N3566, loc. #989, BM8. I. internal mold left valve with *Sciponoceras gracile* Shumard x1 MNA N232 loc. #271, BM10. J. internal mold some shell adhearing right valve x1 MNA N9120, loc. #236, BM8. Figures C, D. *Inoceramus flavus* Sorney. C. lateral view left valve x1 MNA N3565, loc. #992, BM8. D. left valve x1 MNA N3565, loc. #992, BM8. Figure K. *Mytiloides submytiloides* (Seitz) left valve x1 MNA N6397, loc. 236, BM8.

PLATE 13 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS SEPTEMSERIATUM* SUBZONE, *SCIPONOCERAS GRACILE* ZONE

Figure A. *Solemya* sp. right valve x4 MNA N5064, loc. #306, BM8. Figure B. *Solemya obscura* Stanton left valve x2 MNA N5166, loc. #262, concretion between BM8 and BM10. Figures C, D. *Lucina subundata* Hall and Meek. C. left valve x2 MNA N5156, loc. #262, concretion between BM8 and BM10. D. right valve x2 MNA N5157, loc. #271, BM10. Figures E, F. *Veniella goniophora* Meek. E. latex peel left valve x1 MNA N5075, loc. #813, BM8. F. right valve x4 MNA N5065, loc. 989, BM8. Figure G. *Tenea* sp. internal mold right valve x2 MNA N5168, loc. #298, BM8. Figure H. *Goniomya* n. sp. right valve x4 MNA N5160, loc. #989, above BM8. Figure I. *Corbula kanabensis* Stanton left valve x4 MNA N5067, loc. #989, BM8. Figure J. *Corbula* sp. left valve x4 MNA N5165, loc. #306, BM10. Figure K. *Pholadomya* sp. right valve x1 MNA N3551, loc. #262, just above BM10. Figure L. *Teredolithus* sp. calcified burrow lining x2 MNA N5172, loc. #306, BM10. Figure M. *Terebrimya* sp. right valve x2 MNA N5170, loc #271, BM10. Figures N, O. *Psilomya meeki* (White). N. left valve x1 MNA N20, loc. #236, BM8. O. right valve x2 MNA N5159, loc. #989, BM8. Figures P, Q. *Poromya lohaliensis* n. sp. P. Holotype, left valve x2 MNA N5150, loc. #992, BM10. Q. Paratype, left valve x2 MNA N5149, loc. #992, BM10. Figures R, S. *Euspira stantoni* n. sp. R. Holotype, apertural view x2 MNA N5140, loc. #989, BM8. S. Paratype, x1 MNA N2078, loc. #298, BM8. Figures T, U. *Eunaticina textilis* Stanton. T. uncoated x2 MNA N5143, loc. 306, BM10. U. apertural view x2 MNA N5143, loc. 306, BM10. Figure V. *Gyrodes* sp. cf. *G. tramitensis* Stephenson x2 MNA N5137, loc. 989, BM10. Figures W, X, Y. *Perissopteria prolabiata* (White). W. x2 MNA N5133, loc. #298, BM10. X. x1 MNA N1207, loc. #303, BM8. Y. lateral view x2 MNA N5133, loc. #298, BM10. Figures Z, AA, BB, CC. *Drepanochilus ruidium* (White). Z. apertural view x2 MNA N5128, loc. #271, BM10. AA. x2 MNA N5125, loc. #271, BM10. BB. x2 MNA N5126, loc. #271, BM10. CC. x2 MNA N5123, loc. #271, BM10.

PLATE 14 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS SEPTEMSERIATUM* SUBZONE, *SCIPONOCERAS GRACILE* ZONE

Figures A, B, F, G. *Cerithiopsis sohli* n. sp. A. Lectotype, x4 MNA N5134, loc. #298, BM8. B. Holotype, x1 MNA N1235, loc. #307, BM8. F. Paratype, x2 MNA N5135, loc. #298, BM8. G. Lectotype, x1 MNA N1148, loc. #262, BM8. Figure C. *Cerithioderma darcyi* n. sp. Holotype x4 MNA N5129, loc. #324, BM10. Figures D, E. *Turritella whitei* Stanton. D. x2 N5136, loc. #306, BM10. E. x1 MNA N5132, loc. #324, BM10. Figure H. *Turritella* sp. B. x2 MNA N5131, loc. #308, BM8. Figure I. *Levicerithium* ? sp. x2 MNA N5144, loc. #989, BM8. Figures J, K. *Eulima* ? *funicula*? Meek. J. x4 MNA N5121, loc. #989, BM8. K. x4 MNA N5120, loc. #306, BM10. Figure L. *Mathilia* ? n. sp. cf. *M. ripleyana* Wade x4 MNA N5130, loc. #992, BM10. Figures M, N. *Charonia kanabense* (Stanton). M. x4 MNA N5114, loc. #989, BM8. N. x2 MNA N5115, loc. #271, BM10. Figures O, P. *Graphidula walcotti* (Stanton). O. x4 MNA N5111, loc. #989, BM8. P. x2 MNA N5110, loc. #306, BM10. Figure Q. *Graphidula* n. sp. x2 MNA N5112, loc. #262, BM10. Figure R. *Dolicholatirus* ? sp. x1 MNA N5146, loc. #271, BM10. Figures S, T. *Pyropsis kochi* n. sp. S. Paratype, x1 MNA N5145, loc. #271, BM10. T. Holotype, x1 MNA N1218, loc. #271, BM10. Figure U. *Acteon propinquus* Stanton. x4 MNA N5106, loc. #262, concretion between BM8 and BM10. Figure V. *Eoacteon* sp. internal mold x4 MNA

N5107, loc. #262, BM8. Figures W, X, Y, Z. *Cylindrotruncatum* n. sp. W. SEM x5 MNA N5105, loc. #989, BM8. X. internal mold x4 MNA N5108, loc. #306, BM10. Y. SEM x5 MNA N5102, loc. #262, concretion between BM8 and BM10. Z. SEM x5 MNA N5104, loc. #262, concretion between BM8 and BM10. Figure AA. *Cylichna* sp. SEM x5 MNA N5103, loc. #262, concretion between BM8 and BM10. Figures BB, CC. *Cadulus praetenuis* Stephenson. BB. SEM x5 MNA N5361, loc. #271, BM10. CC. SEM x5 MNA N5360, loc. #271, BM10. Figure DD. *Dentalium* sp. x5 MNA N5516, loc. #989, BM8.

PLATE 15 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS SEPTEMSERIATUM* SUBZONE, *SCIPONOCERAS GRACILE* ZONE

Figures A, B, C. *Parasimilia* sp. A. x2 MNA N5359, loc. #262, BM8. B. x2 MNA N5358, loc. #262, BM8. C. x1 MNA N942, loc. #271, BM10. Figure D. *Stylotrochus* sp. x5 MNA N1222, loc. #813, BM8. Figures E, I. cf. *Ramphonotus* sp. E. x5 MNA N1200, loc. #303, BM8. I. x5 MNA N1199, loc. #303, BM8. Figures F, G. *Longitubus* sp. F. x2 MNA N5373, loc. #989, BM8. G. x4 MNA N5372, loc. #989, BM8. Figure H. *Solenophragma* sp. x5 MNA N1107, loc. #306, BM10. Figures J, K. *Cylindroserpula intrica* (Stanton). J. x2 MNA N5375, loc. #813, BM8. K. x2 MNA N1095, loc. #236, BM8. Figures L, M, N, O. P. Q. *Hemiaster* n. sp. cf. *H. jacksoni* Cooke. L. apical view x2 MNA N5379, loc. #306, BM10,. M. apical view x2 MNA N5380, loc. #306, BM10. N. lateral view x2 MNA N5380, loc. #306, BM10. O. basal view x2 MNA N5380, loc. #306, BM10. P. lateral view x2 MNA N5379, loc. #306, BM10. Q. basal view x2 MNA N5379, loc. #306, BM10.

PLATE 16 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS SEPTEMSERIATUM* SUBZONE, *SCIPONOCERAS GRACILE* ZONE

Figure A. *Borissiakoceras orbiculatum* Stephenson lateral view x2 MNA N4929, loc. #262, concretion between BM8 and BM10. Figures B, C. *Placenticeras cumminsi* Cragin. B. lateral view x1/2 MNA N3537, loc. #814, BM10. C. ventral view x1/2 MNA N3537, loc. #814, BM10. Figures D. E. *Sumitomoceras conlini* Wright and Kennedy partial body chamber. D. lateral view x2 MNA N1156, loc. #262, concretion between BM8 and BM10. E. ventral view x2 MNA N1156, loc. 262, concretion between BM8 and BM10. Figures F, G, H, K. *Pseudocalycoceras angolaense* (Spath). F. ventral view x2 MNA N4926, loc. #989, BM8,. G. lateral view x2 MNA N4916, loc. #306, BM10. H. ventral view x2 MNA N4916, loc. #306, BM10. K. lateral view x2 MNA N4926, loc. #989, BM8. Figures I, J, L, M, N, O. *Euomphaloceras septemseriatum* (Cragin). I. ventral view x1 MNA N1073, loc. #262, concretion between BM8 and BM10. J. lateral view x1 MNA N1073, loc. #262, concretion between BM8 and BM10. L. lateral view x1 MNA N4931, loc. #262, BM10. M. ventral view x1 MNA N4931, loc. #262, BM10. N. lateral view x2 MNA N1525, loc. 308, BM8. O. ventral view x2 MNA N1525, loc. #308, BM8.

PLATE 17 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS SEPTEMSERIATUM* SUBZONE, *SCIPONOCERAS GRACILE* ZONE

Figures A, B, E, F. *Metoicoceras geslinianum* (d'Orbigny). A. lateral view macroconch phragmocone x1 MNA N4921, loc. #271, BM10. B. apertural view macroconch phragmocone x1 MNA N4921, loc. #271, BM10. E. apertural view microconch phragmocone x1 MNA N4918, loc. #992, BM8. F. lateral view microconch phragmocone x1 MNA N4918, loc. #992, BM8. Figures C, D. *Nanometoicoceras acceleratum* (Hyatt). C ventral view adult microconch x4 MNA N4920, loc. #271, BM10. D. lateral view adult microconch x4 MNA N4920, loc. #271, BM10.

PLATE 18 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS SEPTEMSERIATUM* SUBZONE, *SCIPONOCERAS GRACILE* ZONE

Figures A, B, C. *Metoicoceras geslinianum* (d'Orbigny). A. lateral view phragmocone x1 MNA N1064, loc. #271, BM10. B. ventral view microconch x1 MNA N1134, loc. #262, BM10. C. ventral view phragmocone x1 MNA N1064, loc. #271, BM10. Figure D. *Metaptychoceras reesidei* (Cobban and Scott) lateral view x2 MNA N3556, loc. #271, BM10. Figures E, F, G, I. *Allocrioceras annulatum* (Shumard). E. lateral view microconch x1 MNA N4924, loc. #306, BM10. F.lateral view macroconch x1 MNA N4925, loc. #306, BM10. G. ventral view macroconch x1 MNA N4925, loc. #306, BM10. I. lateral view x2 MNA N1201, loc. #303, BM8. Figure H. *Sciponoceras gracile* (Shumard) lateral view x1 MNA N4923, loc. #306, BM8. Figures J, K. *Yezoites delicatulus* (Warren). J. lateral view macroconch phragmocone x2 MNA N1150, loc. #236, BM8. K. lateral view macroconch x1 MNA N4930, loc. #306, BM10. Figures L, M, N. *Worthoceras vermiculus* (Shumard). L. lateral view microconch x1 MNA N1201, loc. #303, BM8,. M. lateral view microconch x2 MNA N4913, loc. #271, BM10. N. lateral view macroconch x2 MNA N4912, loc. #989, BM8.

PLATES 19 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS IRREGULARE* SUBZONE, *NEOCARDIOCERAS JUDDII* ZONE

Figures A, B, C, D, F. *Archohelia dartoni* Wells. A. encrusting quartzite pebble x1 MNA N1084, loc. #262, lag at base of zone. B. encrusting bone fragment x1 MNA N1072, loc #262, lag at base of zone. C. x2 MNA N5364, loc. #262, lag at base of zone. D. x2 MNA N5365, loc. #262, lag at base of zone. F. x2 MNA N1091, loc. #262, lag at base of zone. Figure E. *Trochocyathus (Platycyathus)* sp. x2 MNA N1069, loc. #262, lag at base of zone. Figure G. *Ringicula codellana* Kauffman and Pope. x5 MNA N5101, loc. #308, BM11. Figure H. *Phelopteria* sp. B x1 MNA N3535, loc. #814, BM11. Figure I. *Pycnodonte newberryi* (Stanton) left valve x1 MNA N1162, loc. #262, lag at base of zone. Figure J. cf. *Arcopagia* sp. A left valve x5 MNA N5158, loc. #262, BM11. Figure K. *Inoceramus nodai* Matsumoto and Tanaka internal mold right valve x1 MNA N3530, loc. #814, BM11. Figure L, M. *Mytiloides submytiloides* (Seitz). L. internal mold left valve x1 MNA N3532, loc. #814, BM11. M. internal mold right valve x1 MNA N5257, loc. #262, BM11. Figure N. *Inoceramus* n. sp. cf. *I. heinzi* Sornay internal mold left valve x1 MNA N3527, loc. #814, BM11.

PLATE 20 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS IRREGULARE* SUBZONE, *NEOCARDIOCERAS JUDDII* ZONE

Figures A, D. *Inoceramus nodai* Matsumoto and Tanaka. A. internal mold right valve x1 MNA N1228, loc. #304, BM11. D. internal mold left valve x1 MNA N 3524, loc. #814, BM11. Figures B, C. *Inoceramus* n. sp. cf. *I. heinzi* Sornay. B. internal mold with shell adhearing left valve x1 MNA N3525, loc. #814 BM11. C. internal mold left valve x1 MNA N3526, loc. #814, BM11.

PLATE 21 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS IRREGULARE* SUBZONE, *NEOCARDIOCERAS JUDDII* ZONE

Figures A, B, C. *Euomphaloceras irregulare* (Cobban, Hook, and Kennedy) Holotype x1. A. ventral view. B. lateral view. C. apertural view. MNA N3500, loc. #814, BM11.

PLATE 22 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS IRREGULARE* SUBZONE, *NEOCARDIOCERAS JUDDII* ZONE

Figures A-L. *Euomphaloceras irregulare* (Cobban, Hook, and Kennedy) A. lateral view phragmocone x1 MNA N3503. B. ventral view phragmocone x1 MNA N3510. C. ventral view phragmocone x1 MNA N3507. D. ventral view phragmocone fragment x1 MNA N3509. E. lateral view x1 MNA N3502. F. ventral view x1 MNA N3502. G. lateral View x4 MNA N3516. H. lateral view x1 MNA N3501. I. ventral view x1 MNA N3501. J. lateral view x2 MNA N3504. K. ventral view x2 MNA N3504. L. lateral view x1 MNA N3506. All specimens from MNA loc. #814, BM11.

PLATE 23 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS IRREGULARE* SUBZONE, *NEOCARDIOCERAS JUDDII* ZONE

Figures A-E, H. *Thomasites* sp. cf. *T. gongilensis* (Woods). A. lateral view x1 MNA N3494. B. lateral view x1 MNA N3520. C. ventral view x1 MNA N3499. D. apertural view x1 MNA N3520. E. lateral view x1 MNA N3499. H. lateral view x1 MNA N3521. Figures F, G. *Rubroceras rotundum* Cobban, Hook, and Kennedy. F. lateral view x1 MNA N3495. G. ventral view x1 MNA N3495. All specimens from MNA loc #814, BM11.

PLATE 24 — LOWER SHALE MEMBER, MANCOS SHALE *EUOMPHALOCERAS IRREGULARE* SUBZONE, *NEOCARDIOCERAS JUDDII* ZONE

Figures A, B. *Burroceras clydense* Cobban, Hook, and Kennedy. A. lateral view x4 MNA N3517. B. ventral view x4 MNA N3517. Figures C, D. *Neocardioceras* ? n. sp. C. lateral view x4 MNA N3498. D. ventral view x4 MNA N3498. Figures E, F. *Nigericeras* sp. cf. *N. ogojaensis* Reyment. E. ventral view x1 MNA N3496. F. lateral view x1 MNA N3496. All specimens from MNA loc #814, BM11.

PLATE 25 — LOWER SHALE MEMBER, MANCOS SHALE *NEOCARDIOCERAS JUDDII* SUBZONE *NIGERICERAS SCOTTI* SUBZONE ?, *NEOCARDIOCERAS JUDDII* ZONE

Figure A. *Hamulus* sp. compacted specimens x2 MNA N5370, loc. #305, around 2-3 meters above BM13. Figures B, C. *Inoceramus pictus* Sowerby s.l. B. right valve x1 MNA N3564. C. right valve x1 MNA N232. Both from loc. 305, concretions associated with BM12 and 13. Figure D. *Phelopteria minuta* Kauffman and Powell right valve x2 MNA N3601, loc. #989, below BM12. Figure E. *Plicatula* sp. cf. *P. ferryi* Coquand right valve x2 MNA N5489, loc #989, a meter above BM13. Figures F. H. *Pycnodonte newberryi umbonata* n. subsp. F. Paratype, left valve x1 MNA N1473. H. Holotype, left valve x1 MNA N1472. Both from loc. #305, lag at Cenomanian/Turonian boundary three meters above BM13. Figures G, I, J. *Psilomya elongata* Stanton. G. left valve x1 MNA N5187. I. left valve x1 MNA N233. J. left valve x1 MNA N5548. All from loc. #305, concretions associated with BM12 and BM13. Figure K. *Drepanochilus ruidium* (White) (a) with left valve of cf. *Arcopagia* sp. A. unwhitened x4 MNA N5224, loc. #989, above BM13. Figure L. *Pseudaspidoceras pseudonodosoides* (Choffat) oblique view x1 MNA N4900, loc. #305, concretion between BM12 and BM13. Figures M, N, Q, R. *Neocardioceras juddii* (Barrois and Guerne). M. lateral view x1 MNA N238, loc. #305, concretion associated with BM12 and BM13. N. compacted specimen lateral view x2 MNA N4965, loc. #305, concretion associated with BM12 and BM13. Q. compacted specimen ventral view x2 MNA N4958, loc. #989, below BM12. R. compacted specimen lateral view x2 MNA N4964, loc. #305, concretion associated with BM12 and BM13. Figures O, S. *Hamites simplex* (d'Orbigny). O. ventral view x2 MNA N4966. S.lateral view x2 MNA N4966. From loc. #305, concretion associated with BM12 and BM13. Figures P, T, V. *Anisoceras coloradoense* Cobban, Hook, and Kennedy. P. lateral view unwhitened x1 MNA N239, loc. #305, concretion associated with BM12 and BM13. T. compacted specimen lateral view x1 MNA N4962, loc. #989, below BM12. V. oblique view x1 MNA N4899, loc. #305, concretion associated with BM12 and BM13. Figure U: *Worthoceras vermiculus* (Shumard) (a) compacted specimen with *Allocrioceras* sp. x1 MNA N4960, loc. #305, 2-3 meters above BM13. Figure W *Sciponoceras gracile* (Shumard) compacted specimen lateral view x1 MNA N4963, loc. #305, concretion associated with BM12 and BM13.

PLATE 26 — LOWER SHALE MEMBER, MANCOS SHALE LOWER TURONIAN

Figure A. *Discinisca* sp. SEM x5 MNA N5297, loc. #308, one meter below BM15. Figures B, C. *Charonia soozi* n. sp. B. Lectotype, latex peel compacted specimen x2 MNA N5268, loc. #262, below BM35. C. Lectotype, x4 MNA N5285, loc. #262, concretion above BM21. Figures D, E. *Anisomyon* n. sp. D. compacted specimen x1 MNA N5270. E. loc. #262, BM30. compacted specimen x1 MNA N5264, loc. #262, above BM15. Figure F. *Anomia cobbani* ? Hasenmueller and Hattin. compacted specimens x2 MNA N5207, loc. #989, one meter below BM27. Figure G, H. *Pseudoperna bentonense* (Logan). G. numerous specimens (b) encrusting *Mytiloides columbiaensis* x1 MNA N5215, loc. #262, BM20. H. right valve x2 MNA N5219, loc. #262, BM30. Figure I. *Pycnodonte kansasense* ? Bottjer, Roberts, and Hattin right valve x2 MNA N5210, loc. #262, BM28. Figure J. *Pseudoperna* ? sp. right valve x2 MNA N5472, loc. #262, middle shale member 10 m above BM54. Figure K, L. *Entolium gregorium* Kauffman and Powell. K. compacted specimens x4 MNA N4815, loc. #989, below BM32. L. compacted specimen internal view right valve x4 MNA N4813, loc. #989, one meter above BM15. Figure M. *Camptonectes* n. sp. A compacted associated valves x2 MNA N4820, loc. #262, below BM32. Figure N. *Psilomya* sp. left valve x2 MNA N5230, loc. #262, below BM35. Figure O. *Lucina subundata* Hall and Meek right valve x2 MNA N5473, loc. #262, below BM37.

PLATE 27 — LOWER SHALE MEMBER, MANCOS SHALE LOWER TURONIAN

Figure A. *Oxytoma* ? sp. compacted specimens x2 MNA N4806, loc. #262, below BM21. Figures B, D. *Phelopteria* sp. C. B. compacted left valve (b) with *Watinoceras devonense flexuosum* Cobban (a) x2 MNA N3618, loc. #262, BM18. D. right valve x2 MNA N3609, loc. #262, BM18. Figures C, E. *Phelopteria minuta* Kauffman and Powell C. compacted right valve x2 MNA N3607, loc. #262, BM18. E. compacted right valve, margins poorly preserved x2 MNA N4810, loc. #262, below BM38. Figure F. *Phelopteria* sp. D compacted right valve x2 MNA N3614, loc. #989, below BM17. Figure G. *Phelopteria* ? sp. E compacted pair of valves x2 MNA N5454, loc. #262, above BM30. Figure H. *Phelopteria* sp. A. compacted right valve x2 MNA N3619, loc. #989, below BM12. Figures I-M. *Phelopteria* sp. F. I. compacted left valve x1 MNA N3624, loc. #989, below BM34. J. latex peel compacted left valve x2 MNA N3622, loc. #989, two meters above BM32. K. compacted internal view left valve x2 MNA N3620, loc. #262, above BM26. L. latex peel left valve x2 MNA N3620, loc. #262, above BM26. M. compacted left valve x2 MNA N3621, loc. #989, BM28.

PLATE 28 — LOWER SHALE MEMBER, MANCOS SHALE LOWER TURONIAN

Figure A. *Mytiloides hattini* Elder in manuscript compacted left valve x1 MNA N5458, loc. #989, below BM14. Figure B-E, G. *Mytiloides elongata* Seitz. B. compacted left valve x1 MNA N5249, loc. #262, above BM15. C. compacted pair of valves x1 MNA N5258, loc. #989, below BM16. D. compacted right valve x1 MNA N5252, loc. #989, above BM14. E. compacted left valve (b) with *Pseudoperna bentonensis* Logan x1 MNA N5546, loc. #262, one meter above BM15. G. compacted left valve x1 MNA N5522, loc. #262, one meter above BM16. Figures F, J. *Mytiloides duplicostatus* Anderson. F. compacted right valve x1 MNA N5051, loc. #813, below BM15. J. compacted right valve ? x1 MNA N5547, loc. 989, BM28. Figures H, I. *Mytiloides* sp. cf. *M. latus* (Sowerby). H. compacted right valve x1 MNA N5238, loc. 306, just above Cenomanian/ Turonian boundary three meters above BM13. I. compacted right valve x1 MNA N5237, loc. #989, two meters above BM16. Figure K. *Inoceramus* sp. cf. *I. nodai* Matsumoto and Tanaka latex peel compacted left valve x1 MNA N5254, loc. #262, two meters below BM21.

PLATE 29 — LOWER SHALE MEMBER, MANCOS SHALE LOWER TURONIAN

Figure A-E, J. *Mytiloides columbianus* (Heinz). A. compacted left valve x1 MNA N5458, loc. #262, below BM15. B. compacted right valve x1 MNA N5246, loc. #262, BM23-24. C. compacted right valve x1 MNA N5251, #989, three meters above BM26. D. compacted right valve x1 MNA N5471, loc. #262, BM18. E. compacted right valve x1 MNA N5244, loc. #262, BM18. J. compacted left valve x1 MNA N5592, loc. #989, below BM27. Figures F-I. *Mytiloides mytiloides* (Mantell). F. compacted right valve x1 MNA N5243, loc. #989, BM30. G. compacted right valve x1 MNA N5255, loc. #262, one meter below BM28. H. compacted right valve x1 MNA N5248, loc. #262, BM18. I. compacted left valve x1 MNA N5235, loc. #262, below BM26.

PLATE 30 — LOWER SHALE MEMBER, MANCOS SHALE LOWER TURONIAN

Figure A. *Mytiloides mytiloides* (Mantell) compacted right valve x1 MNA N5053, loc. #989, BM28. Figure B-D, F. *Mytioloides mytiloides arcuata* (Seitz). B. latex peel compacted right valve x1 MNA N5048, loc. #989, above BM30. C. latex peel compacted right valve x1 MNA N5247, loc. #262, below BM28. D. compacted right valve x1 MNA N5239, loc. #989, BM30. F. latex peel compacted left valve x1 MNA N5049, loc. #989, BM30. Figure E. *Mytiloides labiatus* (Schlotheim) compacted left valve x1 MNA N5523, loc. #989, below BM27.

PLATE 31 — LOWER SHALE MEMBER — BASAL HOPI SANDY MEMBER, MANCOS SHALE LOWER and MIDDLE TURONIAN

Figure A. *Mytiloides labiatus* (Schlotheim) compacted left valve x1 MNA N5241, loc. #262, below BM38. Figure B, C. *Mytiloides subhercynicus* (Seitz). B. compacted right valve x1 MNA N5255, loc. #262, one meter below BM28. C. compacted right valve x1 MNA N3548, loc. #262, below BM28. Figure D, H. *Mytiloides hercynicus* (Petracheck). D. compacted right valve x1 MNA N5253, loc. #262, 11 m above BM54 . H. compacted left valve x1 MNA N3549, loc. #262, three meters above BM54. Figure E. *Sergipia hartti* ? Hessel compacted right valve (b) with external mold of mammitid (a) x1 MNA N5050, loc. #262, above BM32. Figure F, G, I, J. *Inoceramus cuvieri* Sowerby. F. compacted left valve x1 MNA N5236, loc. #262, below BM54. G. compacted right valve x2 MNA N5451, loc. #262, one meter below BM66. I. right valve x1 MNA N5260, loc. #262, three meters above base Hopi Sandy Member. J. latex peel slightly compacted right valve x1 MNA N5047, loc. #262, one meter above BM68.

PLATE 32 — LOWER SHALE MEMBER, MANCOS SHALE LOWER TURONIAN

Figures A, B. *Pseudaspidoceras flexuosum* Powell. A. compacted fragment lateral view x1 MNA N4970, loc. #989, below BM14. B. compacted fragment lateral view x2 MNA N4983, loc. #262, one meter above BM16. Figures C, F. *Fagesia catinus* (Mantell) C. compacted fragment lateral view x1 MNA N4895, loc. #989, below BM14. F. latex peel compacted specimen lateral view x1 MNA N5017, loc. #262, below BM21. Figures D, E, G. *Quitmaniceras reaseri* Powell. D. compacted specimen lateral view x2 MNA N5005, loc. #989, below BM16. E. compacted specimen in lateral view displaying part of venter x2 MNA N5460, loc. #262, two meters above BM15. G. latex peel compacted specimen in lateral view ? x1 MNA N4975, loc. #262, two meters above BM15. Figures H, I. *Vascoceras* sp. H. compacted specimen lateral view x1 MNA N4982, loc. #262, one meter below BM17. I. compacted specimen lateral view x1 MNA N4680, loc. #262, two meters above BM15. Figure J. *Neoptychites cephalotus* (Courtiller) ? compacted specimen lateral view x1 MNA N5010, loc. #262, above BM18. Figure K. *Watinoceras* ? sp. compacted specimen lateral view x1 MNA N4987, loc. #989, below BM16.

PLATE 33 — LOWER SHALE MEMBER, MANCOS SHALE LOWER TURONIAN

Figures A, C, D. *Watinoceras coloradoense* (Henderson). A. latex peel compacted specimen lateral view x1 MNA N4981, loc. #262 below BM16. C. compacted fragment lateral view x1 MNA N4995, loc. #262, BM18. D. compacted specimen lateral view x1 MNA N5015, loc. #262, one meter above BM20. Figure B. *Watinoceras* sp. cf. *W. praecursor* Wright and Kennedy compacted specimen lateral view x1 MNA N4999, loc. #989, below BM16. Figure E, F, H, I, K. *Watinoceras devonense flexuosum* Cobban. E. compacted specimen lateral view x1 MNA N4990. F. compacted specimens lateral view x1 MNA N4988. H. compacted specimen lateral view x2 MNA N4993. I. compacted specimen lateral view x1

MNA N4989. K. abundant compacted specimens with *Mytiloides columbianus* Heinz (a) and *Phelopteria* sp. C x1 MNA N5000. All specimens from loc. #262, BM18. Figure G. *Watinoceras reesidei* Warren compacted specimen lateral view displaying part of venter x2 MNA N4974, loc. #262, one meter above BM15. Figure J. *Puebloites spiralis* Cobban and Scott compacted fragment (b) with *Phelopteria* sp. C (a) x1 MNA N4997, loc. #262, BM18.

