

A REVIEW OF THE BIOSTRATIGRAPHY OF THE POST-LOWER BAJOCIAN JURASSIC AMMONITES OF WESTERN AND NORTHERN NORTH AMERICA

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ABSTRACT

From the beginning of the Upper Bajocian, Jurassic North America straddled two strongly differentiated ammonite faunal realms, the East-Pacific Realm and the Boreal Realm. These in turn overlap so little with the Tethyan Realm, in which the primary chronostratigraphic ammonite zonations have been defined, that direct correlations between North America and the standard European successions continue to be almost impossible in most of the Middle Jurassic. This has led to much uncertainty, the identifications of ammonites and their assigned ages being frequently locked in circular argument. The taxonomy and biostratigraphy of the ammonites are, therefore, reviewed in the light of what has been learned in the last 30 years of their distribution and evolution both in North America and in the rest of the world. Four regions or domains are distinguished: A, the epicratonic Western Interior, from Wyoming to Alberta; B, the mobile Cordillera, from northern California to the Alaska Peninsula; C, epicratonic arctic Canada, including the Archipelago; and D, the Alaskan North Slope. Some 80 ammonite faunas are identified and arranged in four parallel time-ordered sequences, ranging from Upper Bajocian to the top of the Jurassic. Their correlations, among themselves and with standard successions in the Arctic and in Europe, are discussed and indicated as far as the evidence allows. The conclusions are: 1) The Middle Jurassic ammonites of region A formed a distinct Western Interior faunal province within the Pacific Realm. 2) With one exception, all the Middle Jurassic faunas of the Western Interior Province are of Upper Bajocian - Bathonian age, including the ones previously assigned to the Callovian; the Callovian is almost totally unrepresented. 3) The Upper Bajocian and Bathonian are similarly strongly represented in the Cordillera, region B, Lower Callovian being well-developed only in southern Alaska. 4) The succession in region C, arctic Canada, is closely similar to that of the rest of the

Boreal Province as typified by East Greenland, with again an extensive (Boreal) Bathonian sequence and only intermittent evidence of Callovian. 5) Despite apparent faunal disparities, the succession in region D, the North Slope, has close affinities with that of adjacent arctic Canada, region C. 6) Comparison of ammonite distributions within and between domains A and B shows them to be consistent with possible lateral tectonic displacements of accretionary terranes in the Cordillera since the Middle Jurassic of between zero and a maximum of perhaps 2000 km northwards for the Alaska Peninsula relative to the continent. 7) Similarly, strike-slip displacements of northern Alaska relative to the Laurentian Shield are unlikely to have exceeded a few hundred km and could also have been zero.

RÉSUMÉ

A partir du début du Bajocien supérieur, l'Amérique du Nord se partageait entre deux domaines où les faunes d'ammonites étaient fortement distinctes; il s'agissait du Domaine Est Pacifique et du Domaine Boréal. Ceux-ci, à leur tour, ne se superposent que si peu au Domaine Téthysien, où les premières zonations chronostratigraphiques d'ammonites furent définies, que les corrélations directes entre les successions de référence en Europe et celle d'Amérique du Nord continuent à être presque impossibles pour la plus grande part du Jurassique moyen. Ceci a conduit à une grande incertitude, l'identification des ammonites et leurs âges supposés étant fréquemment l'objet de démonstrations circulaires. La taxinomie et la biostratigraphie des ammonites sont donc révisées ici à la lumière de ce que les dernières 30 années nous ont appris sur leur distribution et leur évolution tant en Amérique du Nord que dans le reste du monde. Quatre régions ou domaines sont distingués: A, le "Western Interior" intracratonique s'étendant du Wyoming à l'Alaska; B, la Cordillère mobile, de la Californie Septentrionale à la Péninsule d'Alaska; C, le Canada arctique, intracratonique,



comprenant l'Archipel; et D, le Versant Nord de l'Alaska. Quelques 80 faunes d'ammonites ont été identifiées et disposées en quatre séquences chronologiques parallèles qui s'étendent du Bajocien supérieur au sommet du Jurassique. Les corrélations, aussi bien entre elles qu'avec les successions de référence de l'Arctique et d'Europe, sont discutées et établies dans la mesure des preuves disponibles. Les conclusions suivantes sont tirées: 1) Les ammonites du Jurassique moyen de la région A constituent une province du Western Interior, bien distincte au sein du Domaine Pacifique. 2) A l'exception d'une seule, toutes les faunes du Jurassique moyen de la Province du Western Interior sont d'âge Bajocien supérieur - Bathonien, y compris celles précédemment attribuées au Callovien; cet étage n'est pratiquement pas représenté. 3) De même, le Bajocien supérieur et le Bathonien sont largement représentés dans la Cordillère (région B), le Callovien inférieur n'étant bien développé qu'en Alaska méridional. La succession dans la région C, le Canada arctique, est très semblable à celle du reste de la Province Boréale comme elle a été établie dans l'Est du Groënland, avec encore une séquence très répandue du Bathonien boréal et, seulement, des indications sporadiques de Callovien. 4) Malgré ses apparentes particularités fauniques, la succession de la région D, le Versant Nord, a des affinités étroites avec celle de la région C, contiguë, du Canada arctique. 5) La comparaison des distributions d'ammonites au sein et entre les domaines A et B montre qu'il y a compatibilité avec des mouvements tectoniques horizontaux de zones d'accrétion dans la Cordillère à partir du Jurassique moyen; l'amplitude des mouvements, vers le Nord, de la Péninsule de l'Alaska par rapport au continent peut être évaluée entre zéro et, peut être 2000 km. 7) De même, les décrochements de l'Alaska septentrional par rapport au Bouclier Laurentien n'ont pas dû dépasser quelques centaines de km et ont pu aussi bien être nuls.