PLATE 34 — LOWER SHALE MEMBER, MANCOS SHALE LOWER TURONIAN

Figure A, B. *Watinoceras hattini* Cobban. A. compacted specimen lateral view x1 MNA N5020, loc. #262, below BM23. B. compacted specimen lateral view x1 MNA N5025, loc. #262, below BM26. Figure C, D. *Watinoceras* sp. C. compacted specimen x2 MNA N5028, loc. #262, above BM26. D. compacted specimen lateral view x1 MNA N5040, loc. #262, below BM28. Figure E. *Tragodesmoceras bassi* (Morrow) compacted specimen lateral view x1 MNA N4879, loc. #989, above BM26. Figure F. *Choffaticeras* sp. cf. *C. pavillieri* (Pervinquiere) crushed specimen lateral view x1 MNA N4876, loc. #989, one meter below BM27. Figure G. *Mammites nodosoides* (Schluter) compacted specimen lateral view x1 MNA N4867, loc, #989, BM30. Figures H,I. *Morrowites* sp. H. compacted specimens x1 MNA N4910, loc. #262, below BM28. I. compacted fragment ventral view x1 MNA N4872, loc. #262, below BM32.

PLATE 35 — LOWER SHALE MEMBER, MANCOS SHALE LOWER TURONIAN

Figures A-B. *Mammites nodosoides* (Schluter). A. lateral compressed specimen lateral view with mammitid aptychi ? x1 MNA N4840, loc. #989, BM30. B. compacted fragment lateral view x1 MNA N4873, loc. #262, below BM36. Figure C. *Morrowites* ? sp. compacted fragment oblique view x1 MNA N4868, loc. #296, two meters below BM27. Figure D, I. *Cibolaites molenaari* Cobban and Hook. D, compacted fragment lateral view x1 MNA N4887, loc. #989, below BM34. I. compacted specimen lateral view x1 MNA N4897, loc. #262, one meter below BM33. Figure E-H, J. *Cibolaites* sp. E. compacted specimens lateral view x1 MNA N4870, loc. #262, above BM32. F. compacted specimen lateral view x1 MNA N4893, loc. #989, one meter above BM32. G. compacted specimen lateral view x2 MNA N4901, loc. #262, two meters below BM35. H. compacted specimen lateral view x2 MNA N4904, loc. #262, one meter above BM32. J. compacted specimen lateral view x2 MNA 5045, loc. #262, two meters above BM32. Figures K, L. *Puebloites greenhornensis* Cobban and Scott. K. compacted specimen lateral view x1 MNA N4875, loc. #989, below BM27. L. compacted specimen lateral view x1 MNA N4866, loc. #262, above BM30.

PLATE 36 — LOWER SHALE MEMBER-UPPER SHALE MEMBER, MANCOS SHALE MIDDLE TURONIAN

Figure A. *Acmaea* sp. compacted specimen x4 MNA N5282, loc. #262, one meter below BM64. Figure B. trochid ? indet. internal mold with shell adhearing x2 MNA N5271, loc. #262, four meters above BM66. Figure C. *Nerita* sp. compacted specimen apical view x5 MNA N5273, loc. #262, below BM38. Figure D. *Turritella cobbani* n. sp. Holotype, x2 MNA N5275, loc. #262, three meters above BM54. Figure E. *Turritella kauffmani* n. sp. Holotype, latex peel x2 MNA 5280, loc. #262, three meters above base Hopi Sandy Member. Figures F, H, I. *Levicerithium* sp. cf. *L. timberanum* Stephenson. F. x2 MNA N5269, loc. #262, two meters below base of Hopi Sandy Member. H. x4 MNA N3599, loc. #989, 13 m above base of Hopi Sandy Member. I. x4 MNA N3600, loc. #989, 13 m above base of Hopi Sandy Member. Figure G. *Neritina* sp. compacted specimen apical view x5 MNA N5272, loc. #262, for meters above BM54. Figure J. *Bellifusus* n. sp. compacted specimen x1 MNA N5265, loc. #262, one meter above BM55. Figure K, P. *Bellifusus* sp. cf. *B. willistoni* (Logan). K. latex peel compacted fragment x1 MNA N5266. P. compacted specimens x1 MNA N5266. From loc. #262, above BM68. Figures L-O. *Nucula coloradoensis* Stanton. L. latex peel internal view right valve bored by naticid x4 MNA N5197 loc. #262, five meters below base of Hopi Sandy Member. M. right valve x2 MNA N5195, loc. #262, one meter below base of Hopi Sandy Member. N. compacted left valve x2 MNA N5200, loc. #262, one meter above BM66. O. latex peel internal view right valve x2 MNA N5202, loc. #989, upper shale member seven meters above BM77. Figures Q, R. *Solemya obscura* Stanton. Q. compacted left valve x2 MNA N5189, loc. #262, above BM54. R. compacted right valve x2 MNA N5191, loc. #262, two meters above BM66. Figures S, Z. cf. *Arcopagia* sp. B. S. composite molds x4 MNA N5223. Z. compacted left valve x4 MNA N5225. All from loc. #989, four meters above BM65. Figure T. cf *Mytilus* sp. composite mold right valve x2 MNA N5193, loc. #989, one meter above BM61. Figures U, V. *Anomia* sp. B. U. upper valve x2 MNA N5205, loc. #262, three meters above BM54. V. lower valve x4 MNA N5204, loc. #262, 10 m above BM54. Figure W. *Botula* ? sp. internal mold left valve x2 MNA N5194, loc. #262, upper shale member 10 m above top of Hopi Sandy Member. Figure X. *Pycnodonte* sp. left valve x2 MNA N5208, loc #262, below BM36. Figure Y. *Pseudoperna* ? sp. right valve x2 MNA N5221, loc. #989, below BM48. Figures AA, BB. *Pseudoperna bentonense* (Logan) AA. internal view left valve x2 MNA N5216, loc. #262, five meters below BM70. BB. right valve x2 MNA N5217, loc. #262, four meters below BM70.

PLATE 37 — MIDDLE SHALE MEMBER-UPPER SHALE MEMBER, MANCOS SHALE MIDDLE TURONIAN

Figure A, E. *Lucina subundata* Hall and Meek. A. compacted left valve x2 MNA N5474, loc. #262, above BM65. E. composite mold left valve x2 MNA N5479, loc. #262, five meters below BM70. Figure B. *Lucina* n. sp. left valve x2 MNA N5233, loc. #262, below BM70. Figures C, D. *Cyclina* ? sp. C. right valve x4 MNA N3595, loc. #989, 13 meters above base of Hopi Sandy Member. D. left valve x4 MNA N3596, loc. #989, 13 meters above base of Hopi Sandy Member. Figure F. *Parvilucina* sp. composite mold left valve x2 MNA N5447, loc. #262, seven meters below BM64. Figures G, H. *Cyclorisma orbiculata* (Hall and Meek). G. latex peel right valve x2 MNA N5476, loc. #262, three meters above BM65. H. left valve x2 MNA N5229, loc. #262, upper shale member eight meters above top of Hopi Sandy Member. Figures I, J, M. *Tellina carlilana* n. subst. I. left valve x2 MNA N5475, loc. #262, three meters above BM68. J. composite mold shell adhearing left valve x2 MNA N5481, loc. #262, six meters below top of Hopi Sandy Member . M. paired valves x2 MNA N5480, loc. #262, three meters below base of Hopi Sandy Member. Figure K. *Pharodina ferrana* Stephenson left valve x2 MNA N5226, loc. #262, upper shale member six meters below Blue Point Sandstone Tongue. Figure L. *Pollex* ? sp. left valve x4 MNA N5227, loc, #262, one meter above BM65. Figure N. *Corbula kanabensis* Stanton right valve x4 MNA N5488, one meter below BM68. Figure O, Q. *Mytiloides latus.* (Sowerby) sensu Hattin. O. composite mold left valve x2 MNA N5517, loc. #989, below top of Hopi Sandy Member. Q. compacted valves x2 MNA N5240, loc. #298, six meters below top of Hopi Sandy Member. Figure P. *Inoceramus apicalis* Woods right valve x2 MNA N5520, loc. #989, three meters above base of Hopi Sandy Member.

PLATE 38 — LOWER SHALE MEMBER-MIDDLE SHALE MEMBER, MANCOS SHALEMIDDLE TURONIAN

Figures A, B. *Tragodesmoceras socorroense* Cobban and Hook. A. compacted specimen lateral view x2 MNA N4862, loc. #989, four meters below BM67. B. compacted specimen lateral view x2 MNA N4863, loc. #989, five meters below BM67. Figures C-E, H. *Placenticeras cumminsi* Cragin. C. lateral view x1 MNA N4833, loc. #262, concretion one meter below BM70. D. compacted specimen lateral view x1 MNA N4836, loc. #262, five meters below BM70. E. fragment lateral view x1 MNA N4831, loc. #262, concretion one meter below BM70. H. compacted body chamber lateral view x1/2 MNA N4832, loc. #262, concretion one meter below BM70. Figure F. *Hamites* sp. compacted fragment x1 MNA N4890, loc. #989, above BM62. Figure G. *Spathites* sp. compacted specimen lateral view x2 MNA N4861, loc. #989, four meters below BM66. Figure I. *Kamerunoceras turoniense* (d'Orbigny) compacted fragment lateral view x1 MNA N4864, loc. #262, below BM36. Figure J. *Baculites calamus* Morrow compacted specimen lateral view x1 MNA N4865, loc. #262, below BM41. Figure K. *Baculites yokoyamai* Tokunaga and Shimizu compacted specimen lateral view x1 MNA N4835, loc. #262, above BM50.

PLATE 39 — MIDDLE SHALE MEMBER-HOPI SANDY MEMBER, MANCOS SHALE MIDDLE TURONIAN

Figures A, C, D, F, G. *Collignoniceras woollgari woollgari* (Mantell). A. compacted specimen lateral view x1 MNA N4860, loc. #989, three meters below BM66. C. body chamber lateral view x1/2 MNA N3554, loc. #262, concretion one meter below BM70. D. latex peel external mold lateral view x1 MNA N4834, loc. #262, concretion one meter below BM70. F. distorted specimen lateral view x1 MNA N3555, loc. #262, concretion one meter below BM70. G. distorted specimen ventral view x1 MNA N3555, loc. #989, concretion one meter below BM70. Figure B. *Collignoniceras woollgari regulare* (Haas) compacted external mold lateral view x1/2 MNA N1169, loc. #812, Hopi Sandy Member. Figure E. Aptychi x1 MNA N4891, loc. #989, BM59.

PLATE 40 — HOPI SANDY MEMBER, MANCOS SHALE AND BLUE POINT SANDSTONE TONGUE, TOREVA FORMATION MIDDLE TURONIAN

Figure A. *Collignoniceras woollgari regulare* (Haas) lateral view (c) with *Prionocyclus percarinatus* (Hall and Meek) and *Levicerthium* sp. cf. *L. timberanum* Stephenson x1 MNA N3590, loc. #989, 13 meters above base of Hopi Sandy Member. Figure B-F, I. *Prionocyclus percarinatus* (Hall and Meek) B. lateral view x2 MNA N3583, loc. #989, 13 m above base of Hopi Sandy Member. C. ventral view x2 MNA N3583, loc. #989, 13 m above base of Hopi Sandy Member. D. lateral view x2 MNA N3587, loc. #989, 13 m above base of Hopi Sandy Member. E. fragment lateral view x2 MNA N3582, loc. #1150, caprock Blue Point Tongue. F. fragment ventral view x2 MNA N3582, loc. #1150, caprock Blue Point Tongue. I. abundant specimens with scattered plant debris x1/2 MNA N5400, loc. #989, 15 m above base of Hopi Sandy Member. Figure G. *Scaphites patulus* Cobban lateral view x2 MNA N3593, loc. #989, 13 m above base of Hopi Sandy Member. Figure H. *Scaphites larvaeformis* Meek and Hayden lateral view x2 MNA N4843, loc. #1150, caprock Blue Point Tongue.

PLATE 41 — BLUE POINT SANDSTONE TONGUE, TOREVA FORMATION MIDDLE TURONIAN

Figure A. *Serpula* sp. (a) with *Syncyclonema* sp. and *Collignoniceras woollgari regulare* (Haas) x1 MNA N5396, from caprock. Figure B, C. *Weeksia* ? sp. A. apical view x2 MNA N5486. B. apertural view x2 MNA N5486. From caprock. Figure D, E. *Nerita* n. sp. D. apertural view x2 MNA N5487. E. oblique apical view x2 MNA N5487. From main body. Figures F-I. *Gyrodes conradi* Meek. F. oblique apical view of internal mold with external mold of *Serpula* sp. x1 MNA N3474, from caprock. G. oblique apical view internal mold with shell adhearing (b) with *Gyroides depressa* Meek (a) x1 MNA N5408, from caprock. H. oblique apical view x1 MNA N5483, from main body. I. apertural view x2 MNA N5093, fro main body. Figure J, K. *Gyrodes depressa* Meek. J. internal mold apertural view x1 MNA N5501. K. internal mold x2 MNA N5484. From caprock. Figure L. *Cerithiopsis* sp. apertural view SEM x5 MNA N5059, from main body. Figure M. *Cerithioderma occidentalis* (Stanton) (a) with *Ringicula coddellana* Kauffman and Pope x4 MNA N5395, from main body. Figures N, O. *Turritella codellana* n. sp. N. x2 MNA N5528. O. x1 MNA N3472. From main body. Figures P-T. *Anchura hopii* n. sp. P. Paratype, x1 MNA N3468. Q. Holotype, apertural view x1 MNA N3476. R. Paratype, x2 MNA N5355. S. Paratype, x1 MNA N5533. T. Paratype, x1 MNA N5534. From main body. Figures U, V. *Gegania* ? sp. U. apertural view x2 MNA N5490. V. apertural view x4 MNA N5557. From main body. Figure W. *Mathilda* ? sp. apertural view x4 MNA N5500, from main body. Figure X-Z. *Pyktes fusiformis* (Meek) X. x1 MNA N5497. Y. x1 MNA N5387. Z. apertural view x1 MNA N3477. From caprock. All specimens from MNA loc. #1150.

PLATE 42 — BLUE POINT SANDSTONE TONGUE, TOREVA FORMATION MIDDLE TURONIAN

Figures A, B. *Charonia soozi* n. sp. A. Holotype, x2 MNA N5556. B. Paratype, x1 MNA N5509. From main body. Figure C. *Rhombopsis huerfanensis* Stanton x1 MNA N5510, from main body. Figures D, E. *Pyropsis* sp. cf. *P. coloradoensis* Stanton. D. x1 MNA N5085. E. apertural view x1 MNA N5084. From main body. Figure F. *Bellifusus ? gracilicosta* n. sp. Lectotype, apertural view x2 MNA N5515, from main body. Figures G, H, M, N. *Paleopsephaea arizonensis* n. sp. G. Holotype, apertural view x1 MNA N5506. H. Paratype, x1 MNA N5505. M. Paratype, x1 MNA N5532. N. Paratype, x2 MNA N5531. All from main body. Figures I, J. *Gyrotropis nationsi* n. sp. I. Paratype, x2 MNA N5525. J. Holotype, apertural view x1 MNA N5086. Both from main body. Figures K, L, Q, R. *Cryptorhytis utahensis* Meek. K. x1 MNA N5508, from main body. L. apertural view x1 MNA N5503, from main body. Q. apertural view x1 MNA N5504, from main body. R. x1 MNA N5502, from caprock. Figures O, P. *Carota dalli* (Stanton). O. x1 MNA N5507, from main body. P. apertural view x1 MNA N5082, from caprock. Figure S. n. gen. *"Fusus" venenatus* Stanton. S. x1 MNA N5267, from caprock. Figure T. *Lutema hitzi* (Meek) x1 MNA N5384, from main body. Figures U-W. *Acirsa kelseyi* n. sp. U. Paratype, apertural view x1 MNA N5392, from caprock. V. Paratype, x2 MNA N5512, from main body. W. Holotype, apertural view x2 MNA N5511, from main body. Figures X, Y. *Ringicula codellana* Kauffman and Pope. X. apertural view x4 MNA N5514. Y. apertural view x4 MNA

N5513. Both from main body. Figure Z. *Cylindrotruncatum* sp. apertural view x4 MNA N5554, from main body. All specimens from loc. #1150.

PLATE 43 — BLUE POINT SANDSTONE TONGUE, TOREVA FORMATION MIDDLE TURONIAN

Figure A. *Nuculana* sp. internal mold right valve x4 MNA N5061, from caprock. Figure B. *Modiolus coloradoensis* n. sp. Lectotype, right valve x2 MNA N5054, from caprock. Figure C. *Modiolus* n. sp. cf. *M. attenuatus* (Meek and Hayden) latex peel right valve x1 MNA N5398, from caprock. Figures D, E. *Pinna kauffmani* n. sp. D. Paratype, latex peel right valve x1 MNA N5498. E. Holotype, internal mold left valve x1 MNA N5095. Both from caprock. Figures F-I. *Syncyclonema* sp. F. right valve x2 MNA N5530. G. left valve in opening of left valve of *Rhynchostreon suborbiculata* (Lamarck) x4 MNA N5063, from caprock. H. right valve x2 MNA N5552, from mainbody. I. internal view right valve x4 MNA N5096, from mainbody. Figure J. *Crassostrea soleniscus* (Meek) internal mold left valve with inner shell layer adhearing x1 MNA N5402, from caprock. Figure K. *Rhynchostreon suborbiculata* (Lamarck) left valve x1 MNA N3481, from main body. Figures L-P. *Oxytoma (Hypoxytoma) arizonensis* n. sp. L. Paratype, left valve x2 MNA N5550, from main body. M. Paratype, right valve x4 MNA N5060, from main body. N. Paratype, internal view right valve x4 MNA N5060, from caprock. O. Paratypes, right valves (a) with *Syncyclonema* sp. x2 MNA N5088, from main body. P. Holotype, left valve x4 MNA N5055, from caprock. Figure Q. *Lima* sp. aff. *L. utahensis* Stanton left valve x2 MNA N5394, from caprock. All specimens from MNA loc. #1150.

PLATE 44 — BLUE POINT SANDSTONE TONGUE, TOREVA FORMATION MIDDLE TURONIAN

Figures A-D. *Phelopteria gastrodes* (Meek). A. internal view fragmentary right valve x1 MNA N5381, from main body. B. internal view fragmentary right valve x1 MNA N5382, from main body. C. left valve x1 MNA N5094, from caprock. D. left valve x1 MNA N5536, from caprock. Figures E, Q, R. *Crassatella* ? sp. right valve x2 MNA N5390, from main body. Q. left valve x2 MNA N5098, from main body. R. internal view left valve x2 MNA N5098, from main body. Figure F. *Inoceramus cuvieri* Sowerby internal mold left valve x1 MNA N5259, from caprock. Figure G. *Pseudopteria propleura* Meek internal mold left valve x1 MNA N5097, from caprock. Figure H, I. *Parvilucina juvenis* (Stanton). H. left valve x2 MNA N5062. I internal view left valve x2 MNA N5062. From main body. Figure J. *Tenea* sp. left valve x2 MNA N5527, from caprock. Figure K-M, P. *Pleuriocardia pauperculum* (Meek). K. internal view left valve x2 MNA N5555. L. left valve x2 MNA N5555. M. right valve x2 MNA N5091. P. right valves (a) with *Psilomya concentrica* (Stanton) (b), *Parvilucina juvenis* (Stanton) (c), and *Syncyclonema* sp. x1 MNA N5096. All from main body. Figure N. *Legumen* sp cf. *L. ligula* Stephenson. internal mold right valve x1 MNA N5432, from caprock. Figure O. *Cymbophora huerfanensis* Stanton internal mold left valve x2 MNA N5524, from caprock. Figures S, T. *Cymbophora emmonsi* (Meek). S. left valve x2 MNA N5485. T. internal view left valve x2 MNA N5485. From main body. All specimens from MNA loc. #1150.

PLATE 45 — BLUE POINT SANDSTONE TONGUE, TOREVA FORMATION MIDDLE TURONIAN

Figure A, B. *Veniella mortoni* (Meek and Hayden) A. internal view right valve x1 MNA N5080. B. right valve with *Gyrodes* boring x1 MNA N5081. Both from main body. Figure C. *Veniella* n. sp. left valve x1 MNA N5078, from main body. Figure D. *Cyprimera cymprimeriformis* (Stanton) right valve (b) with *Cymbophora utahensis* Meek (a), and *Psilomya concentrica* (Stanton) (c) x1 MNA N5100, from main body. Figure E. *Parmicorbula* sp. left valve x4 MNA 5057, from main body. Figure F. *Corbula* sp. cf. *C. kanabensis* Stanton x4 MNA N5058, from main body. Figure G, I. *Collignoniceras* n. sp. ? aff *C. carolinum* (d'Orbigny). G. ventral view x1 MNA N4850. I. lateral view x1 MNA N4850. From caprock. Figure H. *Teredolithus* sp. x1 MNA N5089, from caprock. Figure J. *Collignoniceras woollgari regulare* (Haas) lateral view x1 MNA N4847, from caprock. All specimens from MNA loc. #1150.

PLATE 46 — BLUE POINT SANDSTONE TONGUE, TOREVA FORMATION MIDDLE TURONIAN

Figure A. *Collignoniceras* n. sp. ? aff. *C. carolinum* (d'Orbigny) lateral view x1 MNA N4894. Figures B-G. *Collignoniceras woollgari regulare* (Hass). B. ventral view x2 MNA N4845. C. lateral view x1 MNA N4845. D. ventral view x1 MNA N3552. E. lateral view x1 MNA N3552. F. ventral view x1 MNA N4846. G. lateral view x1 MNA N4846. All specimens from MNA loc. #1150, caprock.

PLATE 47 — BLUE POINT SANDSTONE TONGUE and LOWER SANDSTONE MEMBER, TOREVA FORMATION at BLUE POINT MIDDLE TURONIAN

Figure A, C. *Placenticeras cumminsi* Cragin. A. lateral view x1 MNA N3553. C. apertural view x1 MNA N3553. From loc. #1150 Blue Point Tongue caprock. Figure B, E, F. *Collignoniceras woollgari regulare* (Haas). B. ventral view x1 MNA N4848, loc. #1150, Blue Point Tongue caprock. E. lateral view x1 MNA N4848, loc. #1150, Blue Point Tongue caprock. F. lateral view x2 MNA N4841, loc. #342, lower sandstone member Toreva Formation. Figure D, G. *Spathites (Spathites) puercoensis* (Herrick and Johnson). D. oblique view x1 MNA N4852. G. lateral view x1 (b) with *Pleuriocardia pauperculum* (Meek) (a) and *Pyktes fusiformis* (Meek) (c) x1 MNA N4851. Both from loc. #342, lower sandstone member Toreva Formation.

PLATE 48 — LOWER SANDSTONE MEMBER, TOREVA FORMATION at BLUE POINT MIDDLE TURONIAN

Figure A, C. *Inoceramus cuvieri* Sowerby. A. internal mold left valve x1 MNA N5250. C. latex peel left valve x1 MNA N4852. Figure B. *Modiolus coloradoensis* n. sp. Lectotype, internal mold right valve x2 MNA N5399. Figure D. *Meekia* ? sp. composite internal mold right valve x1 MNA N5401. Figure E. *Cyprimera cyprimeriformis* (Stanton) latex peel internal view left valve x1 MNA N5417. Figure F. *Cymbophora huerfanensis* (Stanton) internal mold right valve x1 MNA N5410. Figure G. *Cymbophora utahensis* Meek internal mold right valve x1 MNA N5409. Figures H, J. *Linearia whitei* (Stanton). H. internal mold right valve x1 MNA N5412. J. internal mold left valve (a) with internal molds of *Pleuriocardia pauperculum* (Meek) (b), *Pyktes fusiformis* (Meek) (c), and *Pyropsis coloradoensis* Stanton (d) x1 MNA N5411. Figure I. *Cymbophora emmonsi* (Meek) internal mold right valve x1 MNA N5416. Figure K. *Laternula lineata* (Stanton) internal mold right valve x1 MNA N5403. Figure L. *Linearia (Hercodon) striatimarginata* n. sp. Lectotype, internal mold right valve x1 MNA N5405. Figure M. *Pholadomya coloradoensis* Stanton internal mold left valve x2 MNA N5399. All specimens from MNA loc. #342.

PLATE 49 — UPPER SHALE MEMBER, MANCOS SHALE through LOWER SANDSTONE MEMBER, TOREVA FORMATION MIDDLE TURONIAN

Figures A, B. *Lingula subspatulata* Hall and Meek ? A. compacted specimen x5 MNA N5335, loc. #989, six meters above BM77. B. compacted specimen x5 MNA N5295, loc. #989, from seven meters above BM77. Figures C, D. *Lutema hitzi* (Stanton). C. x1 MNA N5262. D. x1 MNA N5261. Both from loc. #989, siderite concretions 19 m below contact with Toreva Formation. Figure E. *Dentalium* sp. B compacted specimen SEM x5 MNA N5296, loc. #989, six meters above BM77. Figure F. *Breviarca* ? sp. internal mold right valve x4 MNA N5192, loc. #989, 11 m above BM77. Figure G. *Lopha belliplicata* (Shumard) right valve x1 MNA N3580, loc. #878, lower sandstone member, Toreva Formation. Figure H. *Inoceramus cuvieri* Sowerby ? internal mold right valve x1 MNA N3581, loc. #989, siderite concretions 19 m below contact with Toreva Formation. Figures I-K. *Mytiloides* sp. cf. *M. teraokai* (Matsumota and Noda). I. internal mold left valve x1 MNA N5435. J. internal mold left valve x1 MNA N5434. K. internal mold left valve x1 MNA N3550. All from loc. #989, siderite concretions 19 m below contact with Toreva Formation. Figure L. *Cymbophora utahensis* Meek external mold left valve x1 MNA N5415, loc. #988, Mancos/Toreva transition zone.

PLATE 50 — UPPER SHALE MEMBER, MANCOS SHALE through LOWER SANDSTONE MEMBER, TOREVA FORMATION MIDDLE TURONIAN

Figures A, F. *Mytiloides* sp. cf. *M. teraokai* (Matsumoto and Noda). A. compacted right valve x1 MNA N5463. F. internal mold left valve x1 MNA N5437. Both from loc. #989, siderite concretions 19 m below contact with Toreva Formation. Figures B-E. *Inoceramus howelli* White B. left valve x1 MNA N3572, loc. #988, Mancos/Toreva transition zone. C. left valve x1 MNA N5440, loc. #988, lower sandstone member Toreva Formation. D. left valve x2 MNA N3578, loc. #988, lower sandstone member Toreva Formation. E. left valve x1 MNA N3570, loc. #988, Mancos/Toreva transition zone. Figures G-I. *Mytiloides* n. sp. ? G. paired valves x1 MNA N3575. H. internal mold left valve x1 MNA N3579. I. right valve x1 MNA N3576. All from loc. #988, lower sandstone member Toreva Formation. Figures J, K. *Inoceramus* sp. aff. *I. dimidius* White. J. left valve x1 MNA N3577, loc. #988, lower sandstone member Toreva Formation. K. left valve x1 MNA N3571, #988, Mancos/Toreva transition zone. Figures L, M. *Prionocyclus hyatti* (Stanton). L. latex peel lateral view x1 MNA N4829. M. compacted specimen lateral view x1 MNA N4830. Both from loc. #989, siderite concretions 19 m below contact with Toreva Formation.

PLATE 1

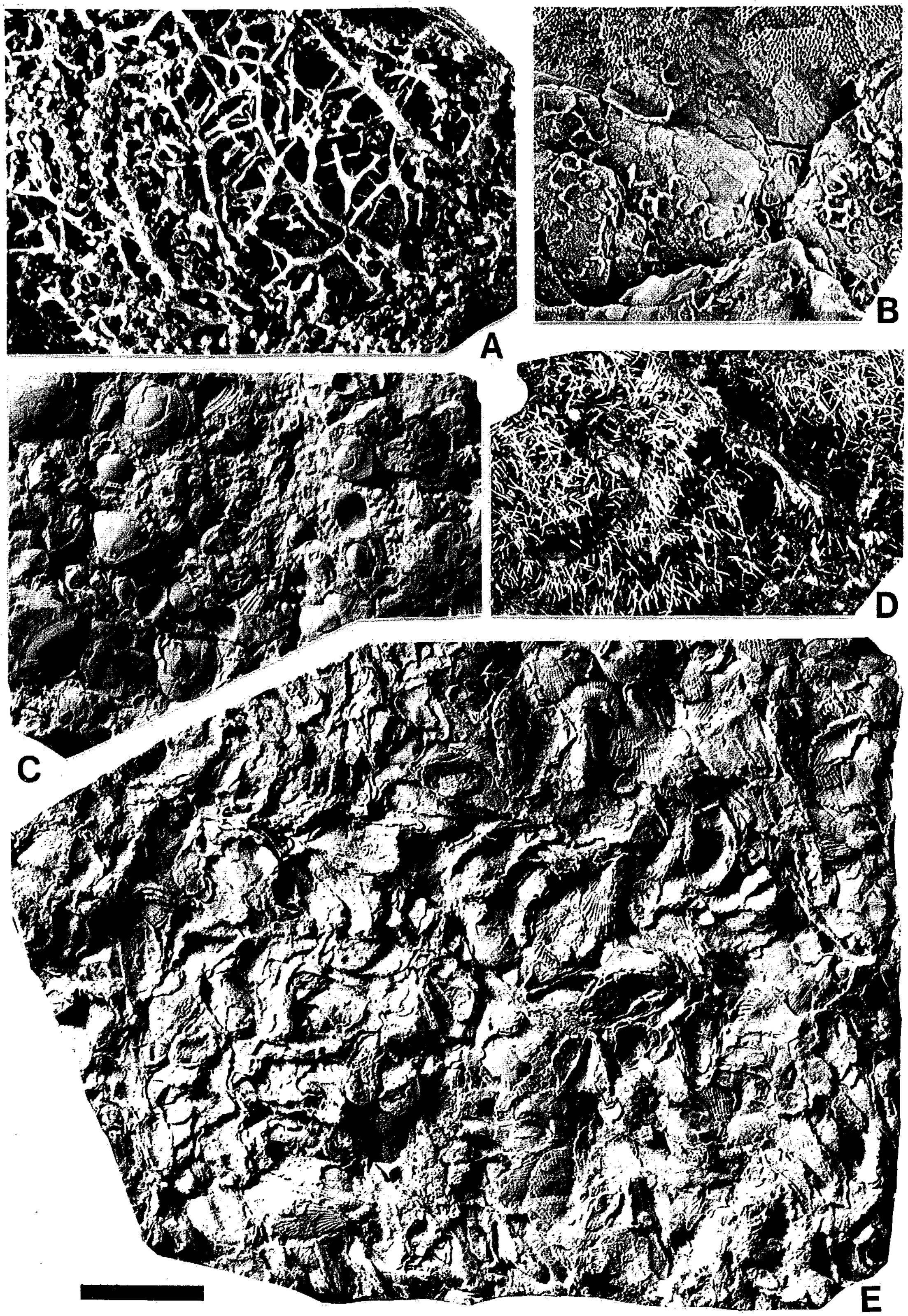


PLATE 2

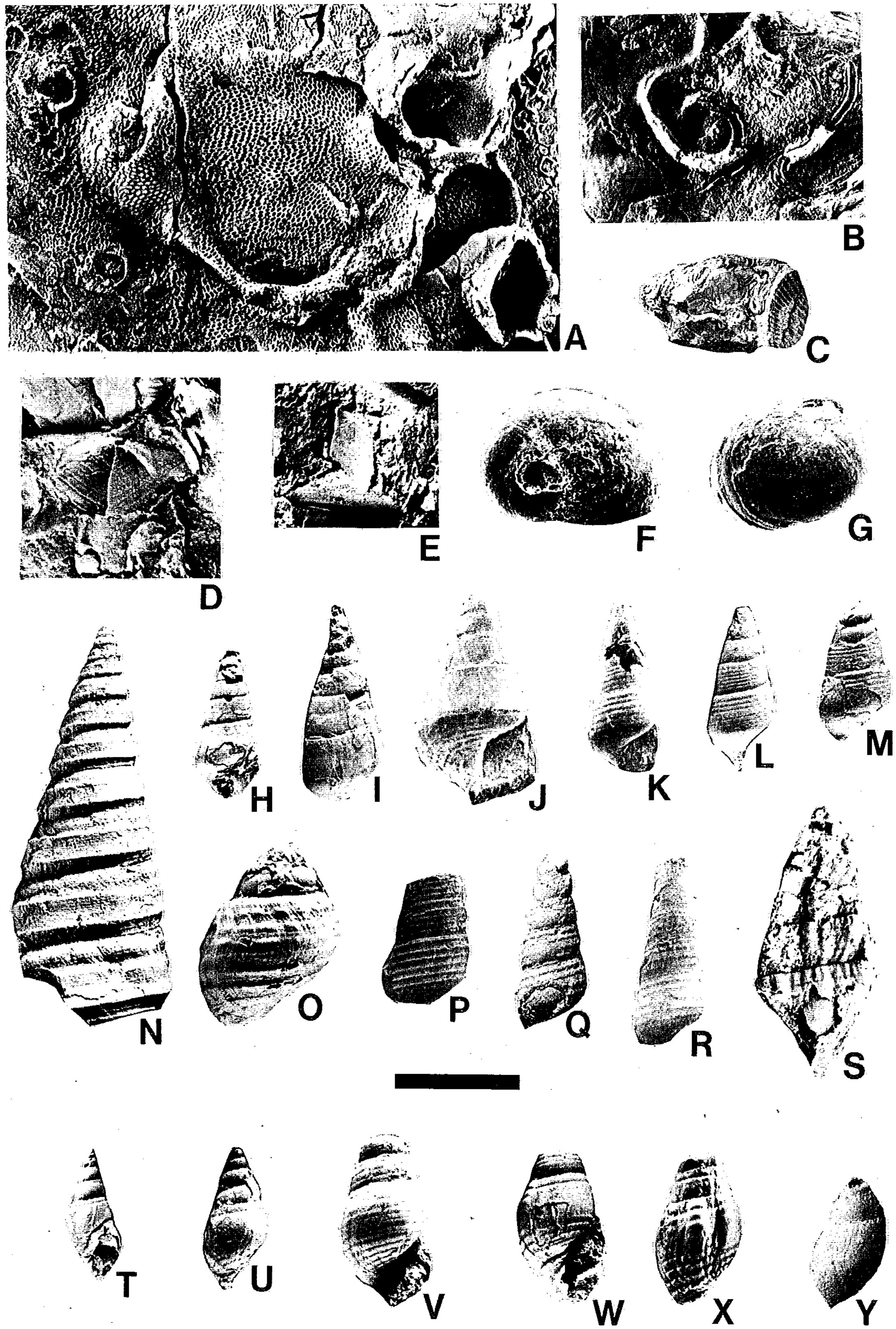


PLATE 3

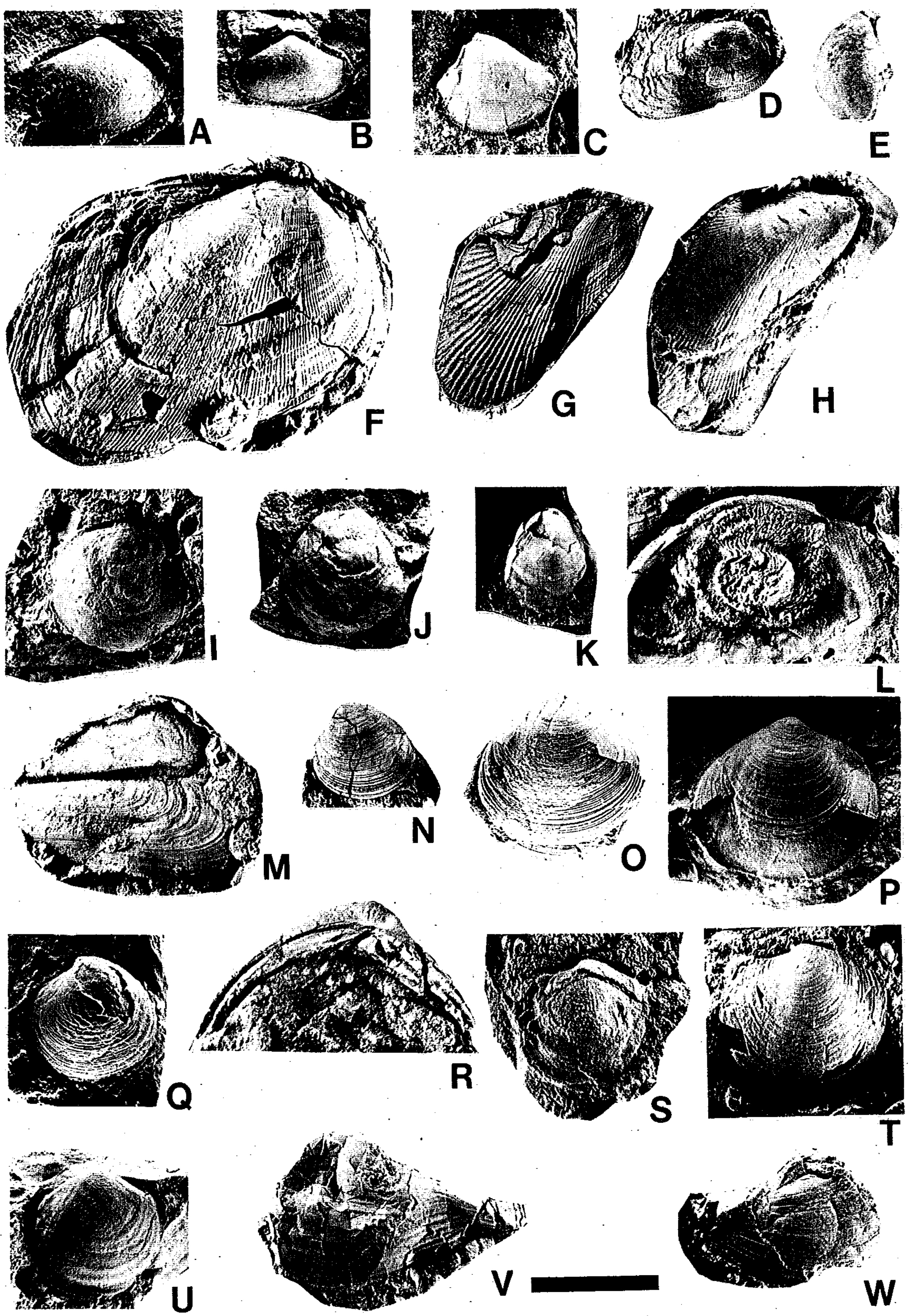
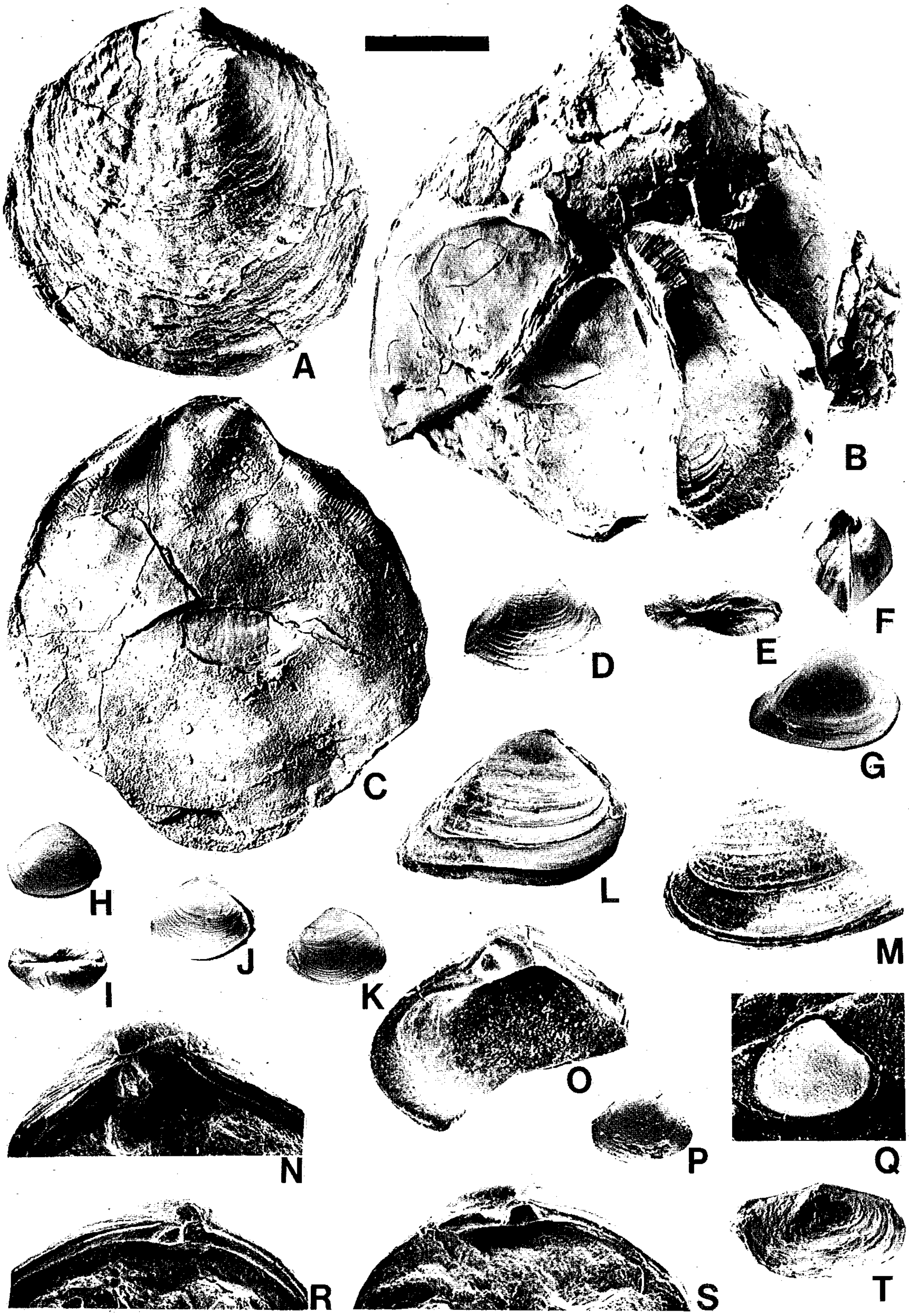


PLATE 4



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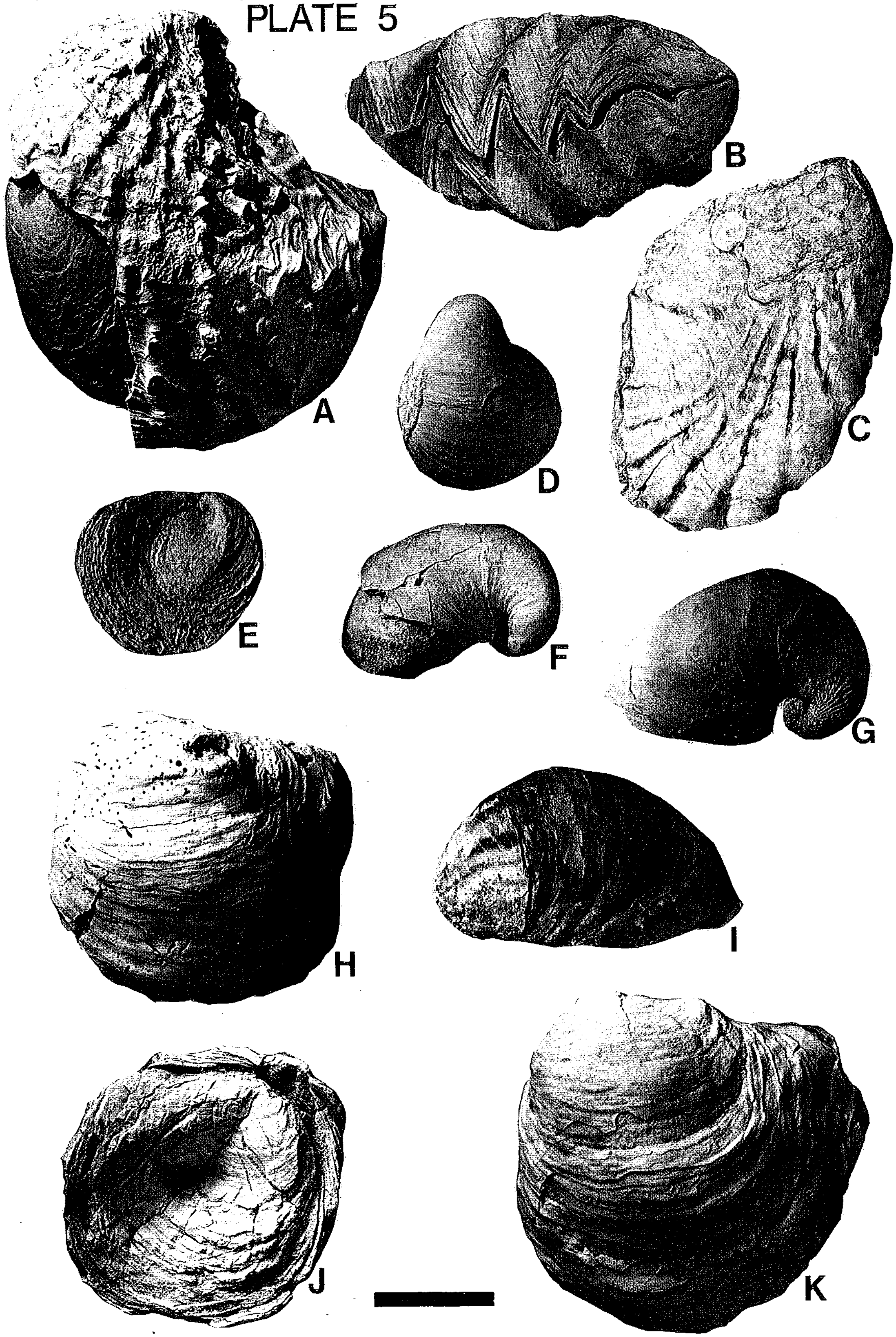

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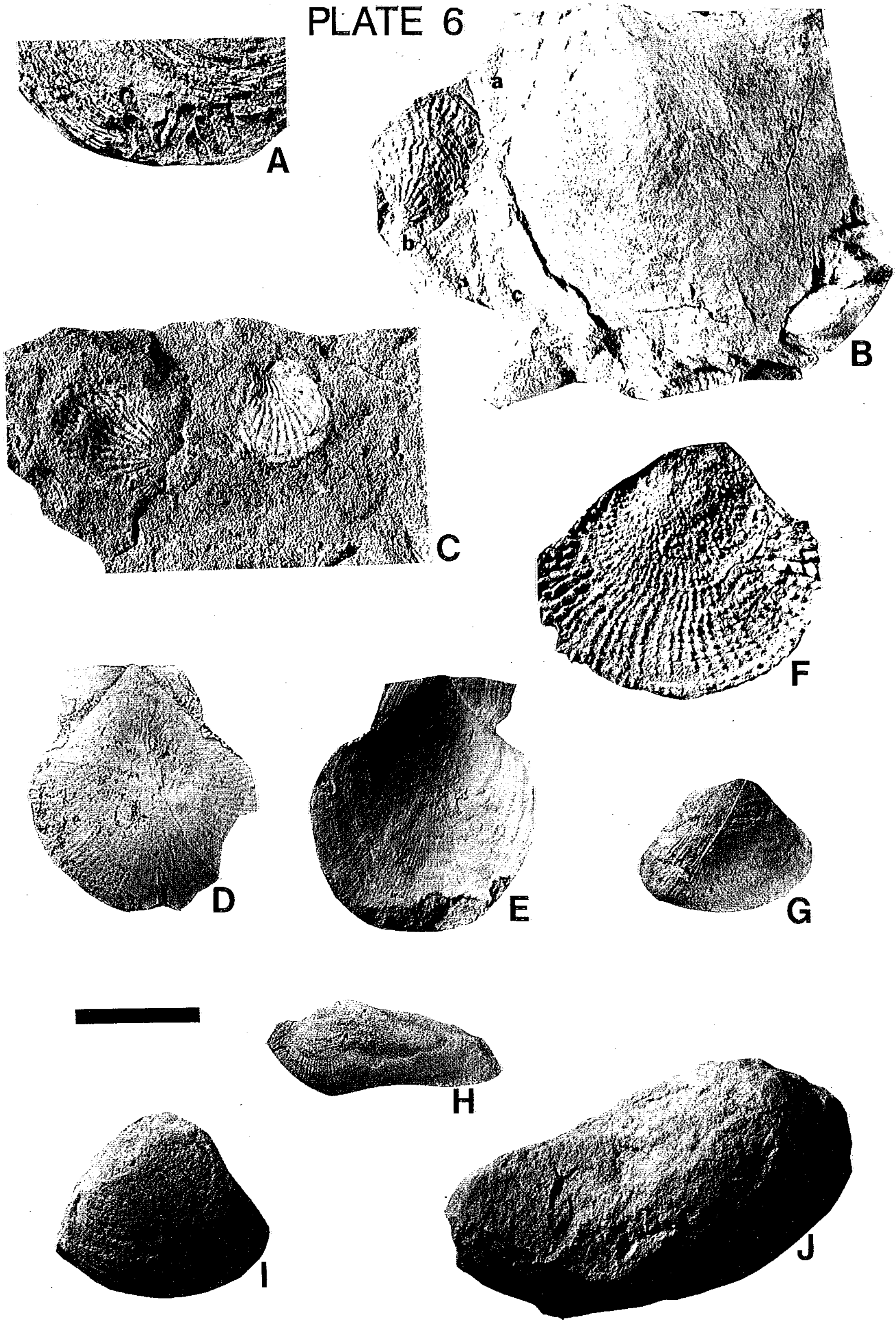

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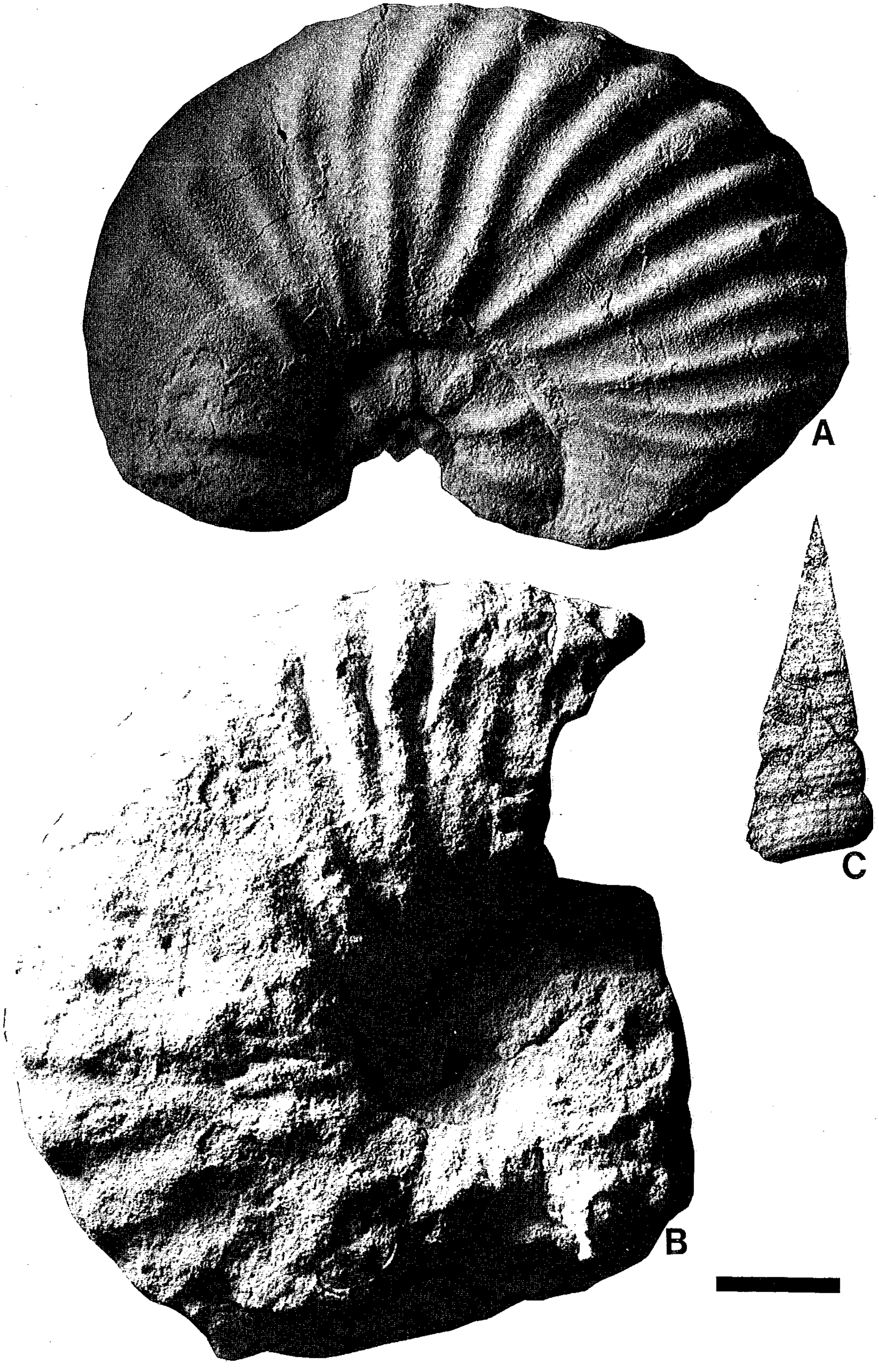

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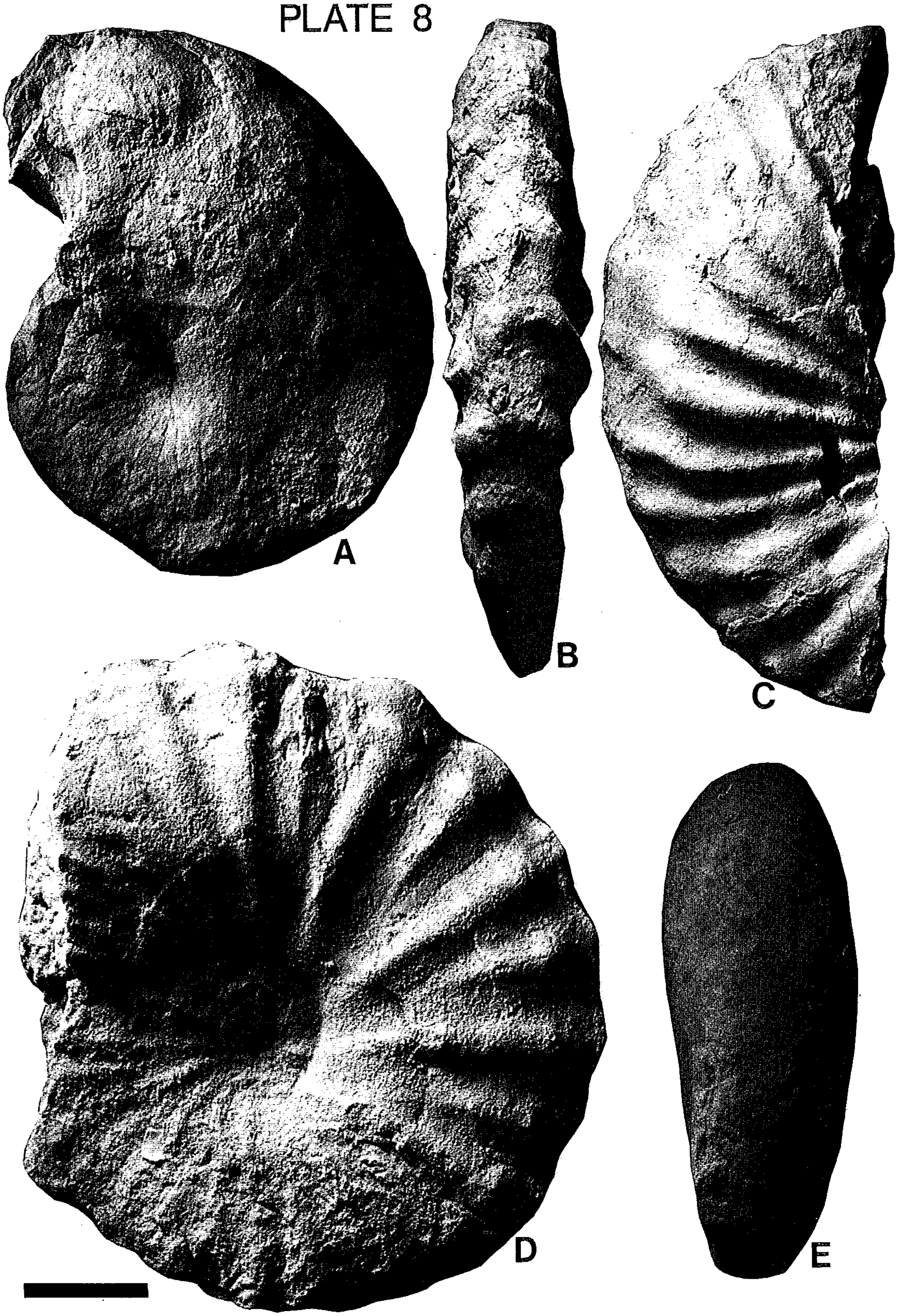
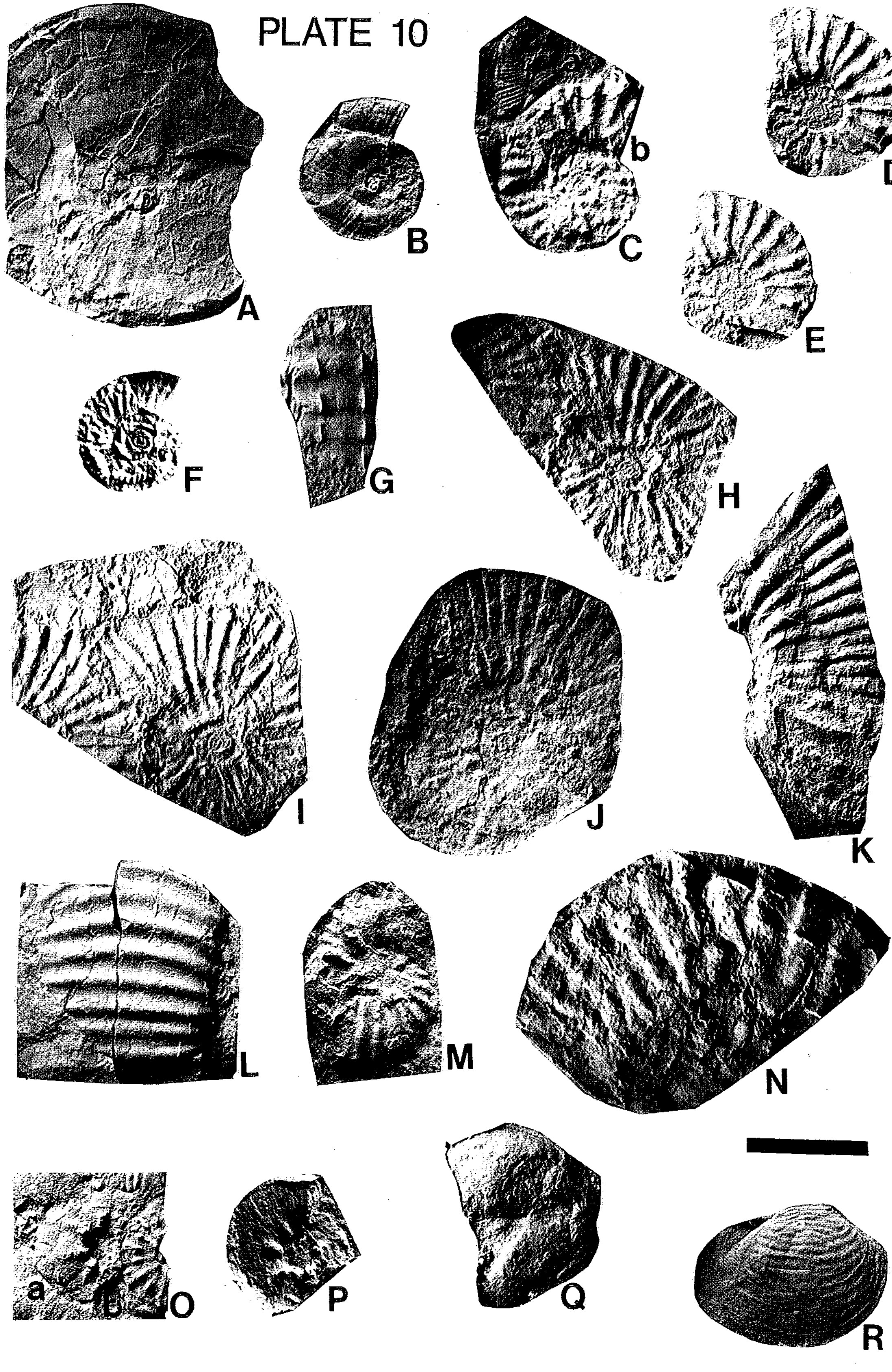