INTRODUCTION

Jurassic rocks have been recorded from almost innumerable localities in the western United States, Canada and Alaska, and listed and reviewed by Imlay in his masterly survey of 1980. Many ammonites have been found and described, but the majority came from scattered localities and were collected by field parties not primarily interested in ammonoid biostratigraphy. The number of places in which collections have been made carefully bed by bed in recorded sections is therefore very small. To work out the correct sequence of ammonite faunas and even the associations of genera and species occurring together in them has been very difficult, and is in many cases still uncertain. We have had to rely to a considerable extent on indirect correlations, mainly lithostratigraphical - the positions of finds within a formation, with luck at levels that could be located relative to the base or top of the formation. While this works quite well in the shallow-water epicratonic sediments east of the Rockies, in Wyoming, Montana and Alberta, in which relatively thin formations can be followed with little change over distances of hundreds of kilometres, it is often barely possible in the Cordilleran deposits whose facies are almost wholly volcanoclastic and often turbiditic, laid down in tectonically unstable basins. Fossils tend to be scattered throughout formations whose thicknesses can be enormous

and rapidly varying, either in depositional wedges or through erosion. Lithologic correlations at the level of ammonite faunal horizons may therefore be reliable over distances no greater than a few kilometres. To collect bed by bed from such successions therefore may never be possible. Nevertheless, great progress has been made, and much of the ammonite sequence can now be pieced together with some confidence. The picture that emerges is as follows.

Correct identification of Lower Jurassic rocks presents no serious problems, for the ammonites they contain resemble those from the well-known standard successions of Europe quite closely - almost always to generic, sometimes even to specific level. Occurrences are scattered and successions locally highly incomplete, but somewhere or other almost every part of the Lias has been recognized. In the Aalenian (Lower Bajocian *olim* and *sensu* U.S. and Canadian Geological Surveys), more and more specifically Pacific elements enter the faunas, extending from the Andes to the Alaskan Peninsula, but broad correlations can be continued upwards as far as the top of the Lower Bajocian (Middle Bajocian *olim* and *sensu americano*), Humphriesian Zone, whose *Stephanoceras*, ranging from the Andes through Oregon, Alberta, the Queen Charlotte Islands, the Talkeetnas to the Alaskan Peninsula, bear an astonishing resemblance to those from Dorset and the Swabian Jura. (For recent reviews see Westermann and Riccardi, 1976, 1979; Hall and Westermann, 1980; and Westermann, 1981). Thereafter, faunal similarities with Europe abruptly cease.

The next higher ammonites found both in South and North America came to be described during the 1920s to 1930s in the heyday of the Buckman-Spath schools of taxonomy, and almost every new ammonite found, no matter how scrappy, had to have its own new generic name: a) *Neuqueniceras* Stehn, 1924 (Andes), b) *Yakounites* McLearn, 1927 (Queen Charlotte Islands), c) *Yakounoceras* McLearn, 1927 (Queen Charlotte Islands), d) *Eurycephalites* Spath, 1928 (Andes), e) *Xenoccephalites* Spath, 1928 (Andes), f) *Miccocephalites* Buckman, 1929 (Alberta), g) *Paraccephalites* Buckman, 1929 (Alberta), h) *Metacephalites* Buckman, 1929 (Alberta), i) *Paracadoceras* Crickmay, 1930 (B.C.), and j) *Lilloettia* Crickmay, 1930 (B.C.).

Nevertheless, the affinities to known groups seemed fairly clear. The second and third [b] and [j], alias *Seymourites* Kilian and Rebol, 1909, were close to *Keplerites* from the Lower Callovian of Europe; (a) appeared close to *Reineckeia* from the Middle Callovian of Europe; and the rest strongly resembled *Macrocephalites* from the Lower Callovian, together with *Reineckeia* the only non-American genera to be widely cited from South America. The ages of the beds containing these faunas were thus firmly ascribed to the Callovian; ergo, immediately succeeding as they did the Lower Bajocian, the whole of the Upper Bajocian and Bathonian had to be missing in North and South America. The situation in the Arctic appeared to be similar. There, Palaeozoic, Liassic or Aalenian rocks were followed by sequences containing *Cranoccephalites*, *Arctoccephalites*, *Arcticoceras* and *Keplerites* also firmly ascribed to the Callovian. Such large and globally widespread non-sequences coincided with a Bathonian developed in northwest Europe often in highly condensed or even non-marine facies. Thus arose the doctrine of the great world-wide Bathonian

regression, followed by the equally great world-wide Cretaceous transgression, summarized by Arkell (1965) and both still widely cited today, often to be found in curves of eustatic sea-level as a function of time.