PLATE 9

PLATE 10



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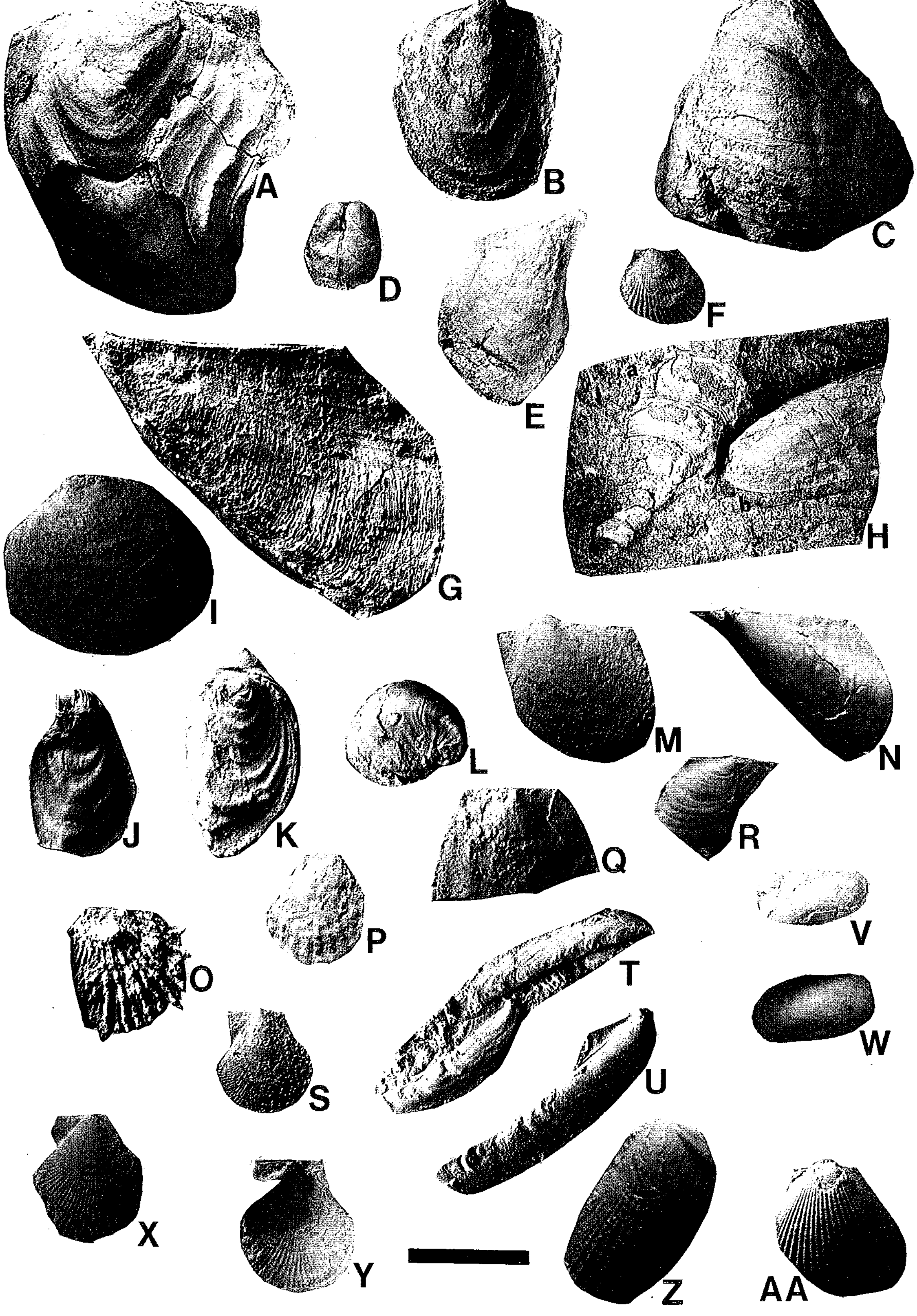

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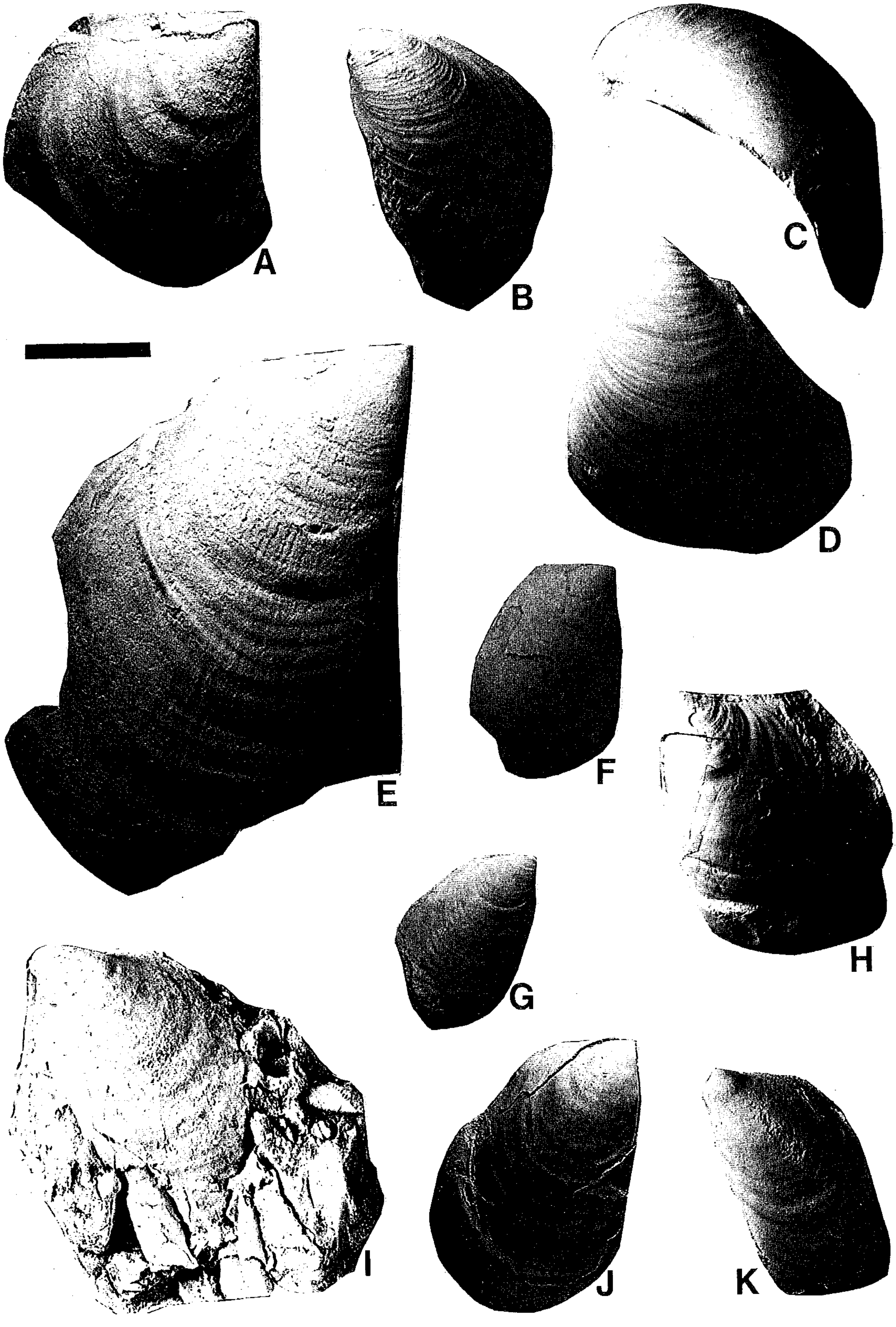

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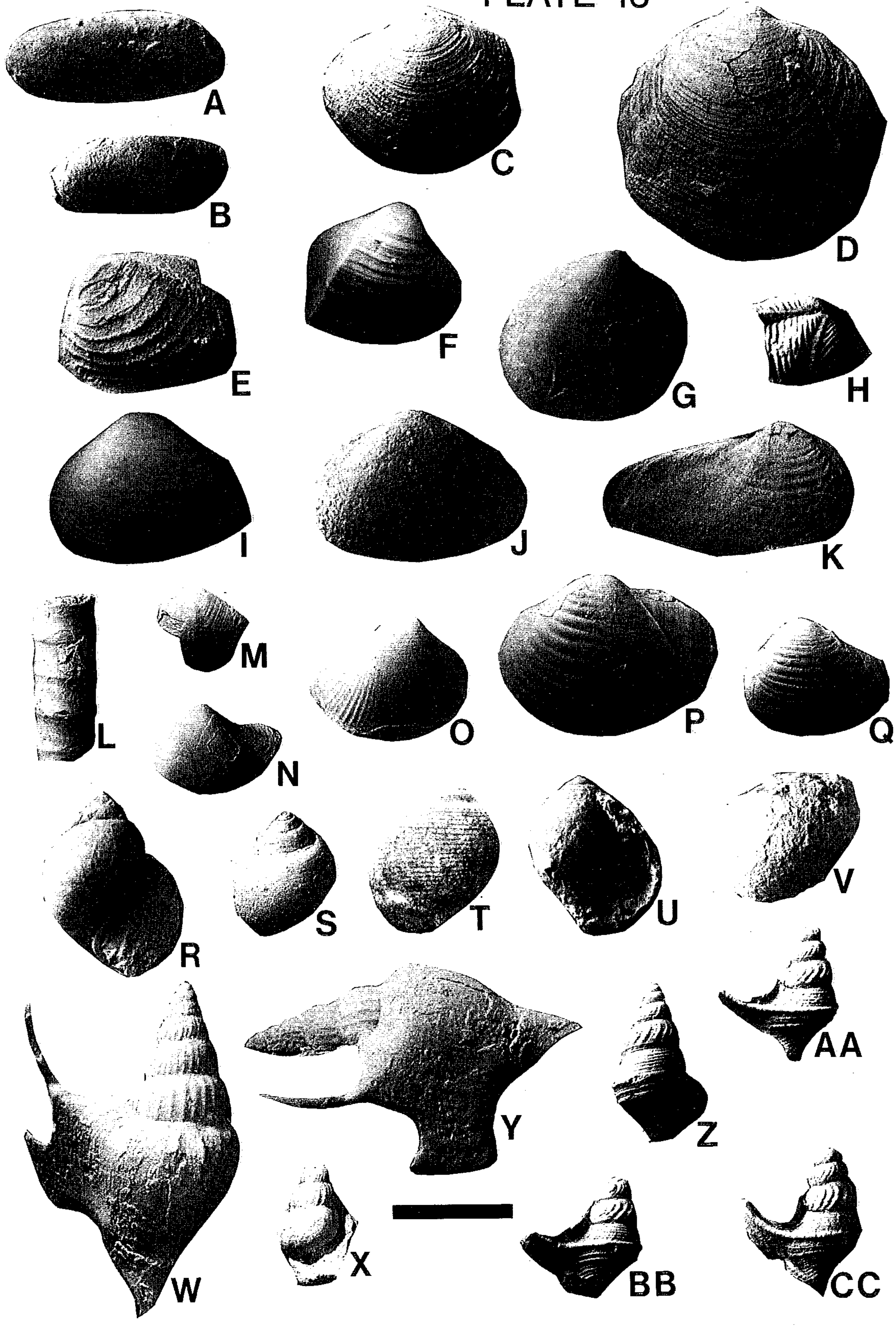

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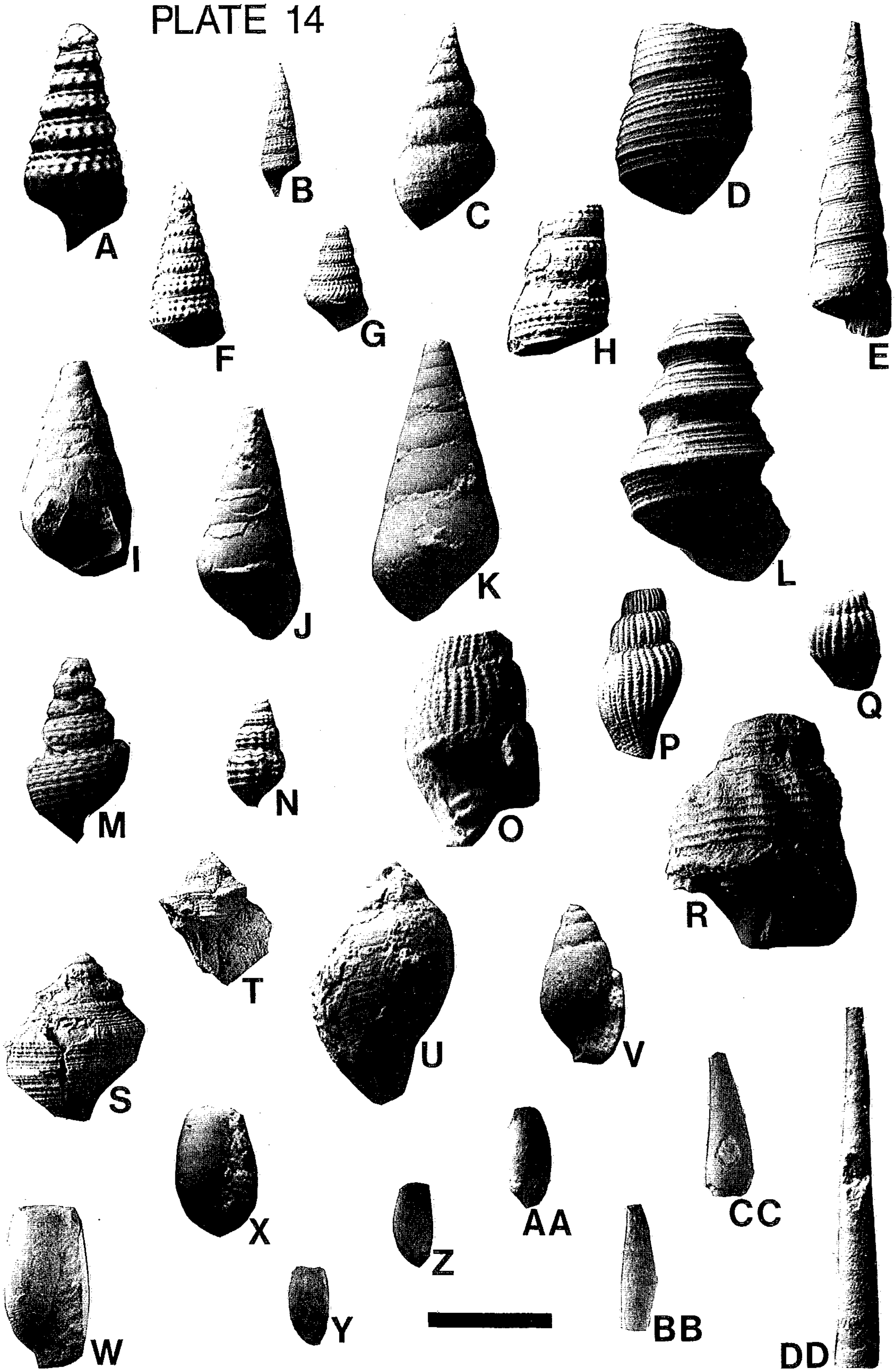

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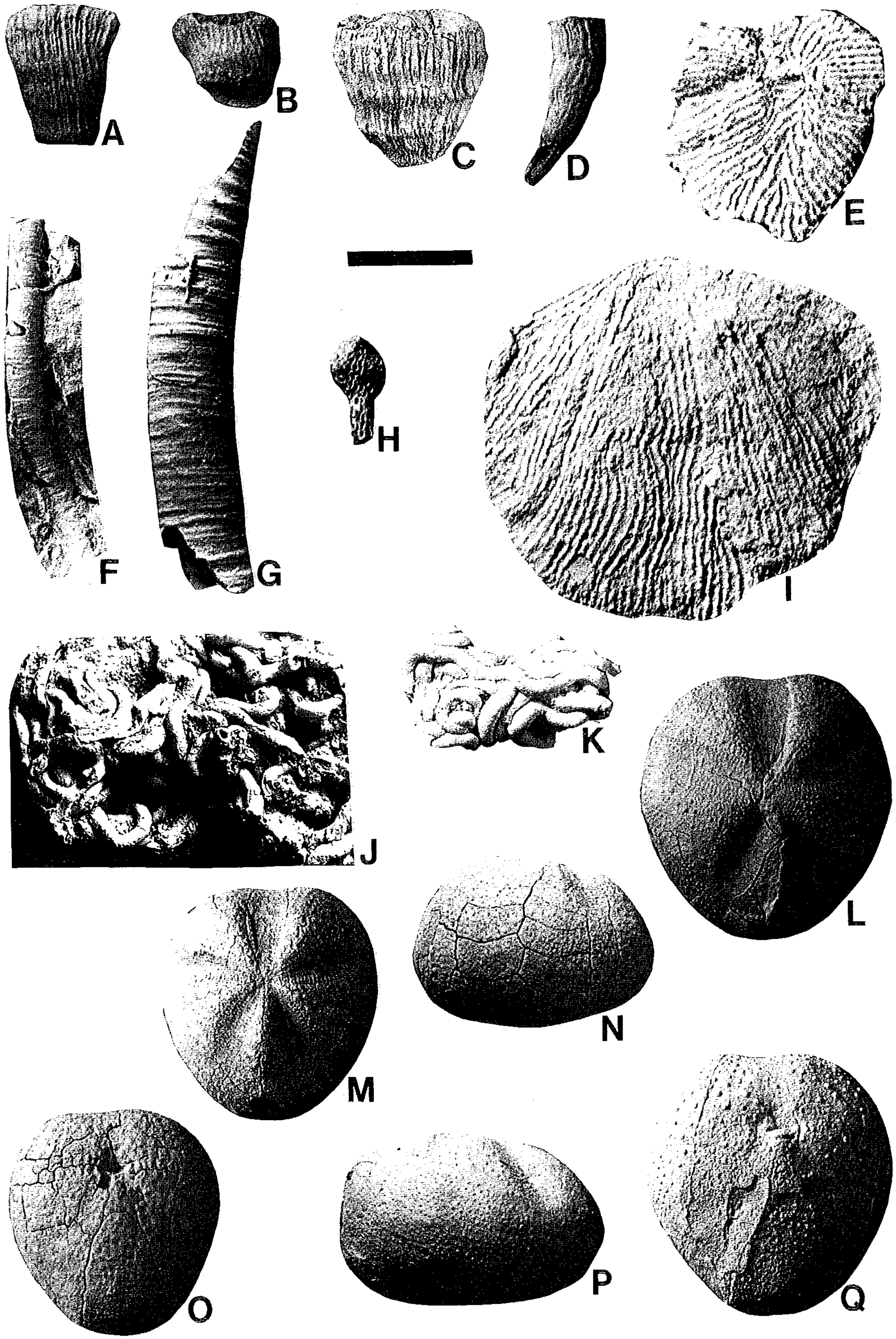

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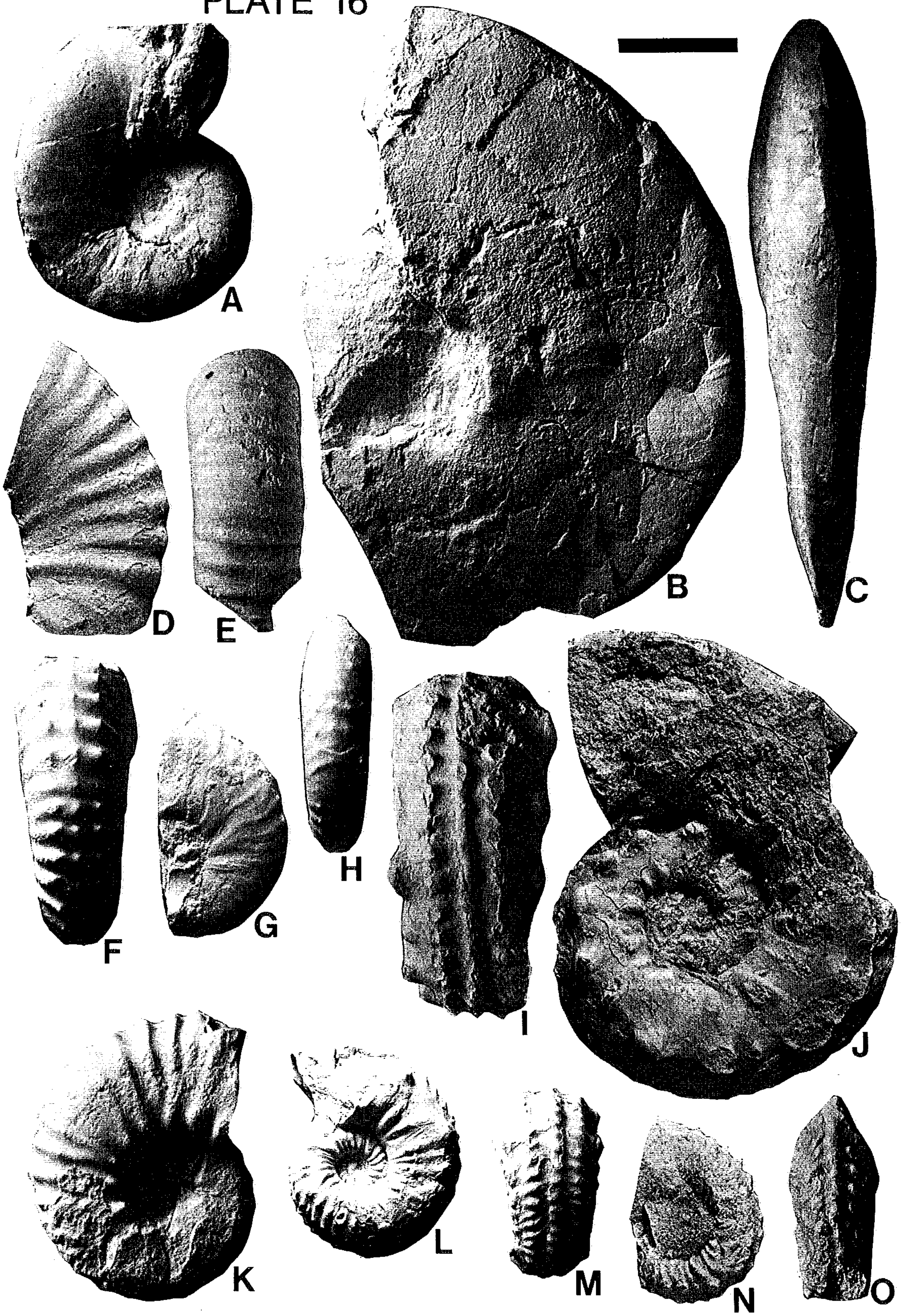

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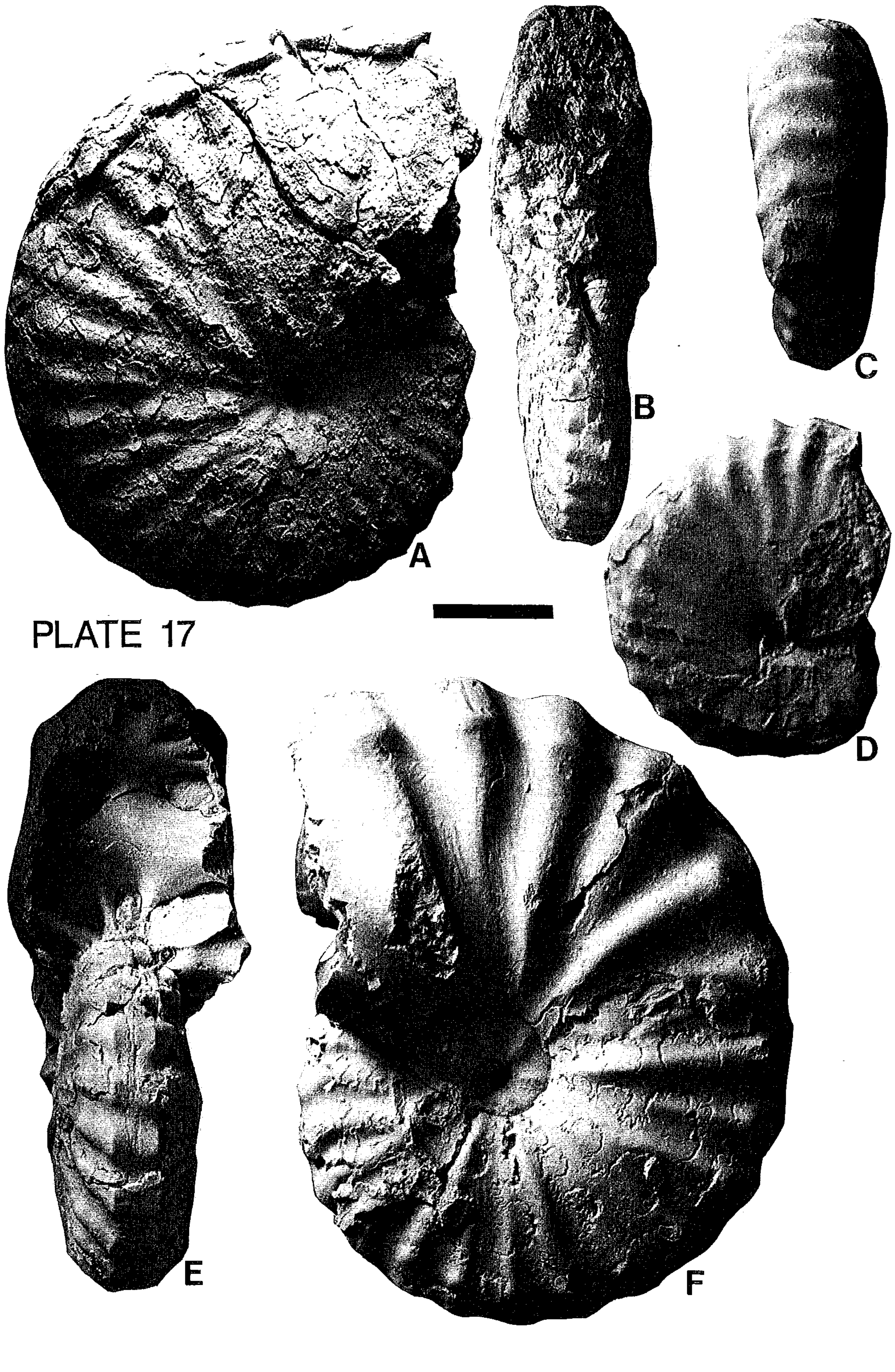