Our knowledge of these Middle Jurassic faunas has been immensely enriched in the last 30 years almost entirely through the untiring efforts of Ralph Imlay and Hans Frebold. Many new faunas from many horizons have been described, yet the similarities with the classical Bathonian and Callovian faunas of Europe have become little closer. New forms now had to be given new generic names out of necessity, to emphasize the faunal differences within the broad similarities. The study of the ammonites was still in the analytical phase (Wright, 1981). It became clear that the main reason for the dissimilarity of American, Arctic and European ammonite successions in the Middle Jurassic was the development of strong faunal provincialism (e.g., Imlay, 1965). At the end of the Lower Bajocian, the differentiation that had begun mildly in the Aalenian became complete and the ammonites segregated into three almost non-overlapping faunal realms: the ancestral Tethyan Realm, with its adjacent epicontinental domains including the Northwest European Province with its rich ammonite faunas that form the primary world standard of Jurassic zonation; the Pacific Realm, including all the circum-Pacific domains from New Guinea via New Zealand through the western cordilleras of South and North America to the Sea of Okhotsk and Japan; and the Arctic or Boreal Realm, from the North Slope of Alaska through the Sverdrup Basin, north and east Greenland, Spitsbergen, the Petchora, through the breadth of north Siberia as far as Kolyma.

It seems an opportune moment to attempt another review of the post-Lower Bajocian ammonites of North America. We begin with a brief systematic review of the classification of the relevant ammonites at generic level and up. There has been progress in this field independently, for besides the recognition of faunal provincialism a lot has been learned in recent years about phyletic relationships among Middle and Upper Jurassic ammonites generally (Callomon, 1981a, b). Together with the recognition of dimorphism, this does much to simplify and bring order into what has grown into a daunting catalogue of generic names.

Next, the published occurrences of ammonites are analyzed into distinguishable assemblages, each of which characterizes a *faunal horizon*. Attempts then to arrange these faunal horizons into time-ordered sequences reveals the presence in western North America, between central California and the Arctic Islands, of four distinct post-Lower Bajocian parallel faunal successions each characteristic of a separate *faunal domain*. Even the correlation of these domains still presents problems for the overlaps are at present tenuous – either because of lack of information, or because they no longer exist. Conversely, the possible reasons for this are interesting and topical, certainly in part due to faunal provincialism (primary), but perhaps also the results of subsequent macrotectonic events now manifested in disjointed terranes (secondary causes).

Finally, to avoid some of the circular arguments of the past, the correlation of the North American successions with the standard successions of Europe is left to the end. The basic

difficulty remains. Despite many new discoveries, there are very few faunal elements between Lower Bajocian and Oxfordian these regions have in common. Neither the Bajocian-Bathonian nor the Bathonian-Callovian boundaries as defined in Europe can be directly recognized in North America, either by ammonites or as yet by any other fossil group. The Bathonian-Callovian boundary however can now be located fairly precisely through indirect correlations via the Arctic. Together with the discovery of what are now known to be undoubtedly Upper Bajocian and Bathonian ammonites in both South and North America, the previously held picture of the distribution of Bathonian and Callovian rocks will need considerable modification. It transpires that most of the formerly "Callovian" ammonites of North America are Upper Bajocian and Bathonian, and that Callovian proper is in turn very scantily represented in many areas, if at all.

SUMMARY OF AMMONITE SYSTEMATICS

The post-Bajocian ammonite faunas to be considered here, together with the numerous localities at which one or more of their elements have been found, are distinctly characteristic of four regions, or *domains*. It seems useful to introduce such a term to describe regions delimited by present-day geographical boundaries, chosen quite possibly wholly or in part for more or less arbitrary reasons of convenience, in contradistinction to faunal realms and provinces, tectonic terranes, and depositional basins, all of which may have contributed to the distribution of fossil faunas as found to-day but in ways usually very imperfectly known and yet to be determined. It corresponds roughly to the 'areas' described on a broader circum-Pacific scale by Westermann and Riccardi (1976). A domain in this sense, therefore, may be part of several faunal provinces and incorporate several terranes and basins. The four domains in North America to be distinguished here all lie north of the 37th parallel, and the Jurassic faunas of southern California, Mexico and the Gulf states, which fall into separate categories, will not be discussed. The domains are:

- A) *Western Interior*: Utah – Colorado – Black Hills of Dakota – Wyoming – Alberta and eastern British Columbia: Rocky Mountains and Foothills as far as the Peace River (56°N). Includes numerous more or less ephemeral basins, including the Wind River, Bighorn, Williston and Fernie Basins.
- B) *Cordillera*: Sierra Nevada of east-central California – east central Oregon – south, central and north-west British Columbia – Vancouver Island – Queen Charlotte Islands – Wrangell Mountains – Cook Inlet – Alaska Peninsula. Includes numerous disjoint tectonic units, terranes and their parts, and a mosaic of rapidly changing, unstable depositional basins.
- C) *Arctic Canada*: northern Yukon Territory (Porcupine River around Old Crow, Richardson Mountains) – Arctic Islands (Prince Patrick to Ellesmere). (Continues to east Greenland – northern Russia – northern Siberia).
- D) *Alaskan North Slope*.

Of these, the first three are of considerable extent. The epicratonic deposits of the Western Interior can be followed

over more than 2000 km – the distance from the Sierra Nevada of California to the Alaska Peninsula is 3000 km and from the epicratonic deposits of the northern Yukon to those of the Petshora in northern Russia is 4000 km. The fourth region is small and is differentiated here only because its succession, as far as it is known, makes it uncertain whether its affinities are closest with those of B or C, and in the context of tectonic discussions this question could be vital.

Leaving aside minor differences, the uniformity of the faunal assemblages and their successions within each of these major regions is remarkable. In contrast, the differences between the regions range from modest to extreme. The problem under discussion is the possible origins of these similarities and differences. Three causes could be invoked:

- 1) Differences in ages. As indicated in the introduction, the successions known today are still very incomplete. It could have been the case, therefore, that highly intermittent regional sedimentary cycles in each of regions A and B, for instance, were responsible for the widespread extent and correlation of the faunas found within them, but that there was a mismatch of cycles between the regions so that the faunal correlation now found between them is correspondingly low on grounds of non-overlapping ages.
- 2) Differences arising from faunal provincialism, e.g., between the Pacific and Boreal Realms discussed in the introduction.
- 3) Differences across geographic boundaries observed today arising from plate-tectonic displacements, i.e., the juxtaposition of disparate fossil faunas by the subsequent movement of one of them from its original place of entombment.

Before assessing the possible importance and contributions of these factors it is necessary to summarize the faunas briefly. We take up the successions immediately above the last horizon to be identifiable world-wide, with ubiquitous *Stephanoceras* marking the top of the Lower Bajocian, Humphriesianum Zone, and begin with a short systematic review to make clear the interpretation of the generic names used. Ammonite taxa whose authors are not listed in the references may be found in the *Treatise* (Arkell, 1957). Dimorphs [M] and [m]: macro- and microconchs.

Superfamily STEPHANOCERATACEAE Neumayr, 1875

The main branches of this major group of Middle Upper Jurassic ammonites are represented diagrammatically in Figure 1 (after Calomon, 1981a).

Family SPHAEROCERATIDAE Buckman, 1920

The derivation of this family from the Otoitidae and its subsequent blossoming world-wide in the Lower Bajocian is not of immediate relevance here. Of interest, however, is the phylogenetic splitting that began in the Humphriesianum Zone at the top of the Lower Bajocian. The family divided into at least three biogeographically separate branches, two of which are of major importance in North America. One branch, the Sphaeroceratinae *sensu stricto*, lingered on with little change in the northern Tethys up to about the Garantina Zone of the Upper Bajocian (Sturani, 1971). Another branch, apparently restricted at first to the Eastern Pacific Province of the Pacific Realm, developed into the Eurycephalitinae. The third branch, probably also originating

in the eastern Pacific, invaded the Arctic and then dominated the Boreal Province of the Boreal Realm as the Cardioceratinae up to the Kimmeridgian of the Upper Jurassic.

Subfamily SPHAEROCERATINAE Buckman, 1920

1a. *Sphaeroceras* BAYLE, 1878

Type species *Ann. brongniarti* J. Sowerby, 1817. Holotype, refigured by Arkell (1952, p.77, Text-Fig.20.2a,b), from the Bajocian of Normandy; microconch.

1b. *Chondroceras* MASCKE, 1907

Type species *Ann. gervillei* J. Sowerby, 1818. Holotype, refigured by Arkell (1952, p.77, Fig.20.3a,b) and Westermann (1956, Pl.1, Figs.1a,b), also from Normandy; microconch.