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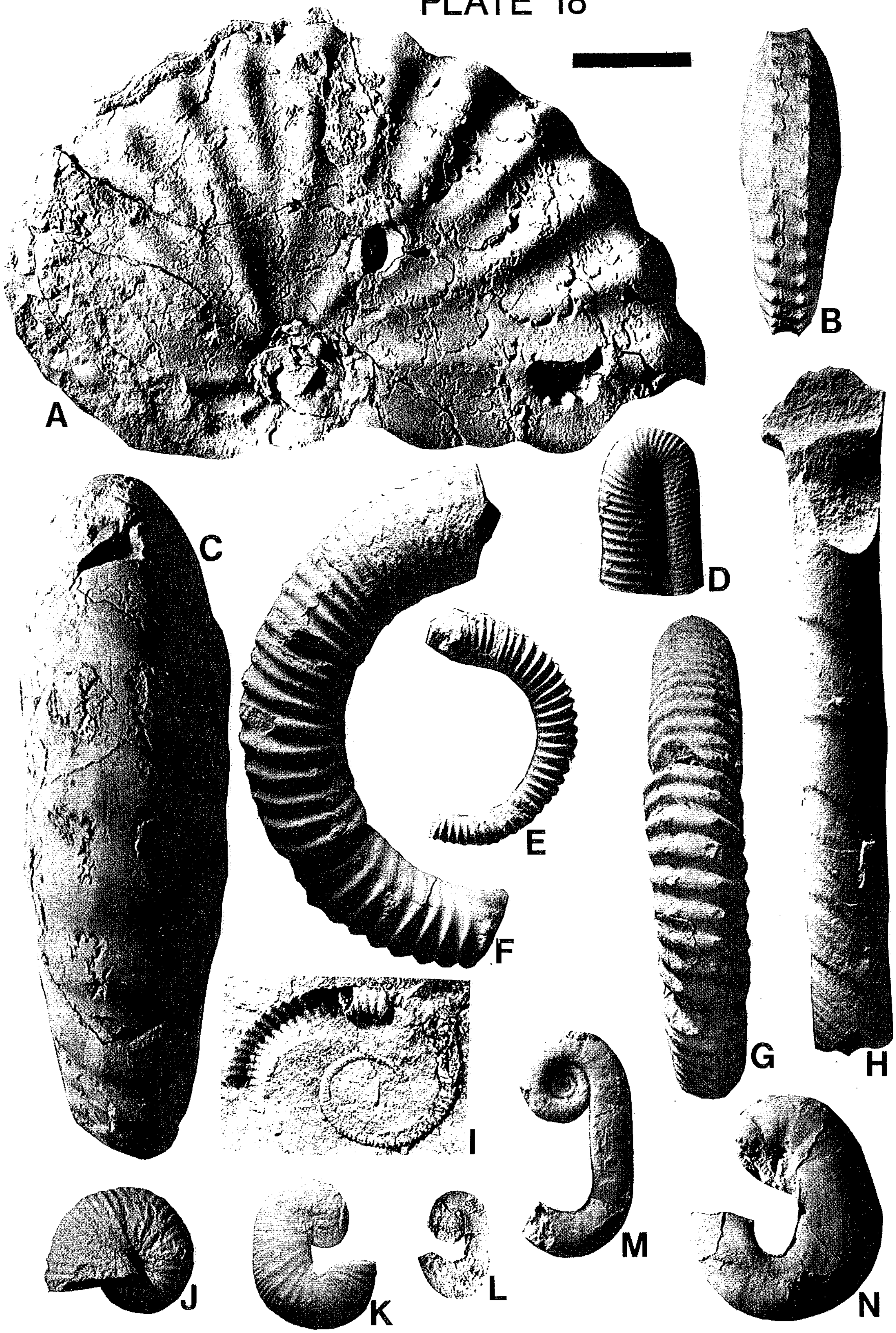

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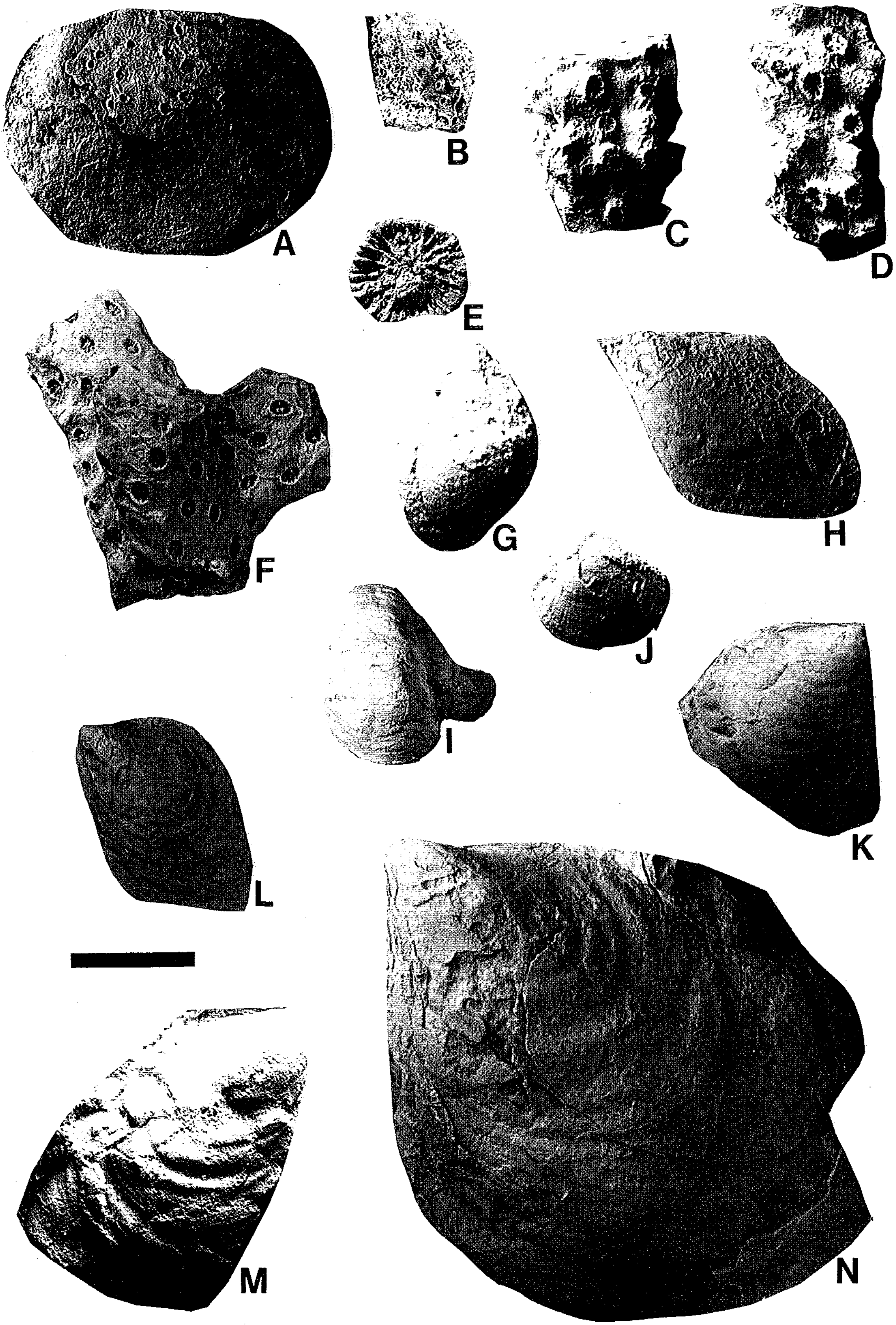

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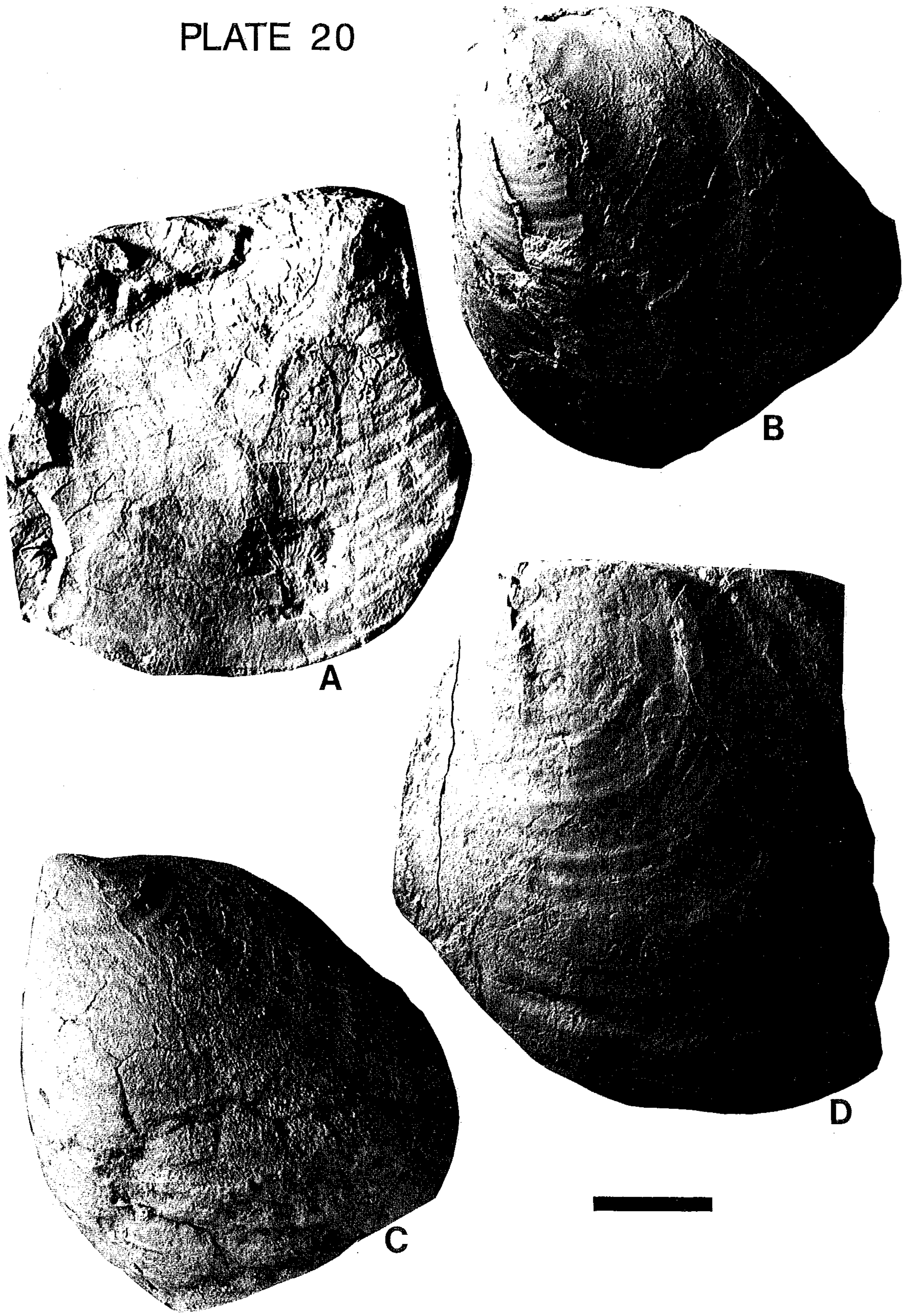

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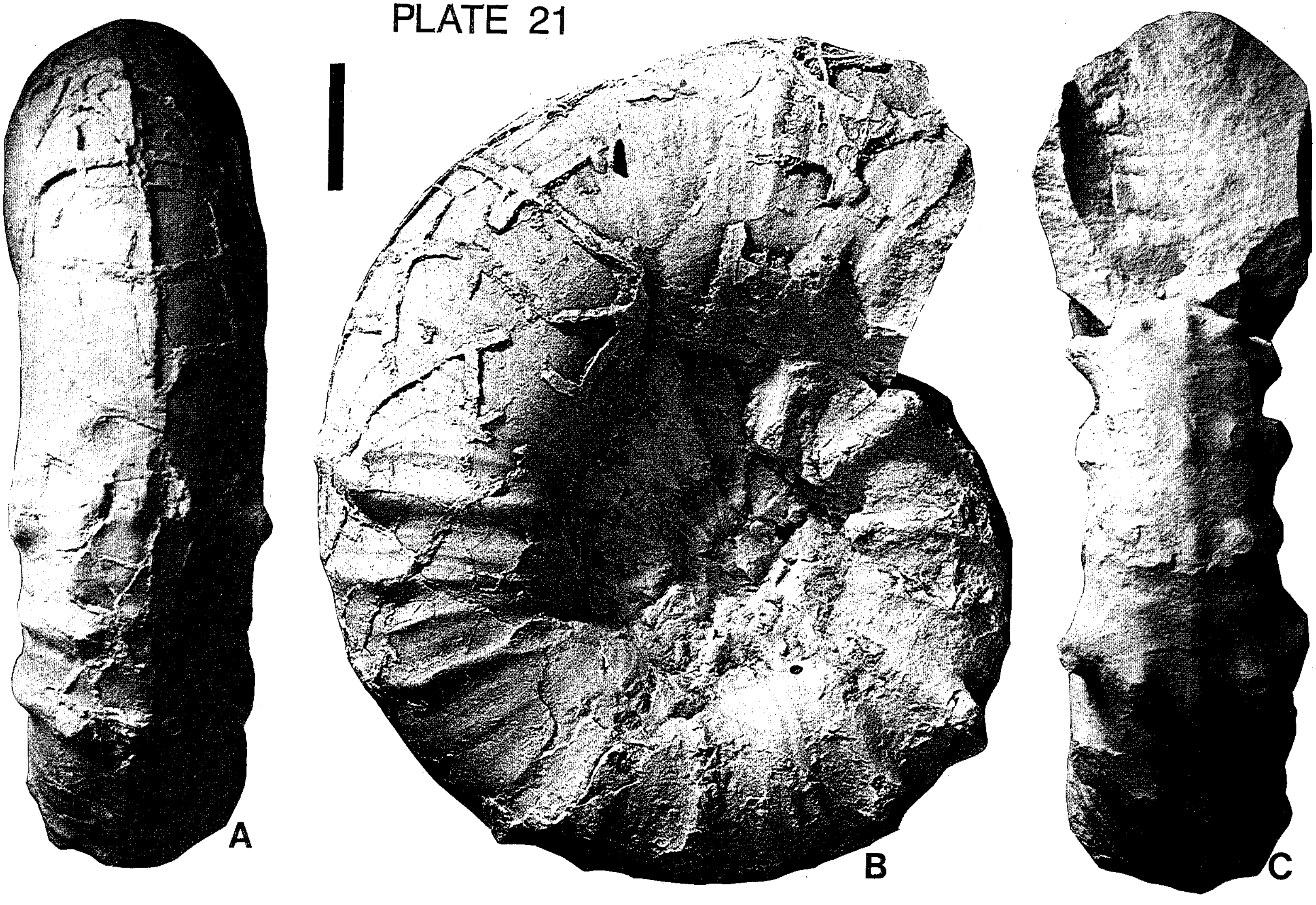

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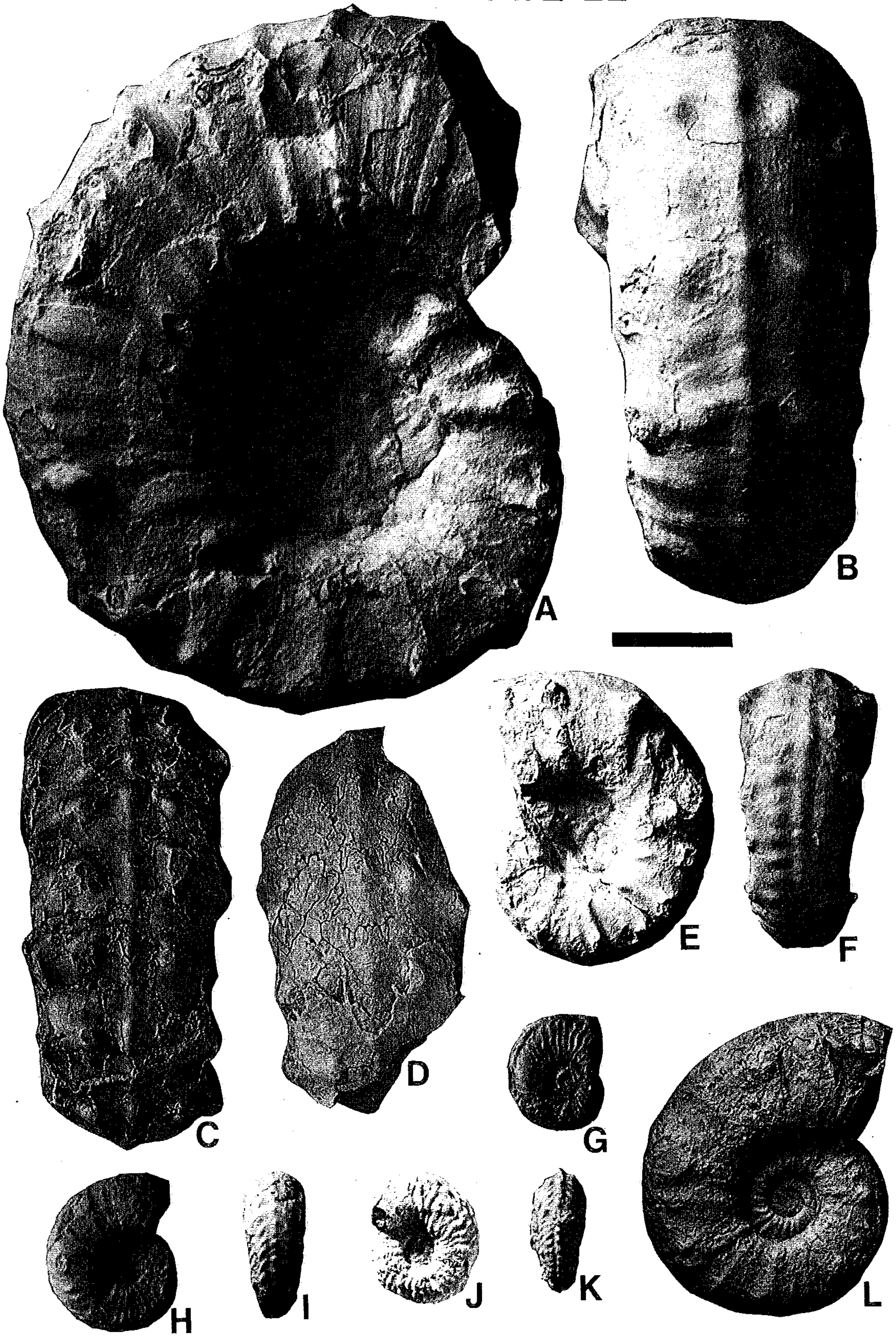

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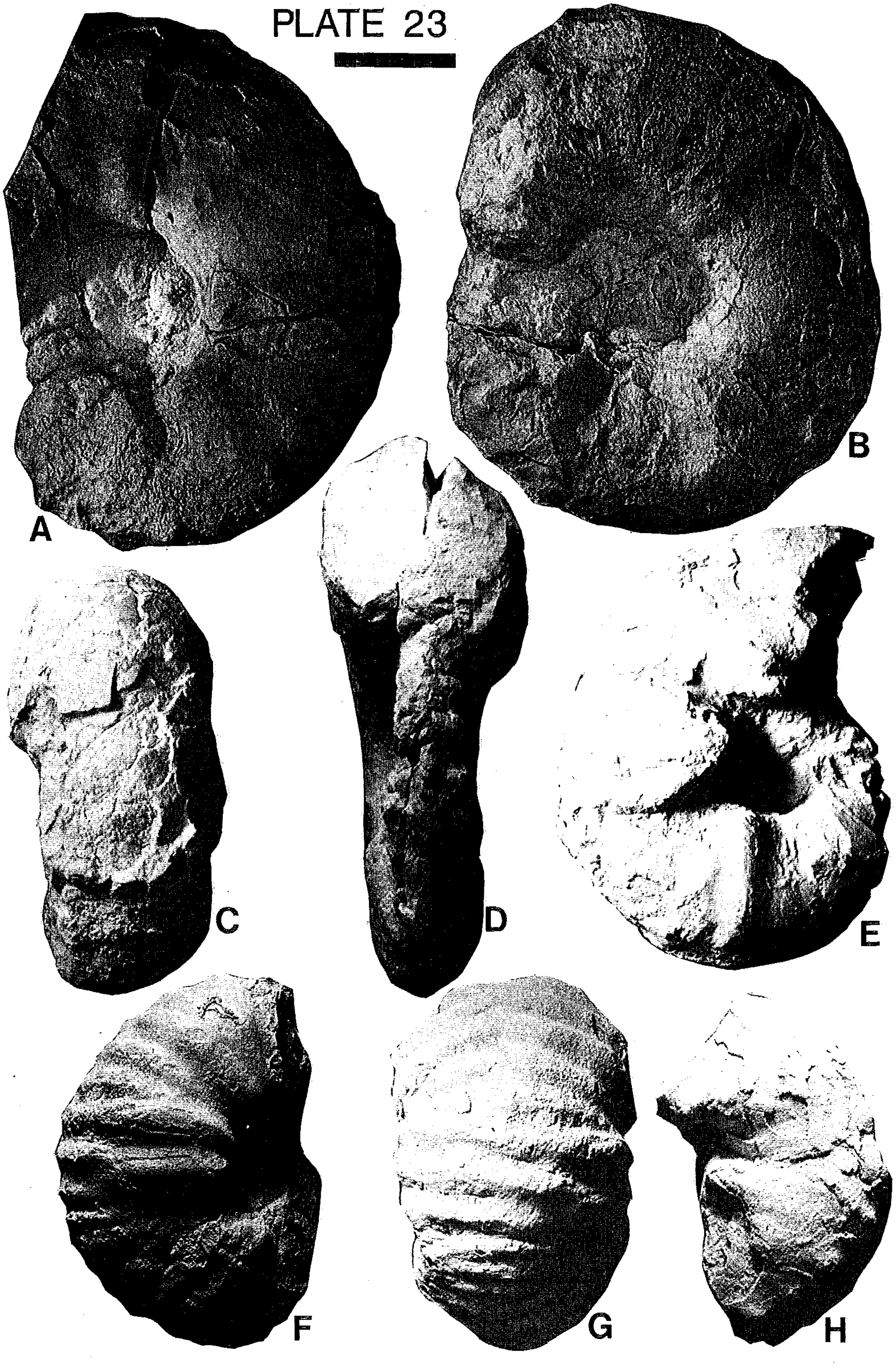
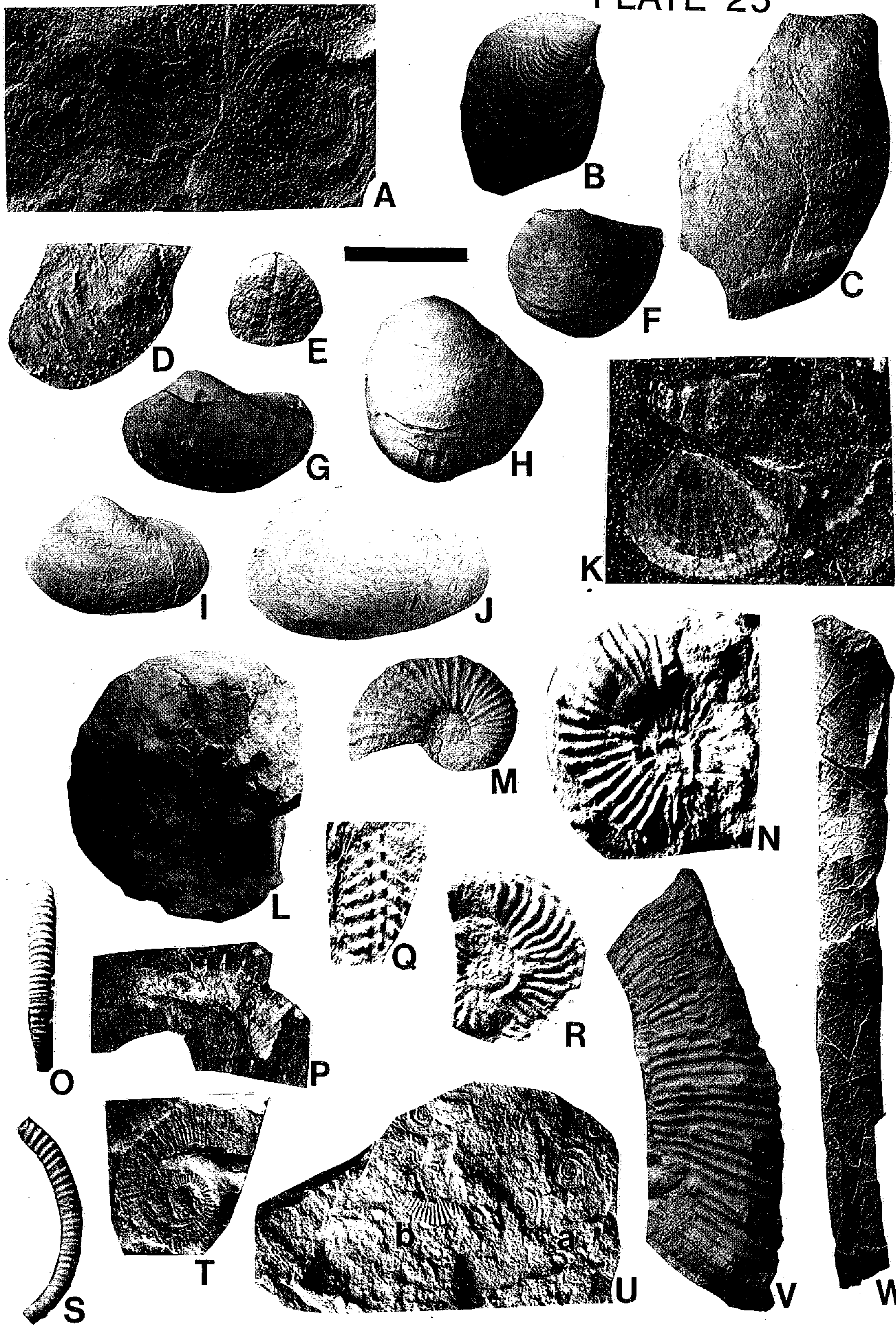


PLATE 24

PLATE 25



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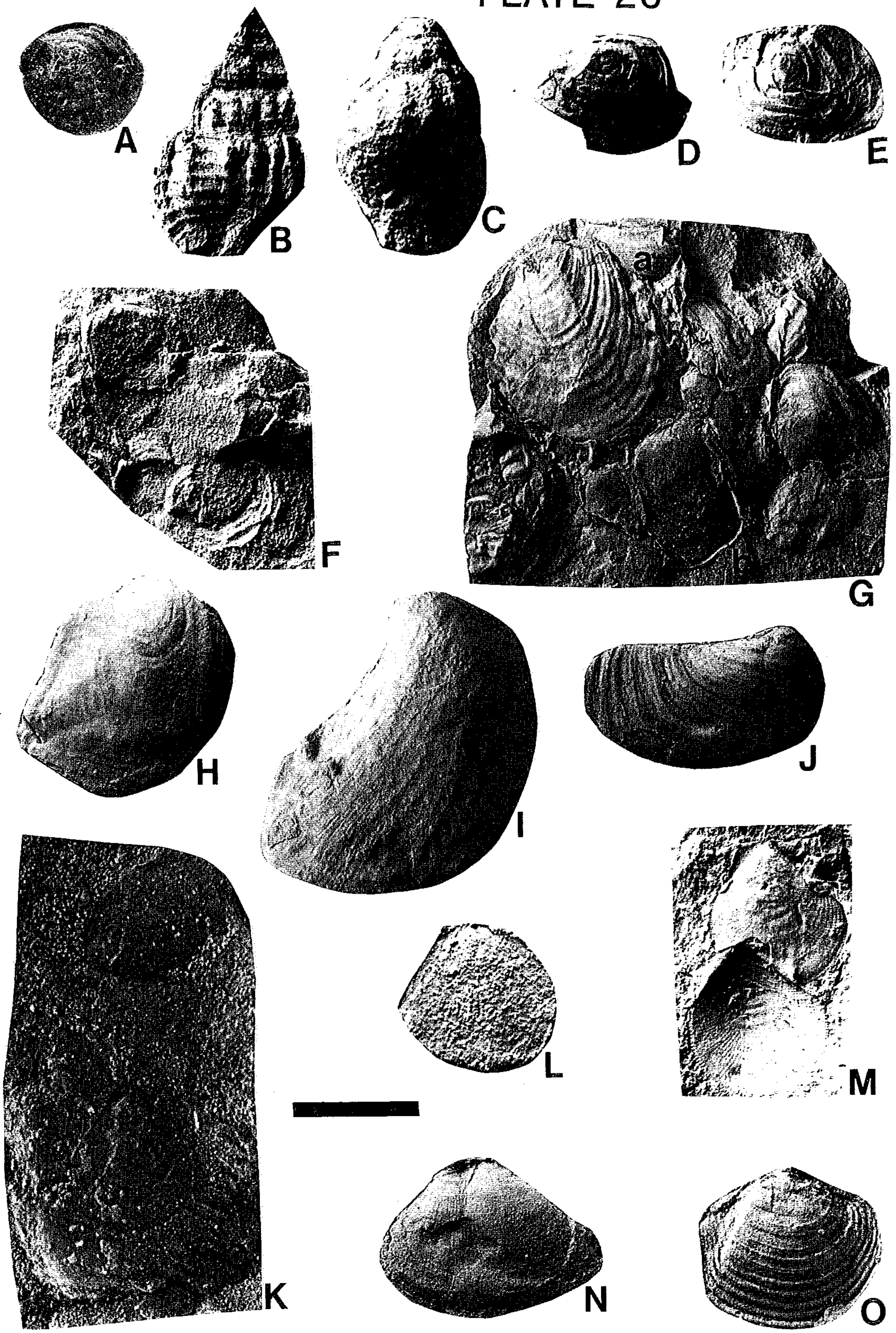