European forms of these two groups have been profusely illustrated by Westermann (1956) and Sturani (1971). Their general dimorphism was subsequently recognized by Westermann (1964c), and it was clearly illustrated by Sturani (1971, p.147, Fig.44), who also studied extensive collections from successive well-resolved stratigraphical horizons. By common consent, the differences between the two European genera were small. In *Sphaeroceras brongniarti* the coiling is globular and the umbilicus so minute as to be occluded. In *Chondroceras gervillei* the coiling is more open and less inflated. Even more evolute and planulate forms were grouped by Westermann into a third genus-group taxon, *Schmidtocheras*. The precise relations between these groups were not very clear. Westermann assumed that *Chondroceras* and *Sphaeroceras* differed in age, but Sturani showed that this was not so. Although the ages of the types of the type species from Normandy will probably never be determined absolutely precisely, topotypes occur together in the same bed in the lower Humphriesianum Zone, the Conglomérat de Bayeux (cf. Rioult, 1964). The extensive collections from northern Italy contain forms that are morphologically typical of all three genera ranging from the Romani Subzone (the lowest of the Humphriesianum Zone, Lower Bajocian, through the whole of the Subfurcatus Zone of the Upper Bajocian). The generic taxa were therefore relegated to subgeneric status, but classification at specific level continued to be based on purely morphological criteria and *Sph. brongniarti* and *Ch. gervillei* were retained as distinct. Since then, large new collections have become available from the Romani Subzone of the Humphriesianum Zone of Sherborne, Dorset (Parsons, 1976, p.131, bed 4b). These contain both typical *Sph. brongniarti* and *Ch. gervillei* as well as intermediate forms, and it seems impossible to draw a dividing line between them. They give the impression of being but a single, highly variable biospecies in the which the typical morphology of the macroconchs is close to that of *Chondroceras wrighi* Buckman (1881: 1923, Pl.415) and the range of variability extends continuously from *Sphaeroceras brongniarti* as the one, involute end-member to *Schmidtocheras orbignyanum* (Wright, 1860) (cf. Westermann, 1956, p.74, Pl.5, Fig.6) as the other, evolute one. Similarly, although not precisely, the same ranges of variability appear then to be the rule at the higher levels also, giving the "form-genera" comparable parallel vertical ranges. On such an interpretation even the type species of *Sphaeroceras* and *Chondroceras* are synonymous, and the retention of *Chondroceras* and *Schmidtocheras* could be justified only in a purely morphological sense on grounds of convenience. Such ranges of variability seem to be typical of many other sphaeroconic relatives of *Sphaeroceras* also, e.g., *Craniocephalites borealis*, the first of the Cardioceratinae, and *Megasphaeroceras rotundum*, the first of the Eurycephalitinae.

2. *Sphaeroceras* (*Defonticeras*) MCLEARN, 1927 (including *Saxitoniceras* McLearn, 1927).

Type species *D. defontii*. This group has recently been revised by Hall and Westermann (1980). It is abundant in western North America.

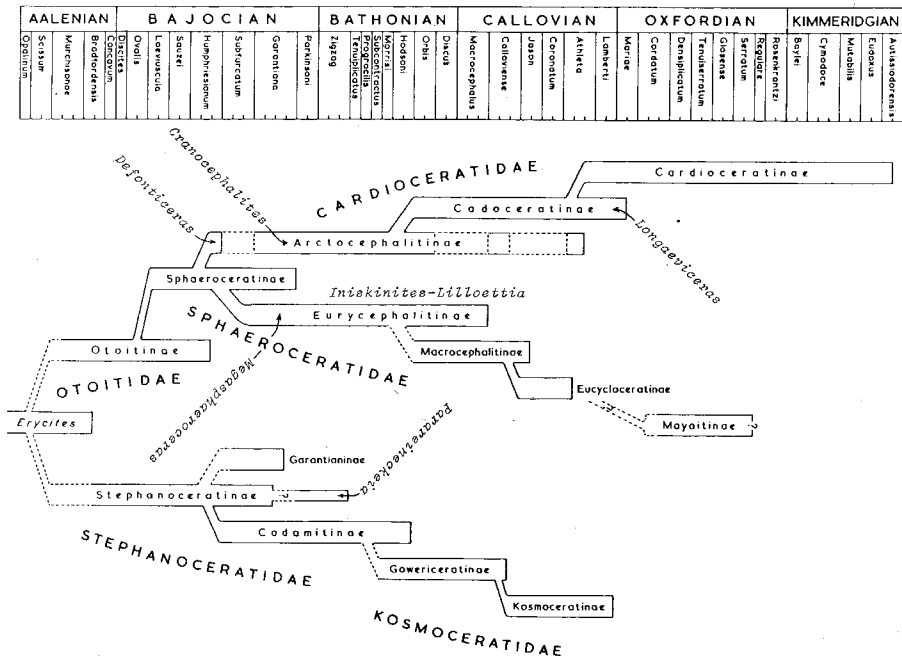


Figure 1. Phylogenetic classification of the Stephanocerataceae. The time-scale at the left is calibrated in units of European standard chrono-Subzones.

both in the Cordillera (region B) from Oregon to Alaska and in the Rockies of the Western Interior (region A); but it appears to be unknown elsewhere. A number of slightly different faunas can be recognized, reflecting small differences in age, but the range of the group appears to extend little beyond the equivalents of the Humphriesianum Zone as indicated by the associated stephanoceratids and other rare elements. One of these faunas, that of *Sphaeroceras oblatum* (Whiteaves), has been chosen as index of an Oblatum Zone in a zonation of the Bajocian of North America (Westermann and Riccardi, 1979, p.112; Hall and Westermann, 1980, p.19), equivalent to the upper part of the Humphriesianum Zone.