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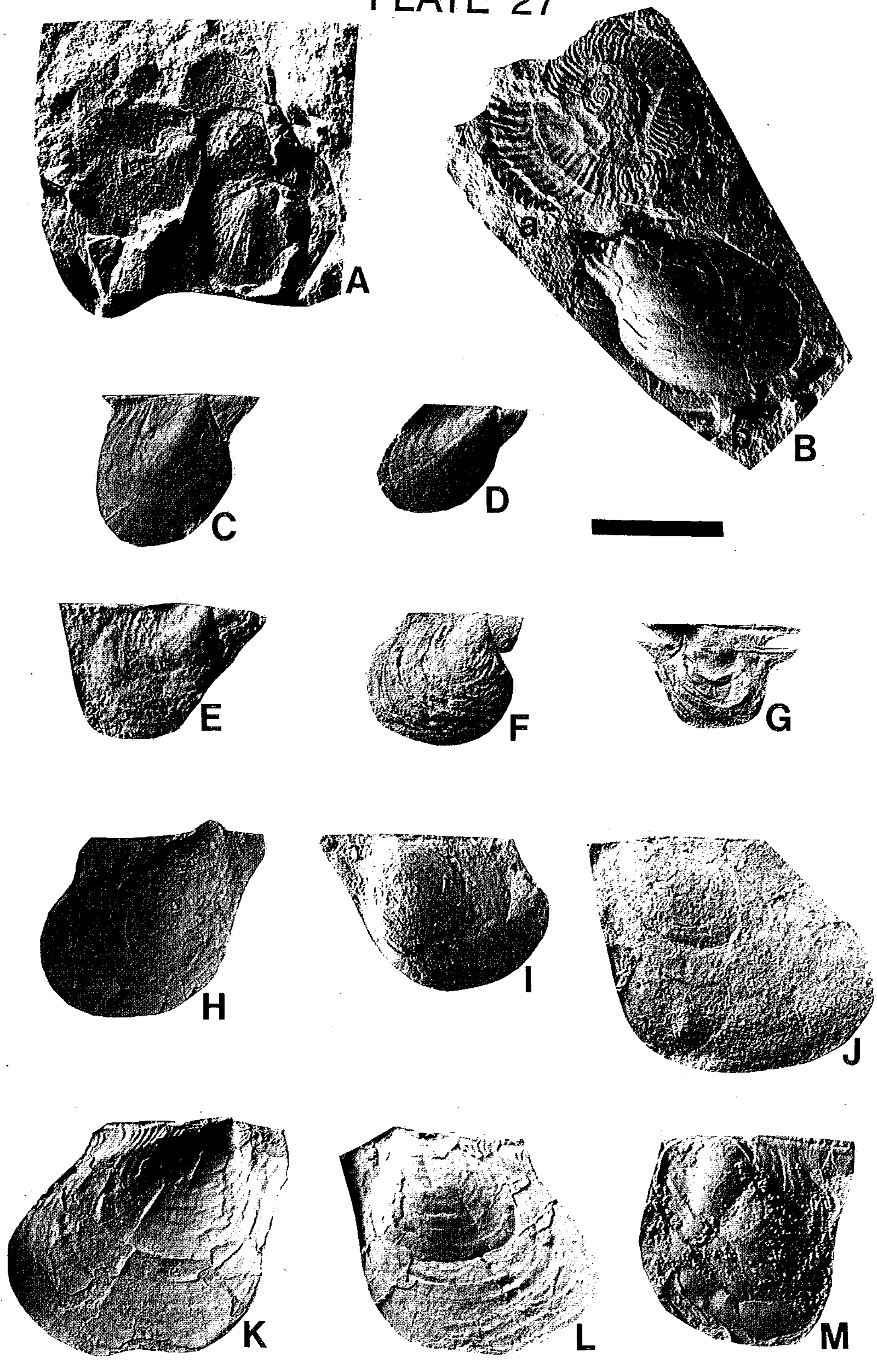

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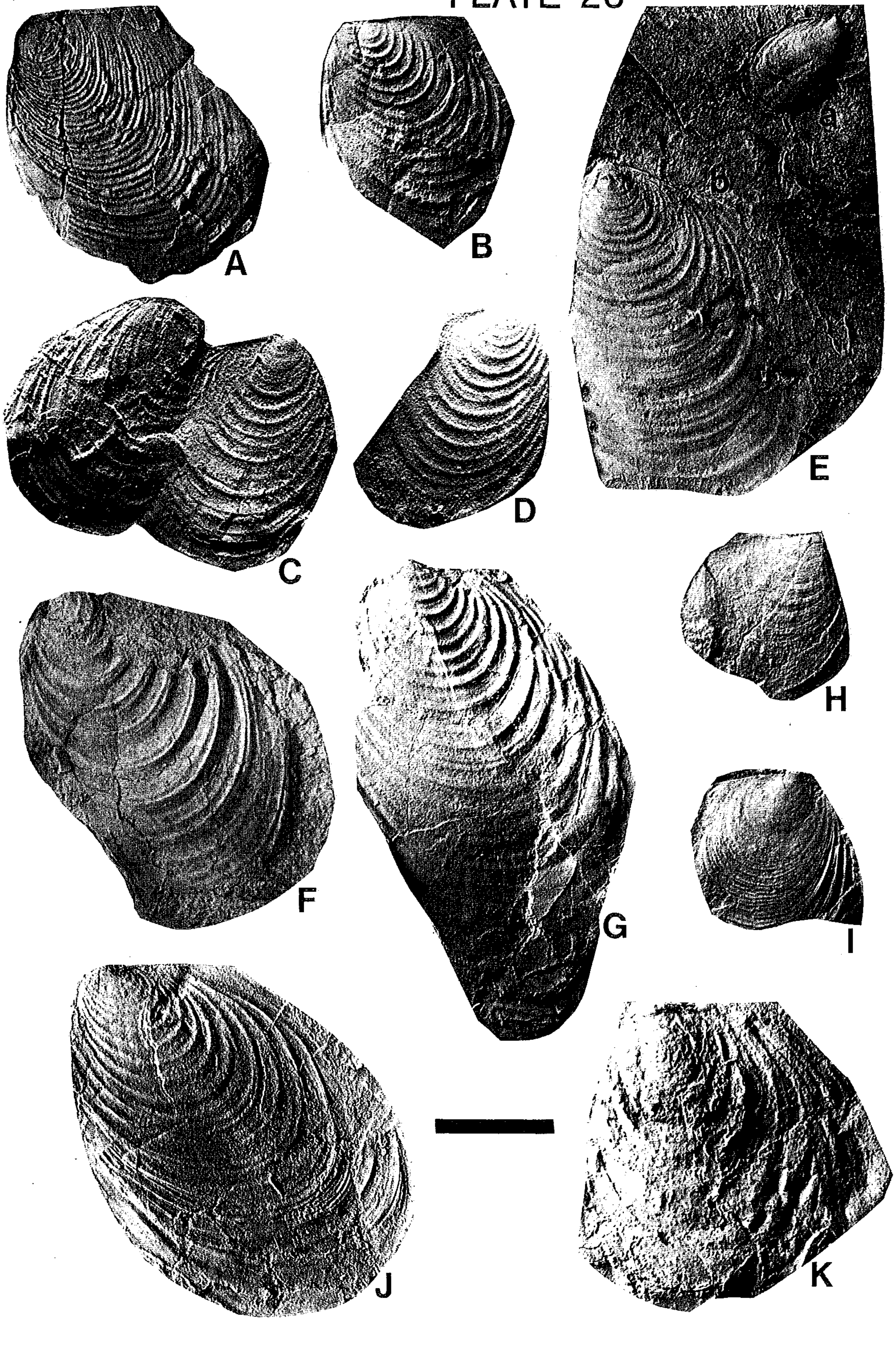

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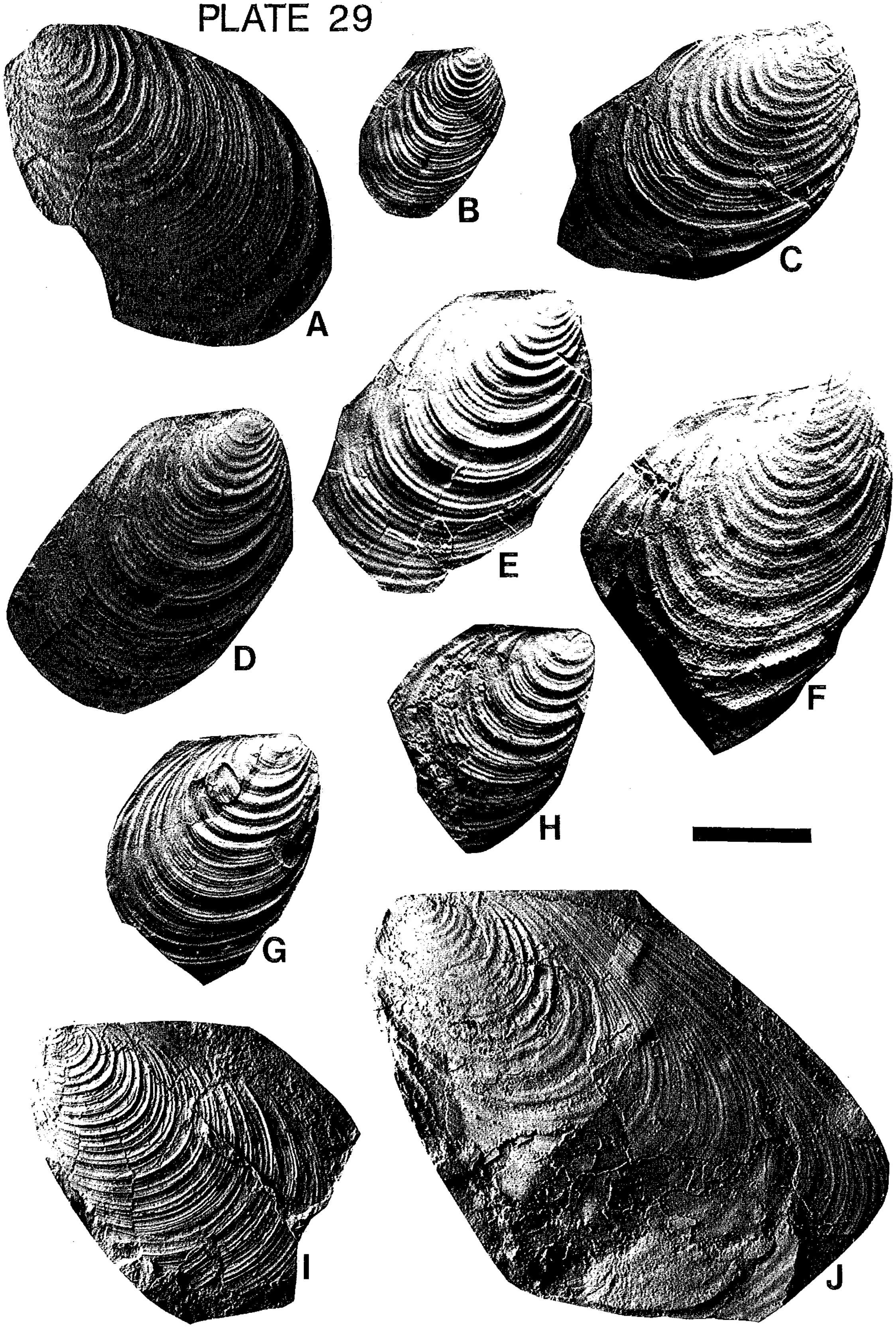

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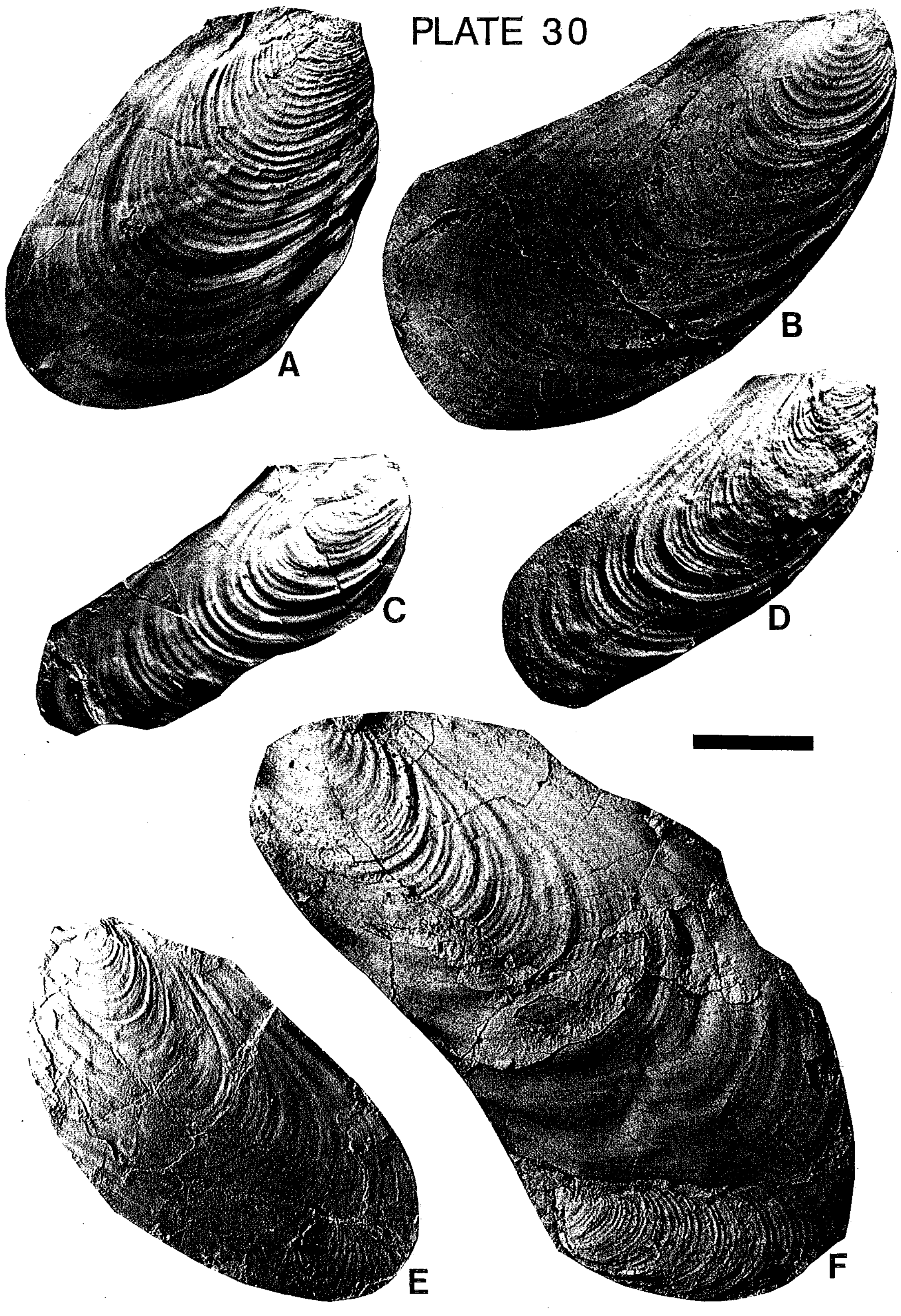

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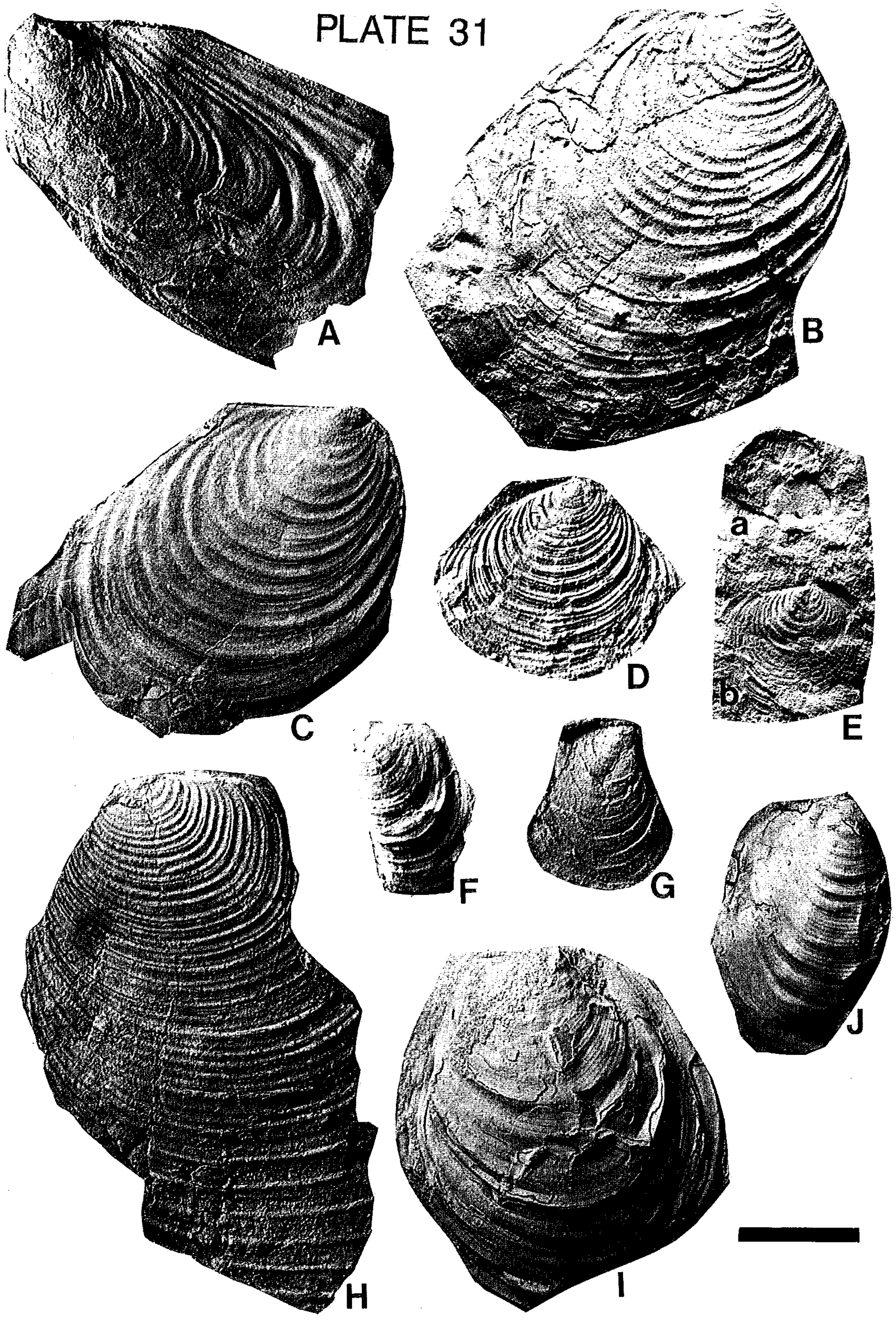

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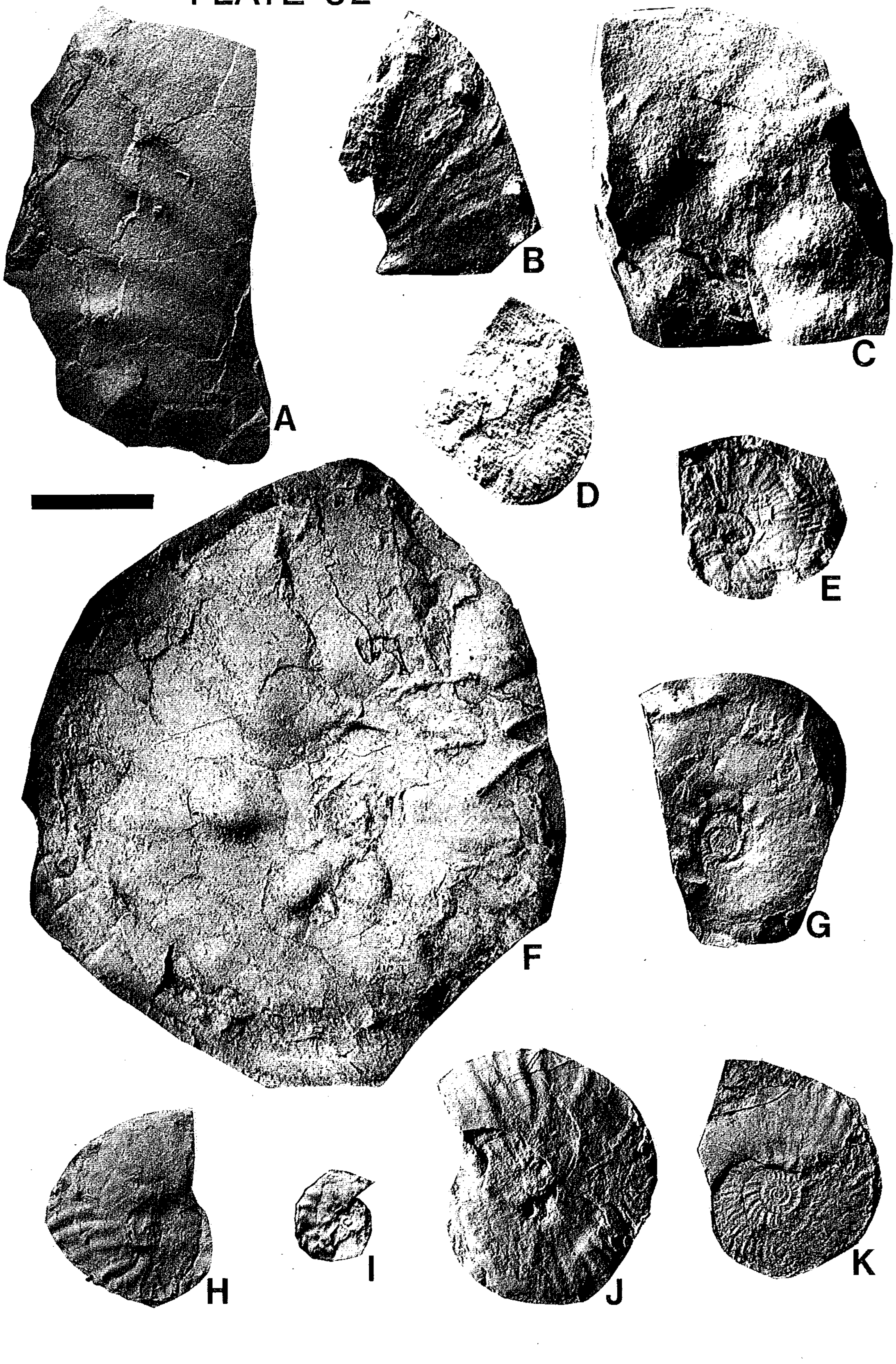

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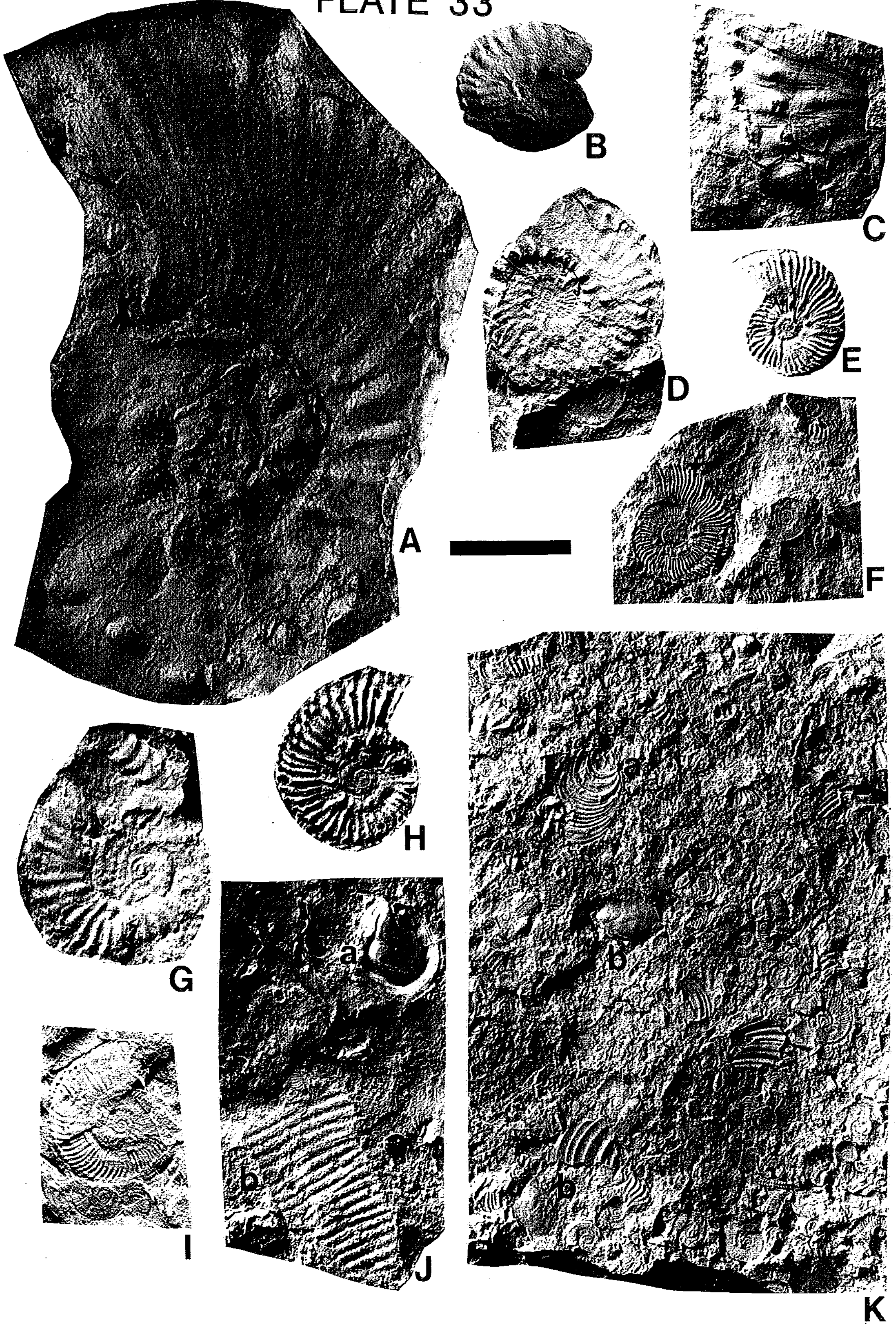

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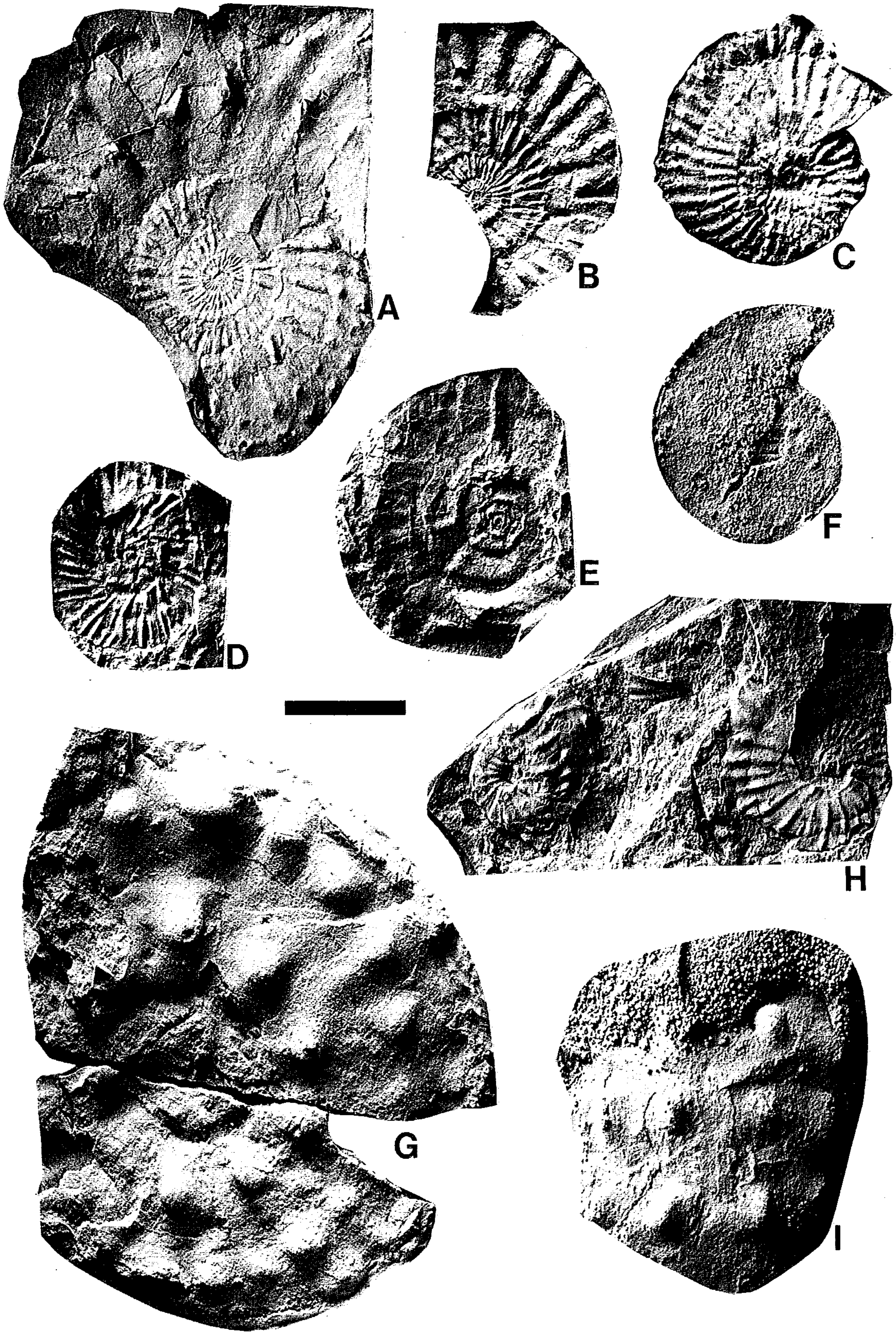

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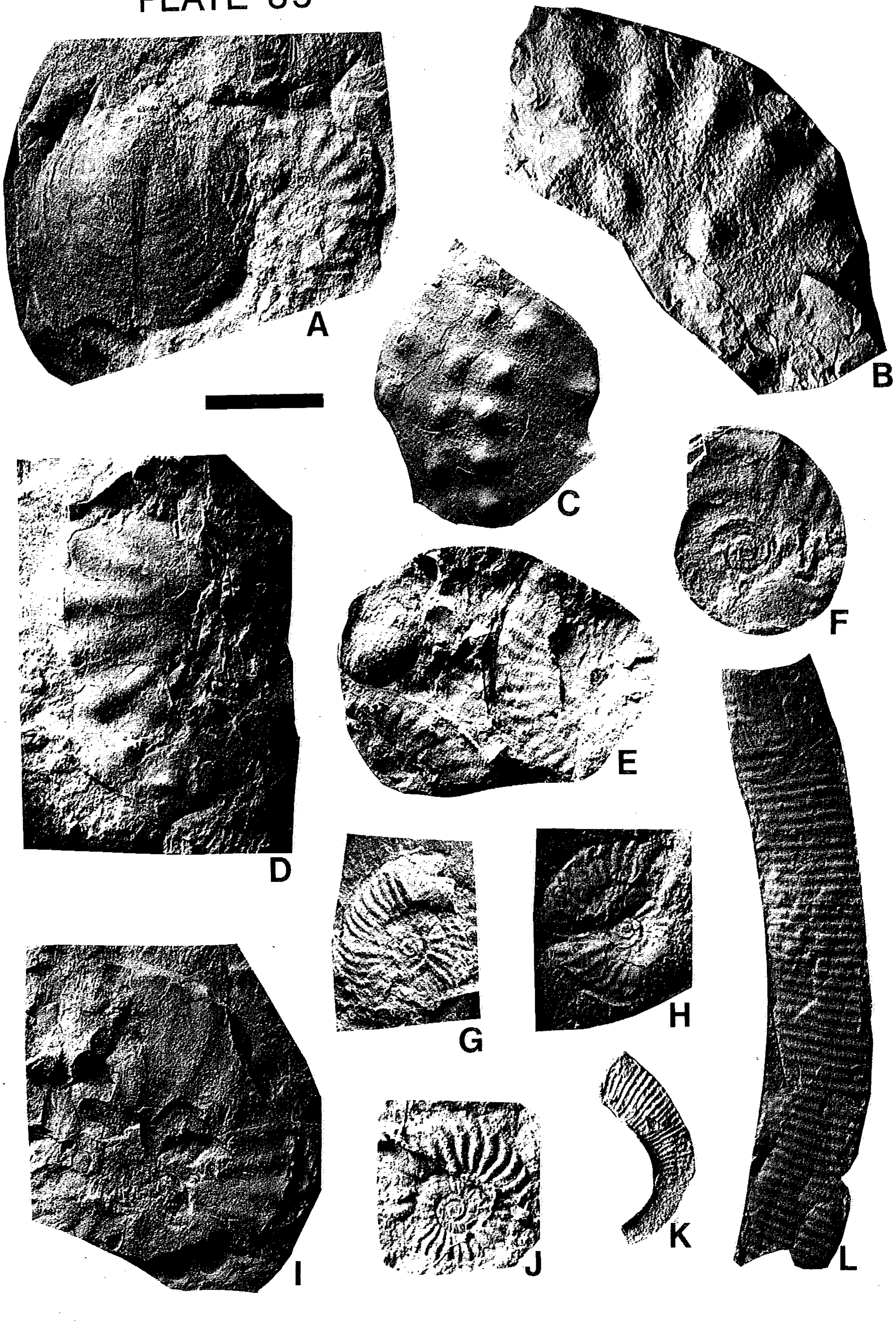

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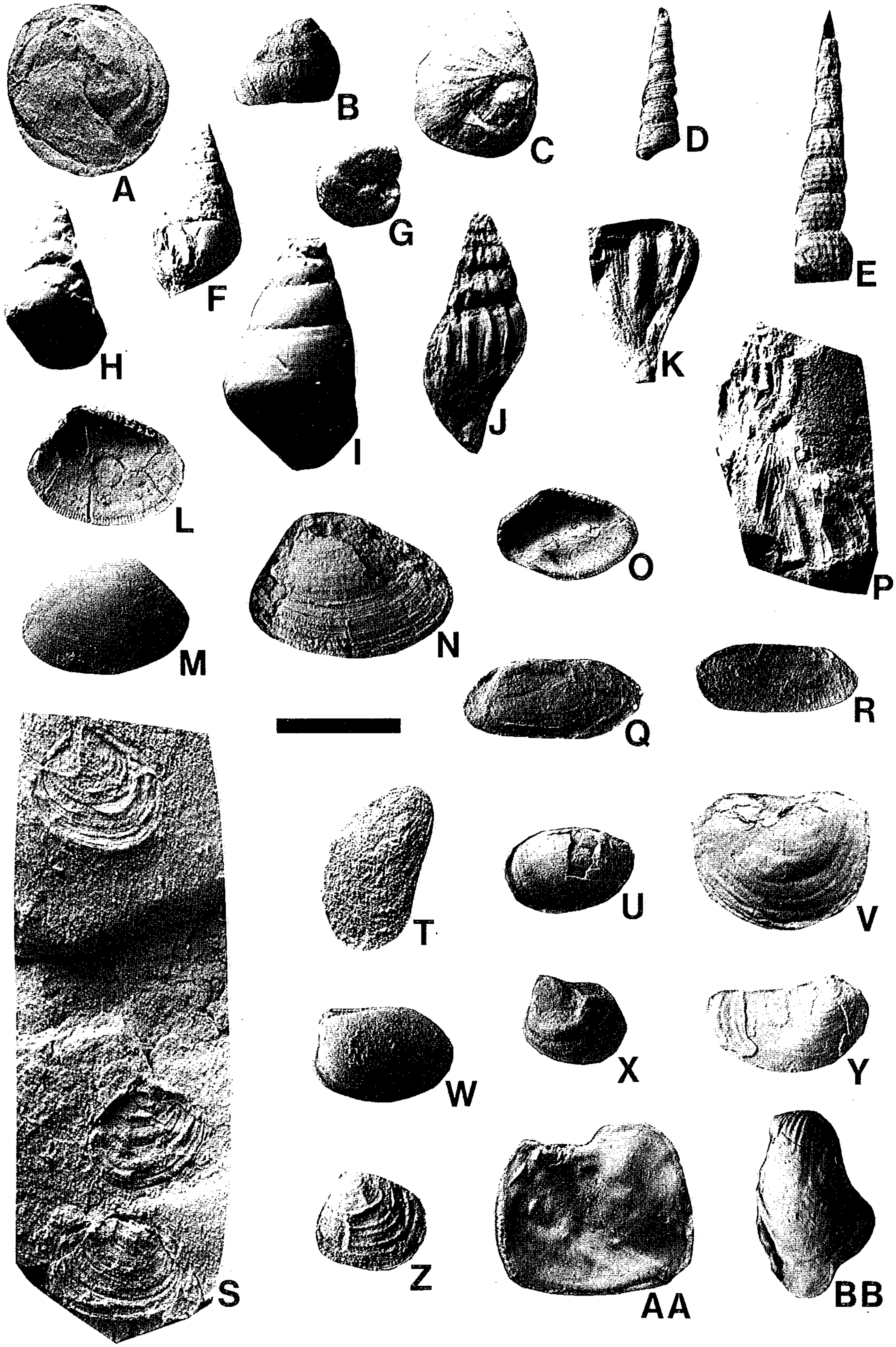

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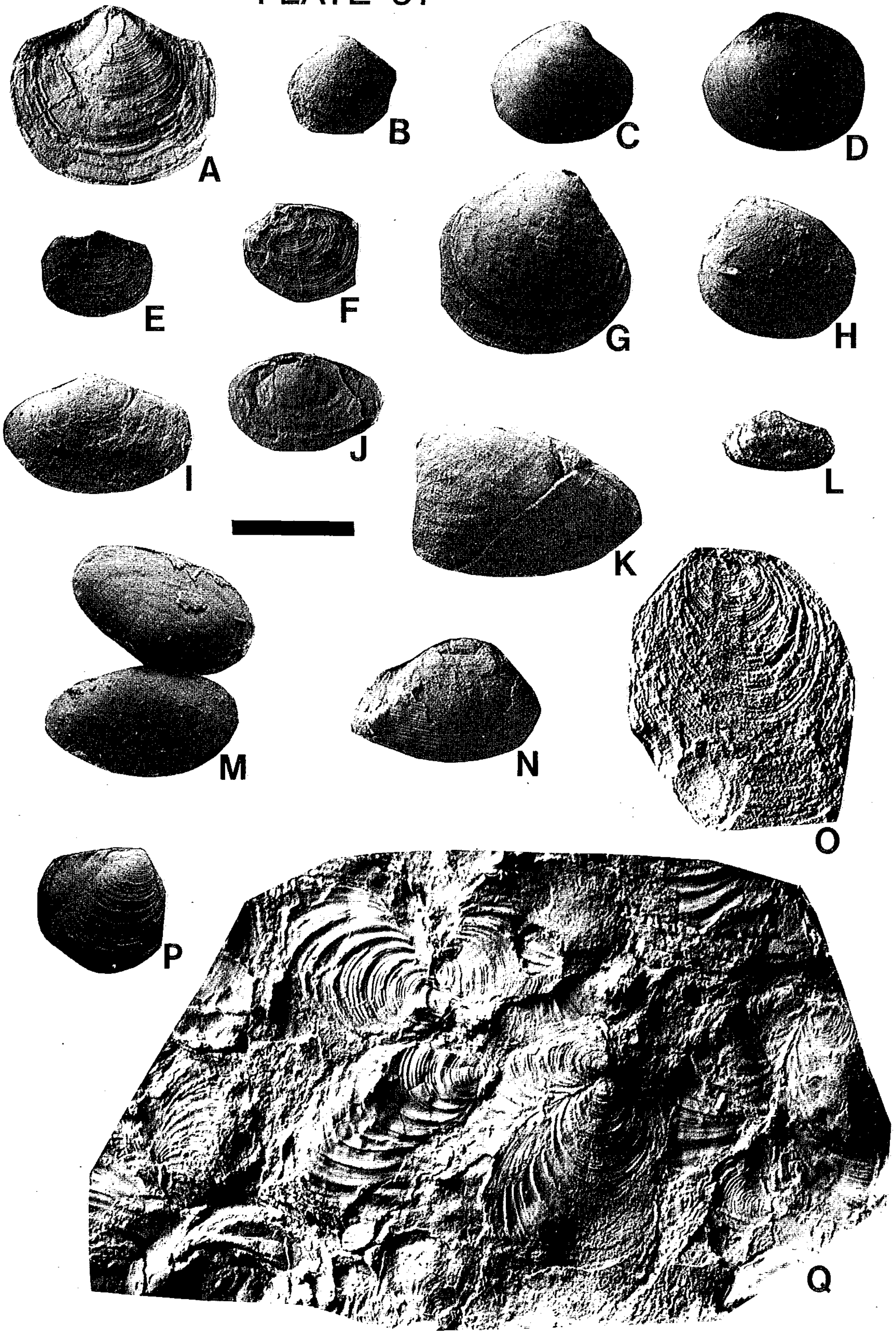

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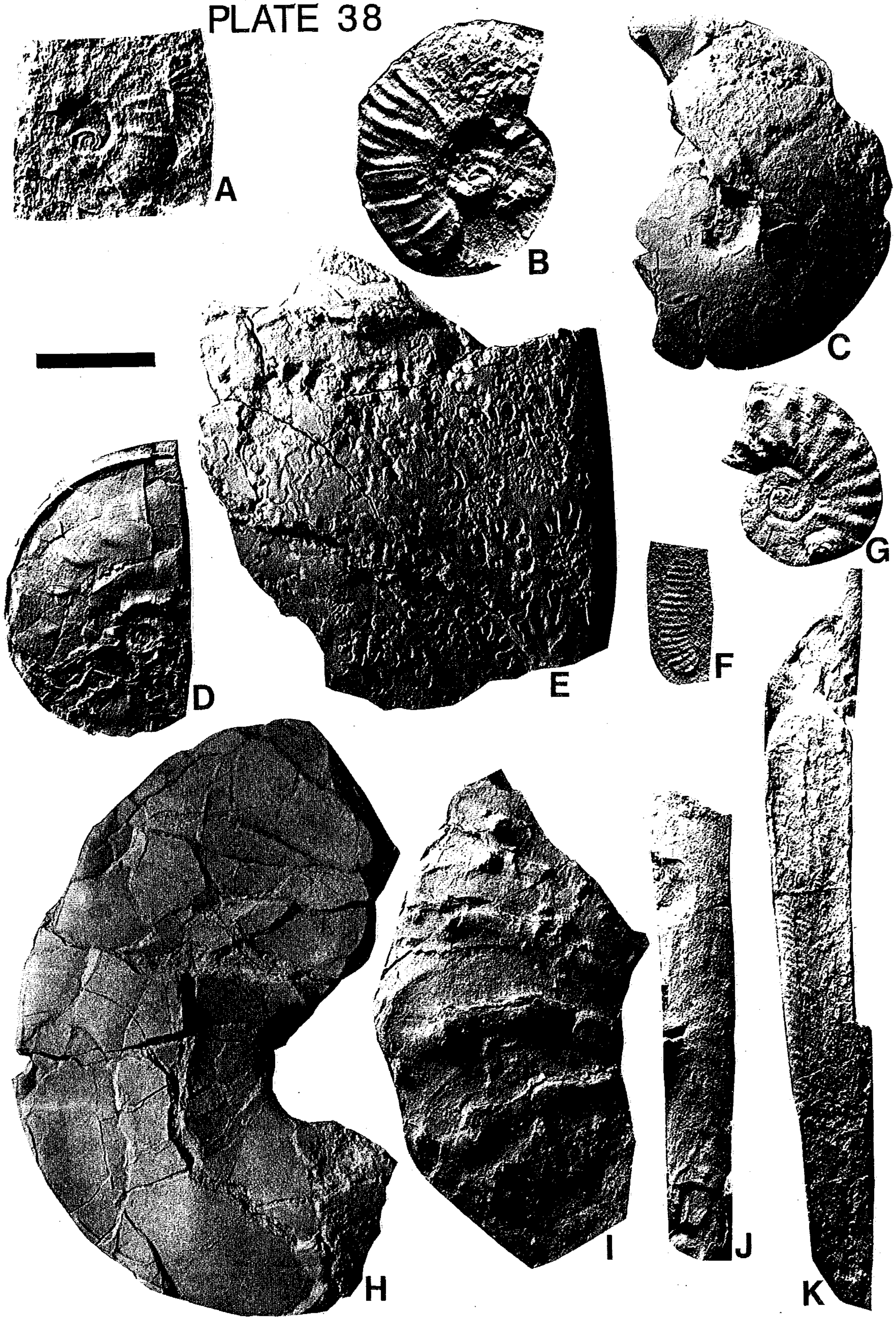

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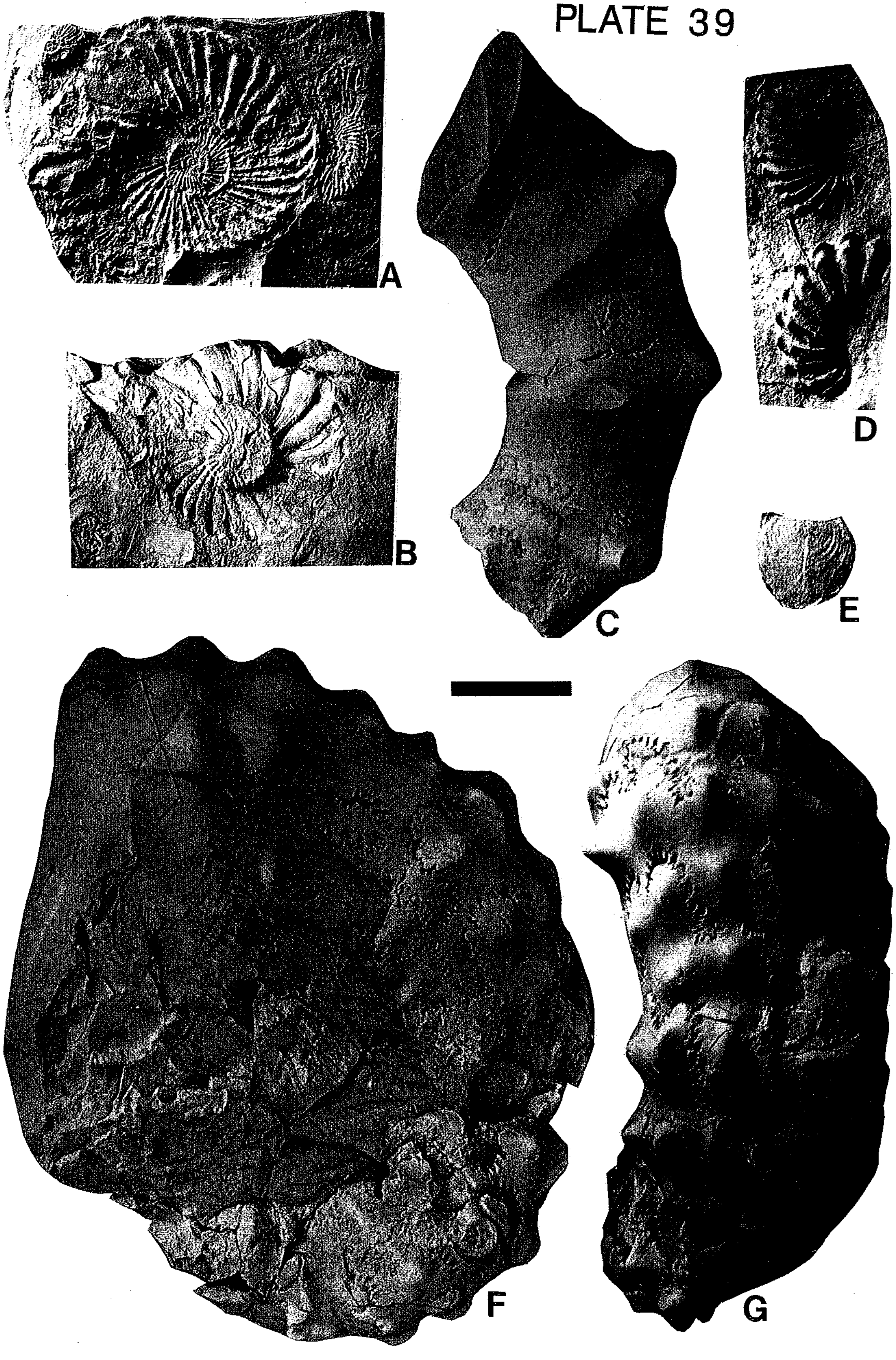

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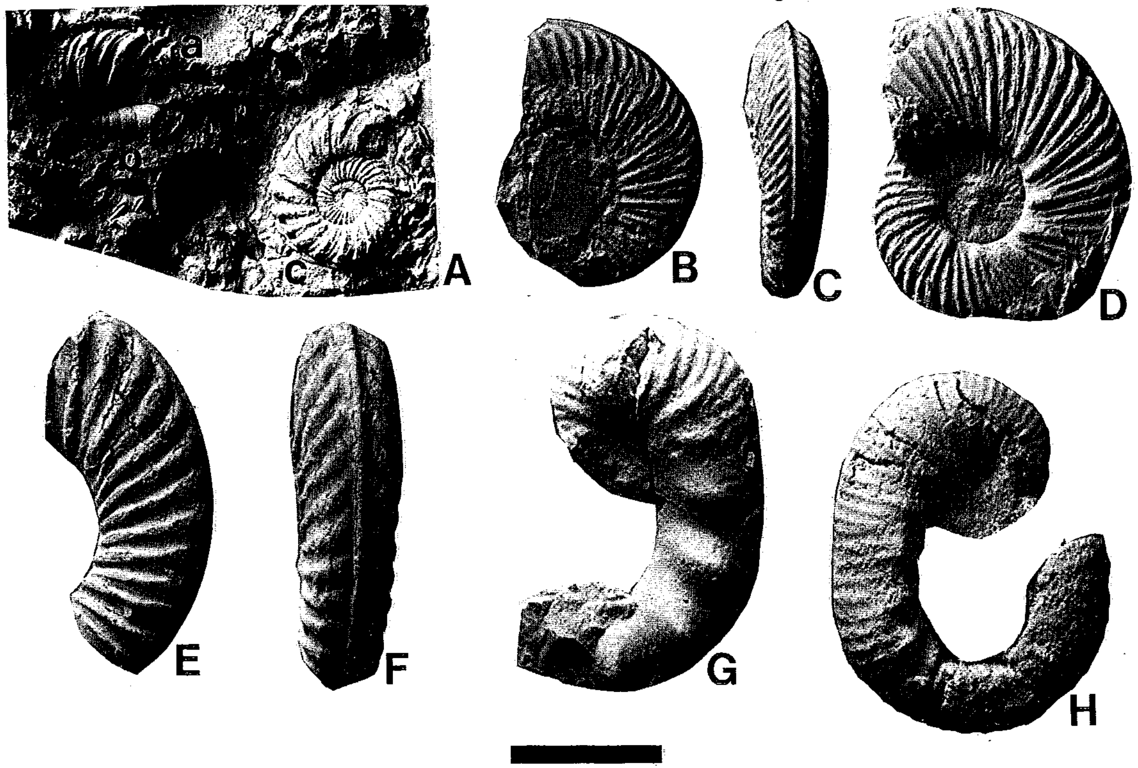

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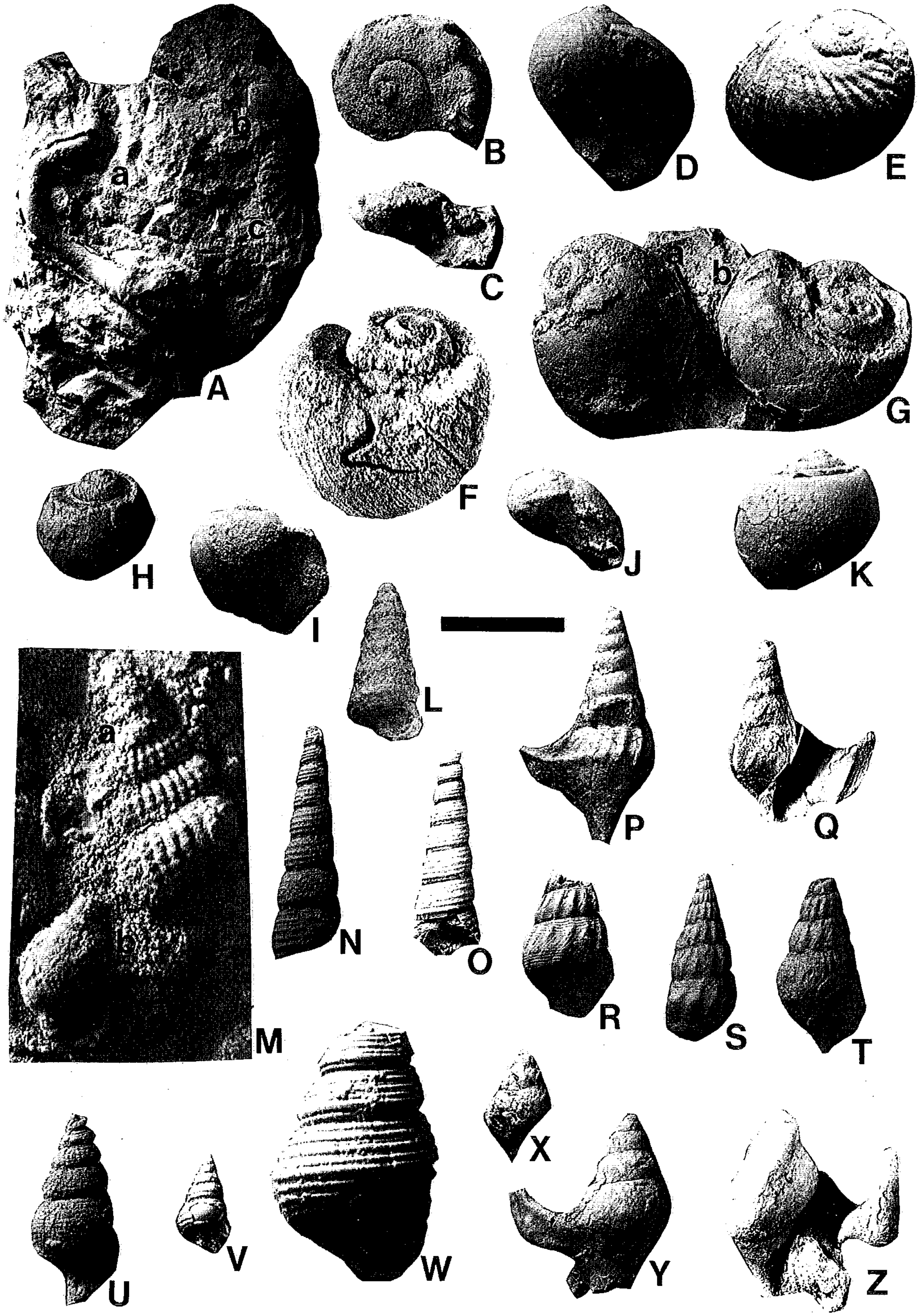