Morphologically, the American assemblages differ from the European ones of the same age in being larger, having less strongly modified adult peristomes, and having somewhat more strongly varicostate macroconchs with characteristically coarse but subdued ribbing on the body chamber. These differences are small but quite consistent; the ranges of variability barely overlap. They hardly merit separation at generic rank and were simply incorporated as separate species in a single comprehensive genus *Chondroceras* by Hall and Westermann. If the problem of variability in the European assemblages is resolved in the manner discussed above, however, the appropriate generic taxon would be *Sphaeroceras*. As the European and American assemblages differ in the same consistent fashion over a range of levels, equivalent to at least two ammonite Subzones, the

distinctions appear to be more than geographically subspecific in a biological sense, i.e., already phylogenetic albeit at an early stage. The appropriate taxonomic distinction seems to be at subgeneric level, therefore, retaining *Defonticeras* as a geographical subgenus of *Sphaeroceras* in a North Cordilleran Province of the East Pacific Realm. (Isolated reports of *Chondroceras* from the Lena Basin of Siberia, e.g., *Ch. sphaericum* and *Ch. custodium* Turchkov, 1972, are most probably based on misidentifications of *Cranocephalites* spp. of the *pompeckji* group).

Subfamily EURYCEPHALITINAE Thierry, 1976 [including *Paracephalitinae* Tintant and Mouterde, 1982]

Successors of *Sphaeroceras* in the Pacific Realm; the dividing line is to some degree arbitrary. The systematic relations between the numerous American "genera" still need to be fully evaluated so that it is necessary to retain a lot of separate names for the time being. Their relation to South American *Eurycephalites* itself has to await a similar revision of the succession in the Andes (A.C. Riccardi, in prep.). Their close affinities are revealed e.g., by the fact that many of them share the same microconch "genus", the highly characteristic *Xenoccephalites* Spath, 1928 – the microconch *sensu stricto* of *Eurycephalites*. Homoeomorphisms are common so that generic identifications without stratigraphical evidence can be hazardous and misleading.

The following names, listed in order of priority, are available. Interpretation is based strictly on type specimens of type species.

1. *Eurycephalites* SPATH, 1928 [M]

Type species *Macrocephalites vergarensis* Burckhardt, 1903, from Mendoza. Assigned by Imlay to the Bathonian which resembled the European *Morrisceras*; it was subsequently removed to the Callovian during the period in which Bathonian was regarded as unrepresented in the Andes (Arkell, 1956; Westermann and Riccardi, 1976). More recently the genus has been cited as ranging from late Bajocian to early Callovian (Westermann, 1981), but pending a full systematic and stratigraphical revision the use of the name for North American fauna seems of questionable value.

2. *Xenocephalites* SPATH, 1928 [M]

Type species *Macrocephalites neuquenensis* Stehn, 1924. The microconch of *Eurycephalites* in South America; but also used extensively in North America for forms that are microconchs of other "genera", including *Lilloetia*, *Paracephalites* and *Inskinites partim*.

3. *Paracephalites* BUCKMAN, 1929 [M] [incl. *Metacephalites* Buckman, 1929 *Micocephalites* Buckman, 1929 (see revision by Frebold, 1963), and *Oligocadoceras* Meledina, 1977 [m]]

Includes the group of "*Cadoceras*" *muelleri* Imlay, *pipereense* Imlay, *tetonenae* Imlay (all [M]) and *shoshonense* Imlay ([m], type species of *Oligocadoceras*, = *Xenocephalites*?)

4. *Lilloetia* CRICKMAY, 1930 [M] incl. *Buckmaniceras* Crickmay, 1930

Type species *L. lilloetensis*, from an isolated horizon of uncertain stratigraphical position in southern British Columbia. The use and meaning of this generic name also has oscillated among its close homoeomorphs, as synonym of *Arctocepalites* (Spath, 1933, p.878), or subgenus of *Macrocephalites* (Arkell, 1956, p.541) and, more recently, as subgenus of *Eurycephalites* (Westermann and Riccardi, 1976; Westermann, 1981, and this volume). Its supposed age has ranged from Middle Bathonian (Westermann, 1981) to Middle Callovian (e.g., Imlay, 1953b, Frebold and Tipper, 1967), but the age now proposed for it is early Lower Callovian. The microconchs include typical *Xenocephalites*.