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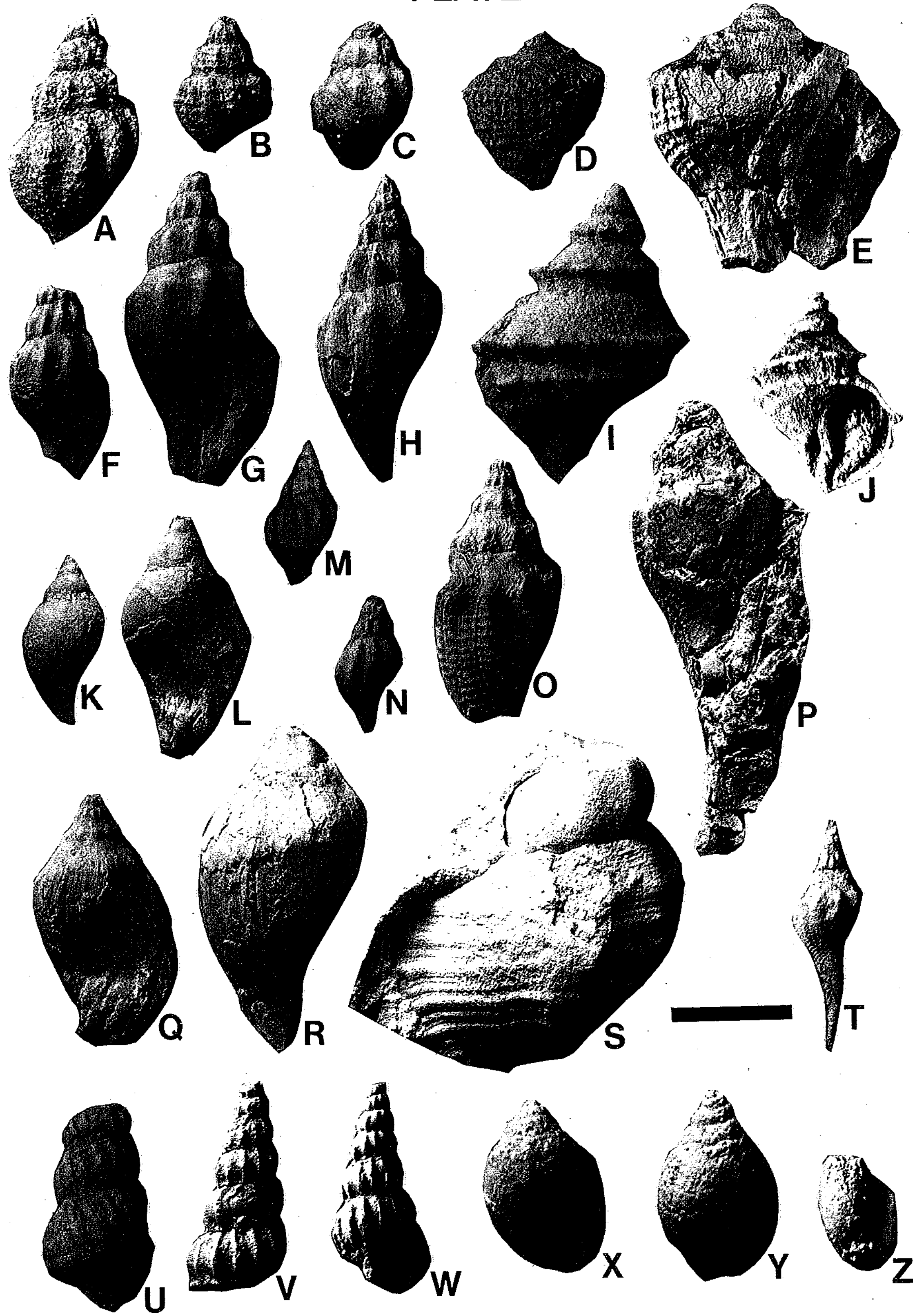

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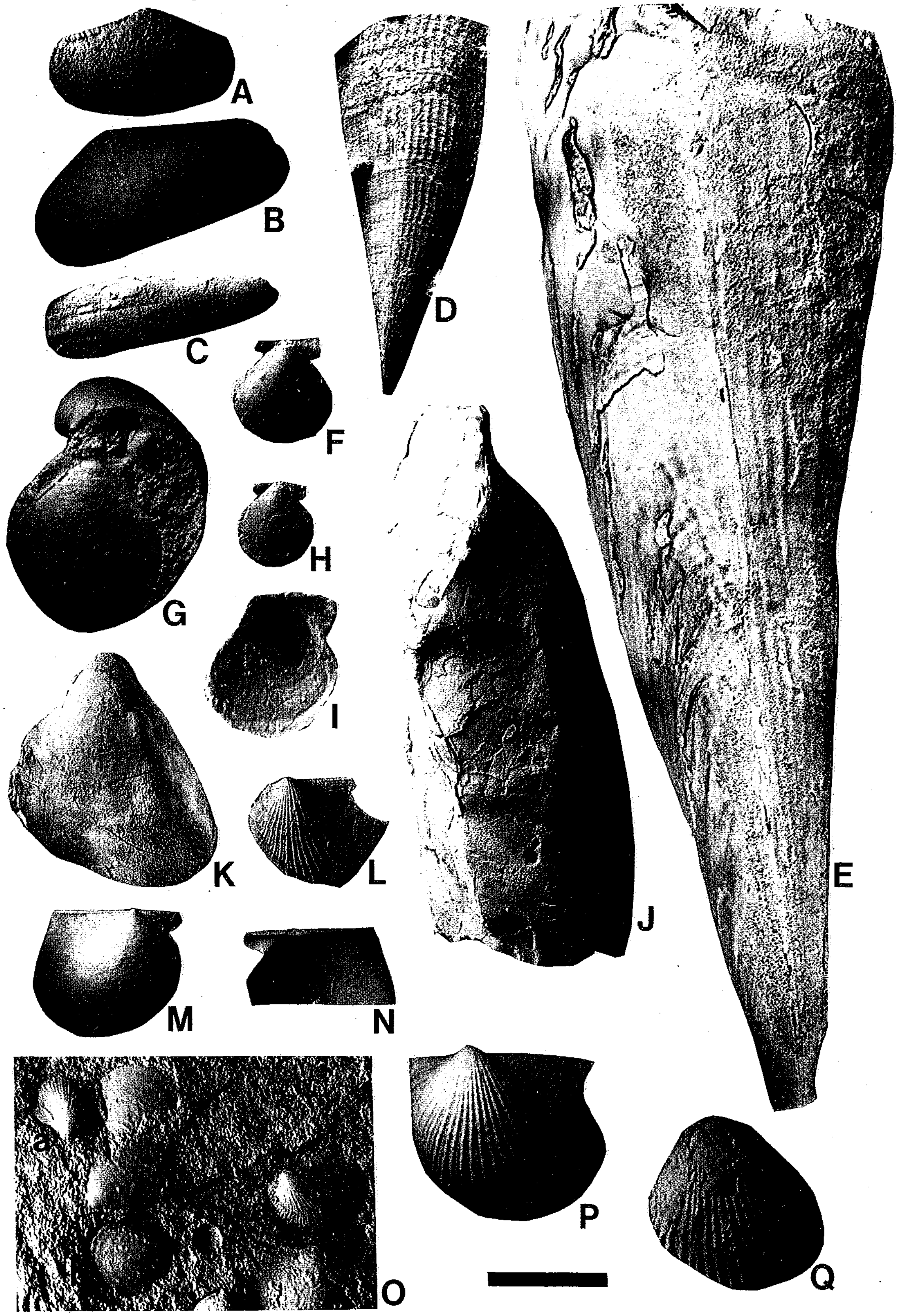

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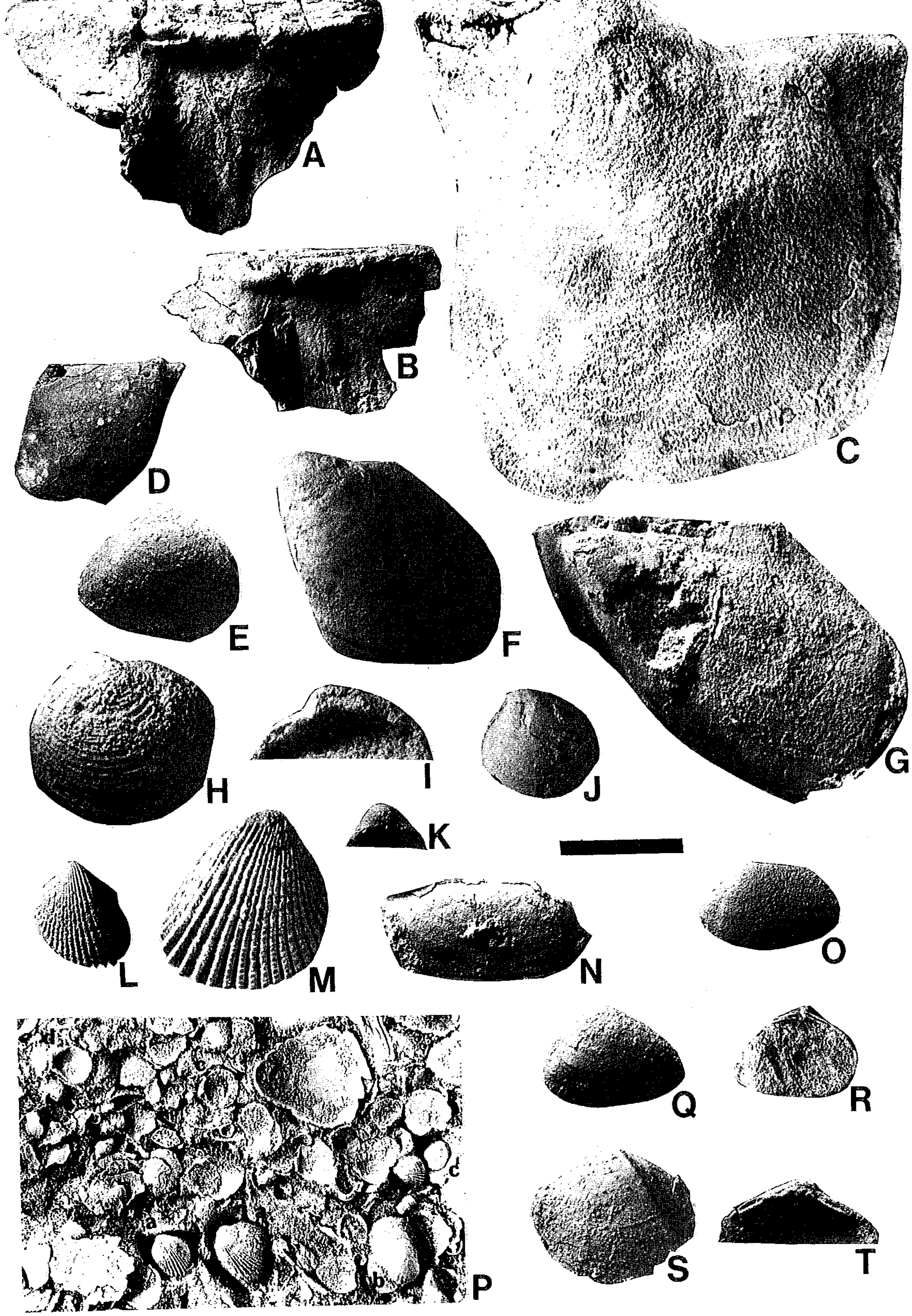

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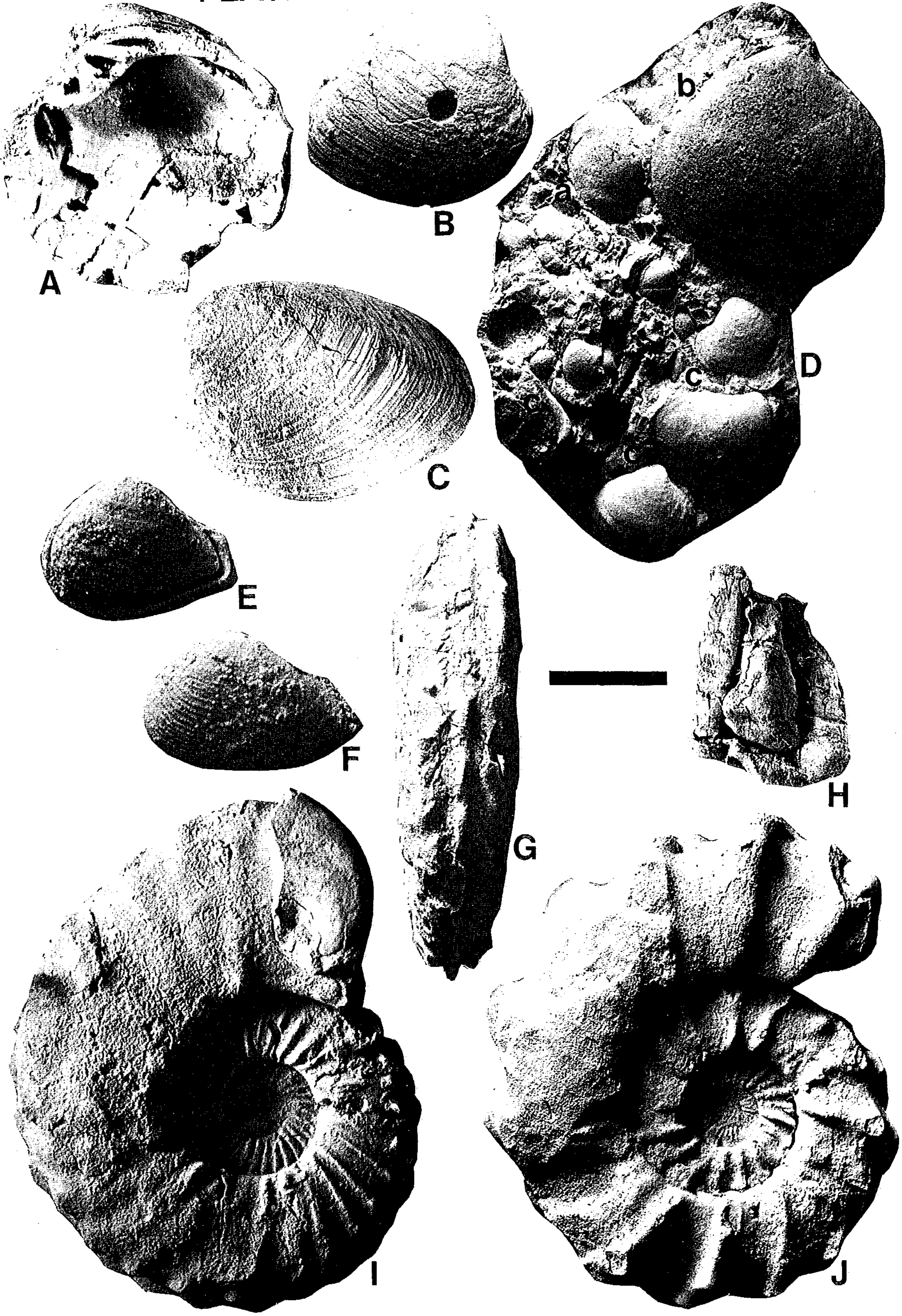

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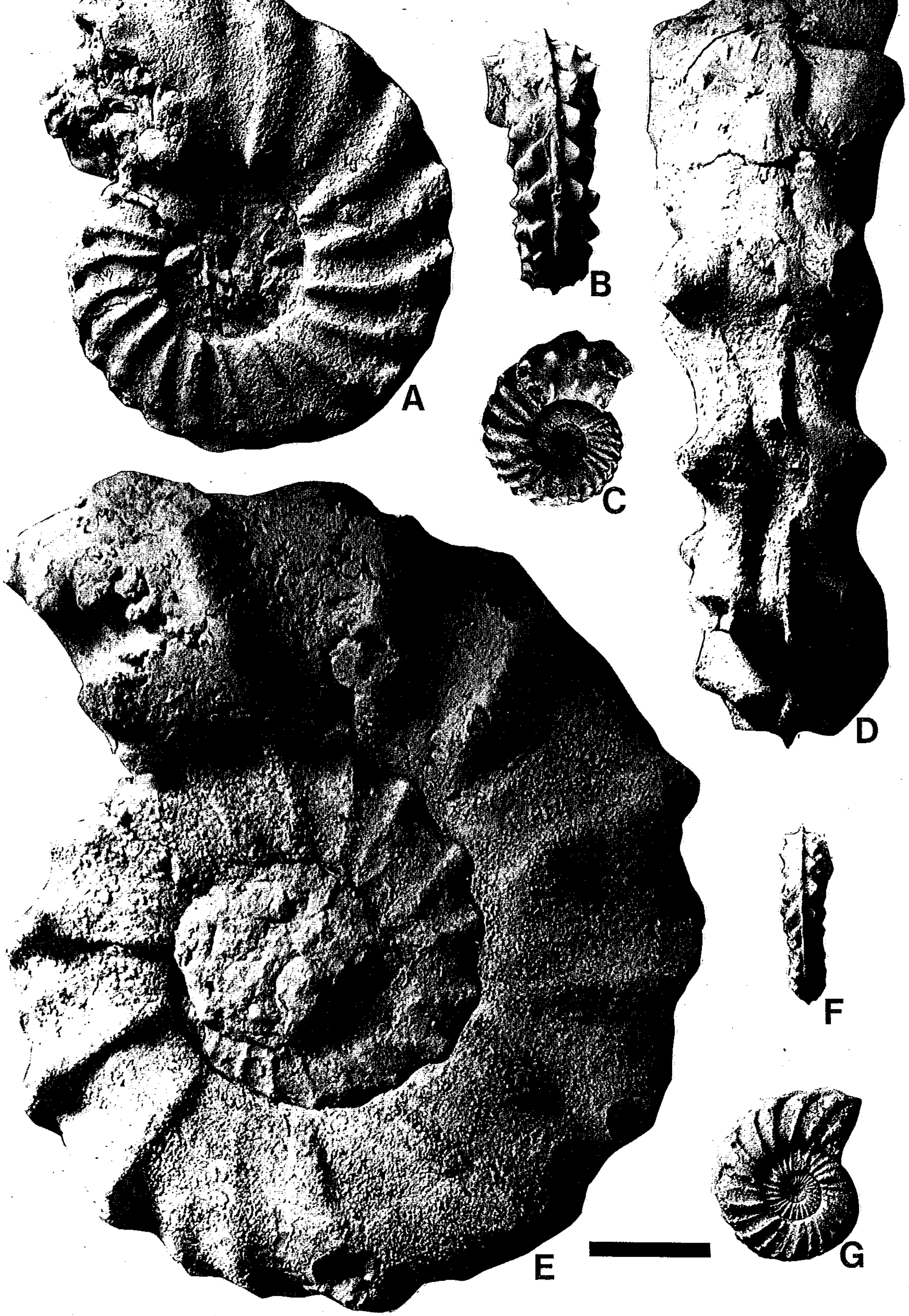

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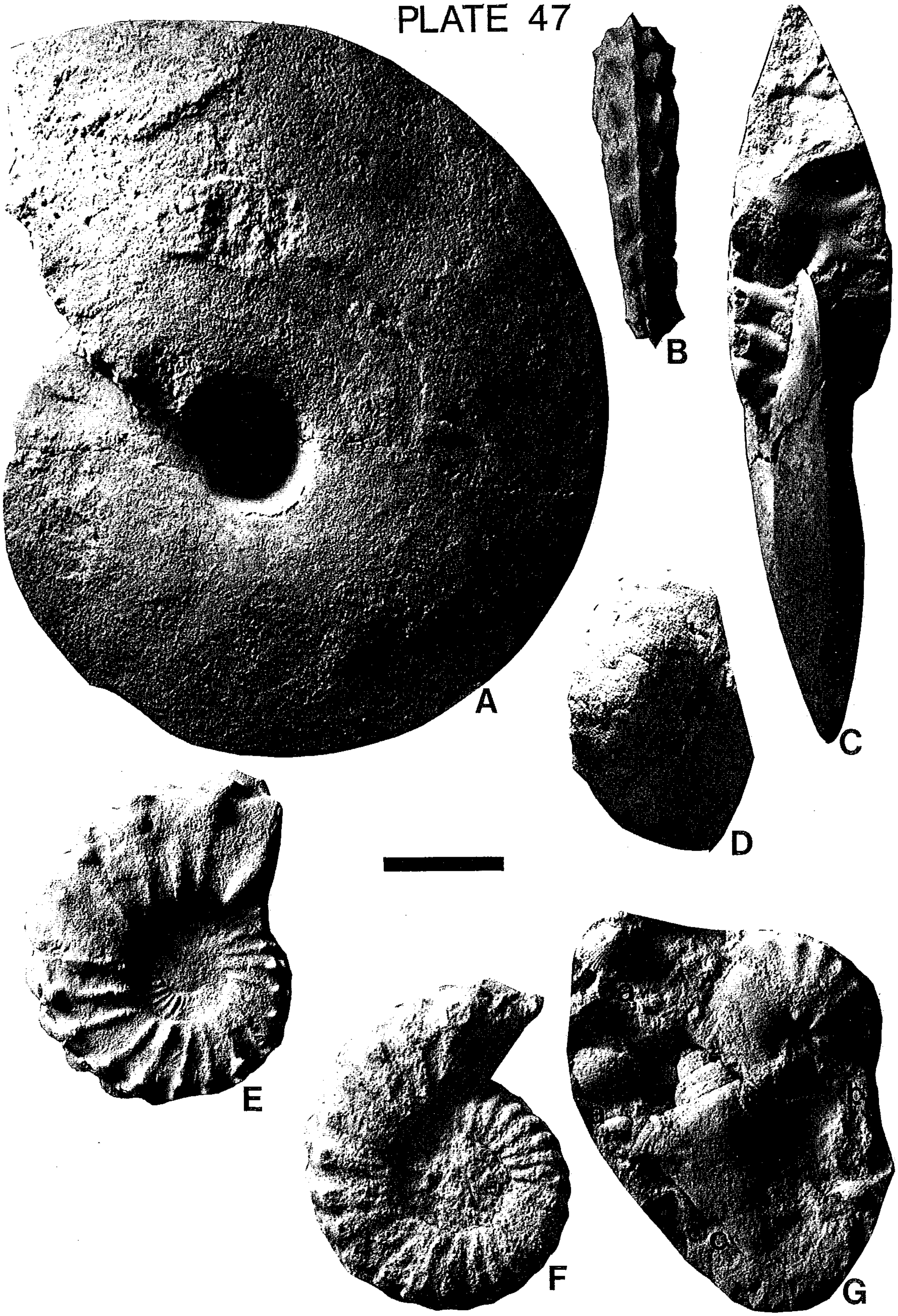

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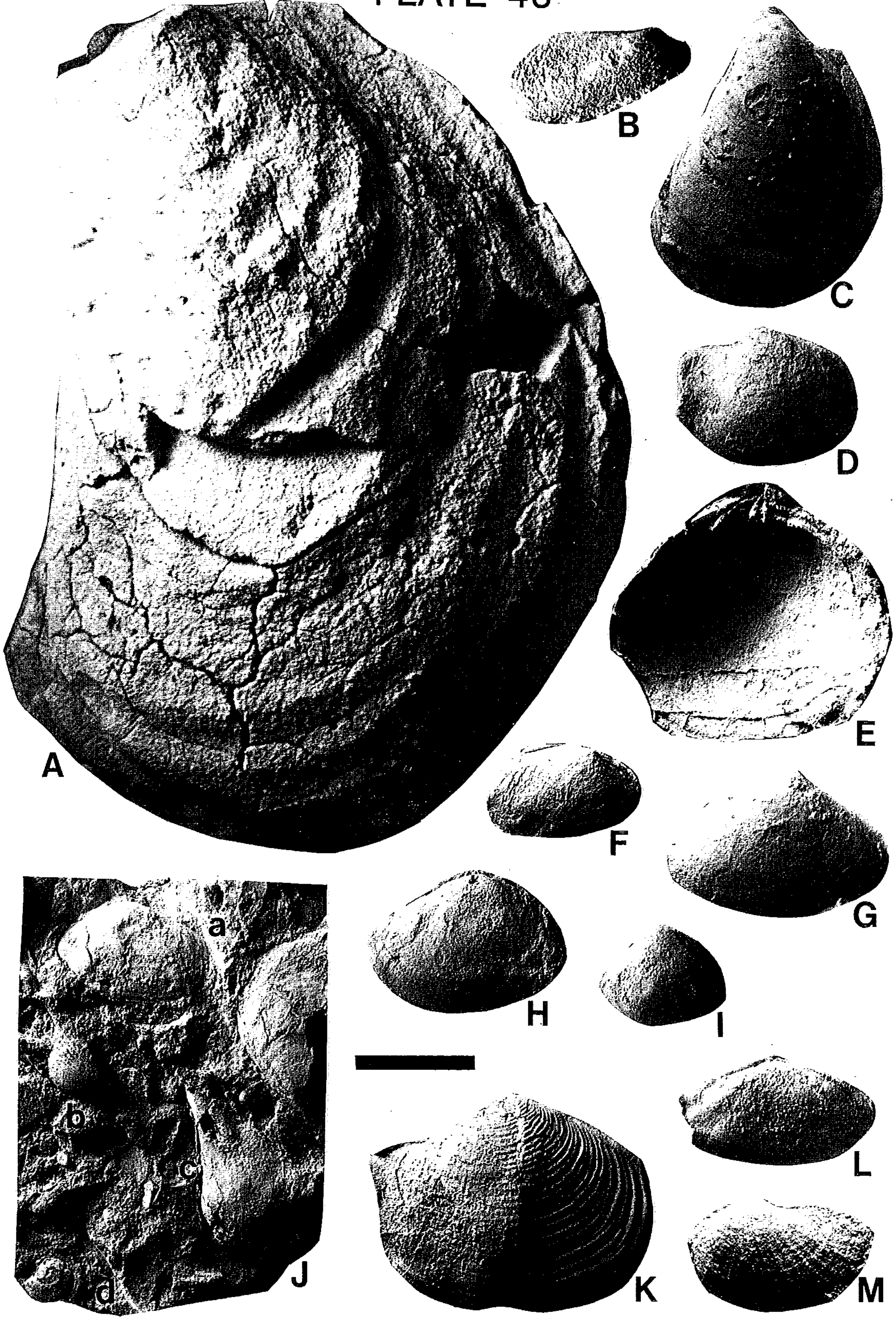

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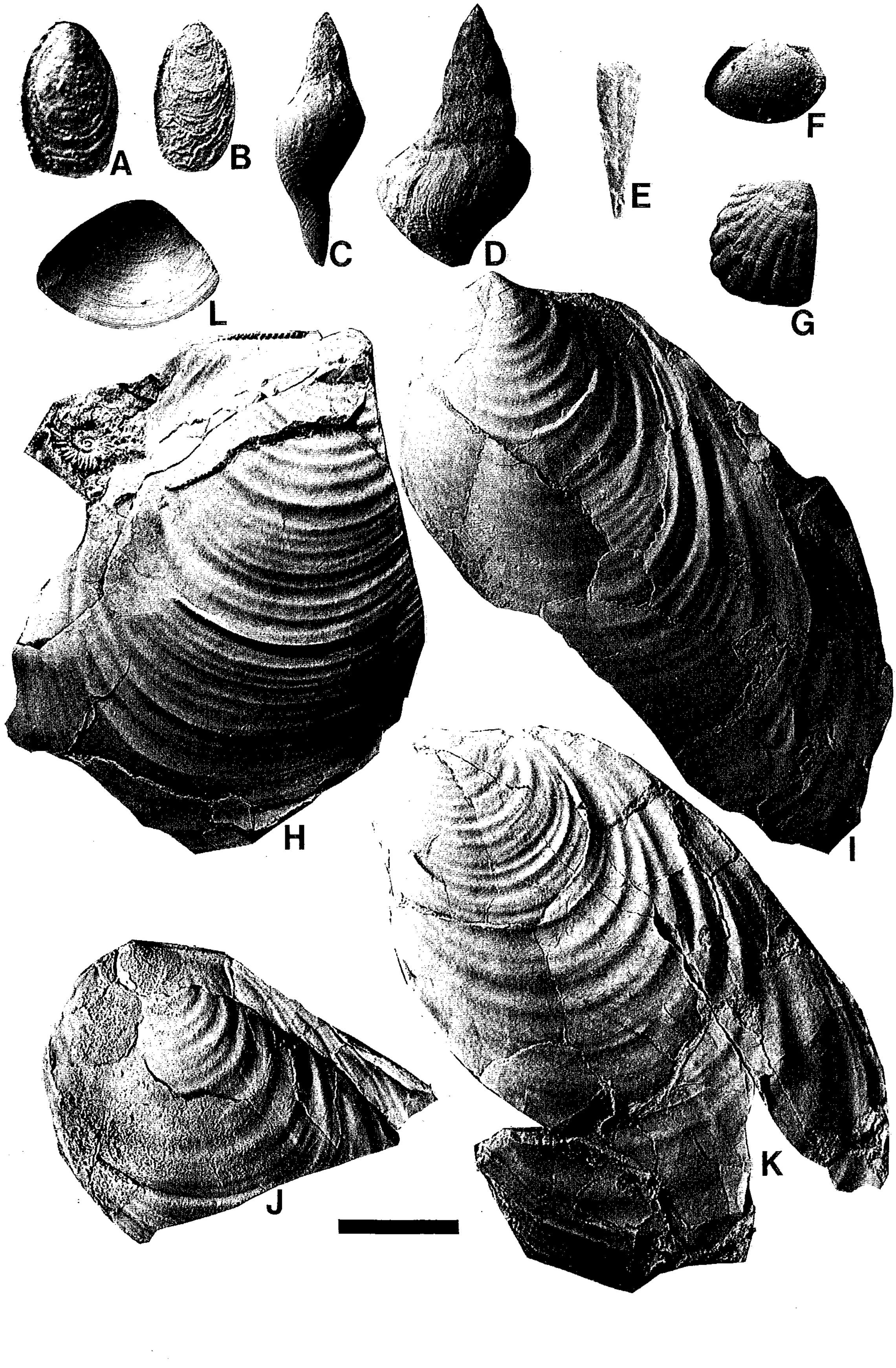

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