5. *Megasphaeroceras* IMLAY, 1961a [M]

Type species *M. rotundum*, from southern Alaska. The microconch appears plausibly to be *Sphaeroceras talkeetanum* Imlay (1962b). As a pair their morphological affinities are closest with Tethyan *Sphaeroceras* s.s. as most probable ancestors, rather than with North Pacific *Sph. (Defonticeras)*. They have the fine, sharp, dense ribbing and, in the case of the microconch, the strongly collared and hooded peristome of *Sphaeroceras* s.s. They differ principally in the much larger size. This contrasts with the coarse but subdued ribbing of adult *Defonticeras*. They could, therefore, still be included in *Sphaeroceras* of the Sphaeroceratinae as a subgenus in the same way as *Defonticeras* has been. *Megasphaeroceras* appear sharply early in the Upper Bajocian along the whole of the eastern border of the Pacific, from southern Alaska through Oregon (Imlay, 1973) to Peru (Westermann, 1981), Chile (Hillebrandt, 1970), possibly Mendoza (Hall and Westermann, 1980) and Antarctica (Quilty, 1970) - a distribution that characterizes the East-Pacific Realm of Westermann (1981). It is succeeded by numerous morphologically similar groups that constitute the *Eurycephalitinae*, initially confined to the same area, and is most probably their root. Because of this affinity and its complete biogeographical segregation from the coeval *Sphaeroceras* s.s. of the Tethys and *Arctocepalitinae* of the Boreal Province, it seems most appropriate to draw the dividing line at the Lower-Upper Bajocian boundary and to include *Megasphaeroceras* already in the *Eurycephalitinae* as their first member.

6. *Warrenoceras* FREBOLD, 1963 [M]

The involute, smooth compressed forms originally recorded as *Arcticoeras henryi* Meek and Hayden, 1865; microconchs again typical *Xenocephalites* ("*Arcticoeras*" *crassicosatum*, *loveanum* Imlay, 1953a).

7. *Imlayoceras* FREBOLD, 1963 [M]

Used so far only for a single isolated fauna from the Miette-Rock Lake area of the Rocky Mountains, Alberta (53°-53½°N). Possibly only an inflated *Lilloetia* or a coarse-ribbed *Inskinites*.

8. *Eocephalites* IMLAY, 1967 [M]

Questionably distinct from *Megasphaeroceras*; early forms, probably still Upper Bajocian.

9. *Parachondroceras* IMLAY, 1967 [M] [incl. *Sohlites* Imlay, 1967 [M]]

Local fauna in the Western Interior, probably still of Upper Bajocian age (see fauna A2).

10. *Inskinites* IMLAY, 1975 [M]

The densely-ribbed forms with minute umbilici, often sphaeroconic, originally recorded as *Kheraiceras*.

11. *Chinitines* IMLAY, 1975 [M]

The microconchs of *Inskinites*; closely related to, if not synonymous with, *Xenocephalites*.

12. *Talkeetnites* IMLAY, 1980b [M]

Probably merely the inflated end-members of the variational range of a group, the most typical variants of which are still usually recorded as *Craniocephalites* Spath, although the resemblance is probably homoeomorphic ("*Cr.*" *costidensius* Imlay; see below, faunas B4 and D1).

13. *Tuxedonites* IMLAY, 1980b [M]

The microconch of *Talkeetnites*; also closely related to *Xenocephalites*.

Family CARDIOCERATIDAE Siemiradzki, 1891
Subfamily ARCTOCEPALITINAE Meledina, 1968

1. *Craniocephalites* SPATH, 1932 [M] and [m] [incl. *Boreiocephalites* Meledina, 1967, and *Pachycephalites* Meledina, 1973]

The first of the Arctocepalitinae - *Craniocephalites borealis* (Spath) - appeared throughout the whole of the Boreal Province as close to simultaneously as one can tell, and these early forms bear such a strong morphological similarity to *Sphaeroceras (Defonticeras)* that a close and direct derivation seems highly likely (see Fig. 2, and fauna C1 below). Thereafter the distribution and development of the subfamily appears to have been purely Boreal, with the possible exception of one group occurring in the Cordillera and on the Alaskan North Slope, that of "*Craniocephalites*" *costidensius* Imlay and "*Cr.*" *ignenkensis* Imlay (see discussion below, faunas B4 and D1).

2. *Arctocepalites* SPATH, 1928 [M] and [m]

Boreal successors of *Craniocephalites*.

3. *Arcticoeras* SPATH, 1924 [M] [including *Costacadoceras* Rawson, 1982 [m].

Boreal successors of *Arctocepalites*. Shares its microconch genus *Costacadoceras* with those of *Arctocepalites* and early *Cadoceras*.

Subfamily CADOCERATINAE Hyatt, 1900

The transition from *Arcticoeras* to *Cadoceras* took place in the Boreal Province, where it is gradual - the dividing-line being to some extent arbitrary. The diagnostic character of *Cadoceras* is a sharp edge on the umbilical margin of at least the adult macroconch body-chamber. This immediately distinguishes it from many forms that have been assigned to it in the past, e.g., "*Cadoceras*" *muelleri*.

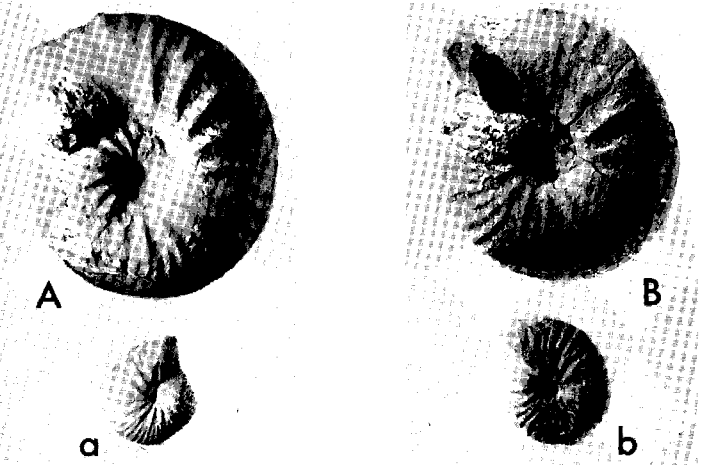


Figure 2. The morphological affinities of the Sphaeroceratinae and the Arctocephalitinae. A.a: *Sphaeroceras (Defonticeras) oblatum* (Whiteaves). Oblatum Zone (equivalent to the upper Humphriesianum Zone), Canada. B.b: *Cranocephalites borealis* (Spath), Borealis Zone, East Greenland (A: macroconch; R.L. Hall collection, Fernie Formation, Ribbon Creek, Alberta. McMaster J1836b, figured Hall and Westermann, 1980. Plate 14. Figures 3a,b. a: microconch; R.L. Hall collection, Yakoun Formation, Queen Charlotte Is., B.C. McMaster J1794a, figured Hall and Westermann, 1980. Figure 8. B: macroconch; more than usually strongly ribbed variant retaining ribbing on the mature bodychamber, Vardekloft Formation, Jameson Land, East Greenland. JHC collection 1368. b: microconch, typical; same locality and collection, JHC 1206a).

pipersense, etc., now placed in the Eurycephalitinae. There are numerous generic names available, and as their relations to each other are well understood, representing in many cases the successive evolutionary stages of an evolving lineage, they can be incorporated in classification at subgeneric level.

1. *Cadoceras* FISCHER, 1882

1a. *C. (Catacadoceras)* BODYLEVSKY, 1960 [M]

The earliest forms, including the American *C. barnstoni* (Meek 1859), and *C. variabile* Spath, 1932, from the Boreal Upper Bathonian in east Greenland.

1b. *C. (Paracadoceras)* CRICKMAY, 1930 [M] [including *Streptocadoceras* Meledina, 1977]

The status of this name continues to be highly unsatisfactory. The holotype of the type species (*P. harveyi* Crickmay, 1930, Pl.16, Figs. 1,2), although complete, appears to be a juvenile; the peristome is distorted, and what looks like a terminal constriction indicating maturity is not real. Neither do the last visible sutures show the approximation and simplification otherwise so common in the Cadoceratinae. *C. (P.) harveyi* could therefore be the immature stages of any of several forms widely distributed in the Cordillera, including many of the ones described by Imlay from Alaska (1953, PP 249-B), e.g., *C. glabrum* (cf. Pl.37, Fig.2), *multiforme*, *chisikense*, etc. This is close to the interpretation followed by Imlay himself. Amplification of the generic name, which unfortunately is the oldest available for macroconchs after *Cadoceras* itself, must therefore be based on the subjective choice of one such species showing the adult stages so necessary for closer characterisation of the Cadoceratinae. *Cadoceras glabrum* Imlay seems as good as any. The characteristic features of the

subgenus as thus interpreted are fairly evolute inner whorls with rounded venter becoming inflated and depressed only gradually, developing the sharp umbilical edge of the genus only on the middle whorls, and retaining a very wide and open umbilicus to the end. The differences between *C. (Paracadoceras)* and *Cadoceras sensu stricto* are only ones of degree, and no sharp line can be drawn between them. On the whole, *C. (Paracadoceras)* is more serpentine and relatively small when adult, whereas *Cadoceras* s.s. tends to become cadicone and large. Density and persistence of ribbing can be quite variable in either. Such an interpretation of *Paracadoceras* fully encompasses *Cadoceras subnituosistatum* Voronets, 1962, the type species of *Streptocadoceras* Meledina, 1977. Both in Europe (*Cadoceras breve* Blake, 1905) and in east Greenland, *C. (Paracadoceras)* occurs in the lowest part of the Lower Callovian and is succeeded by *Cadoceras* s.s. in the Calloviense Zone, upper Lower Callovian.

1c. *C. (Cadoceras)* FISCHER, 1882 [M] [including *Bryocadoceras* Meledina, 1977]

1d. *C. (Stenocadoceras)* IMLAY, 1953b [M]

Inner whorls compressed, involute, subcarinate, heralding the transition to *Longaveiceras* and hence the Cardioceratinae, the umbilicus widening and developing sharp edges only in the middle and outer whorls. Middle Callovian.

1e. *C. (Rondiceras)* TROITSKAYA, 1956 [M]

Similar development to that of *Stenocadoceras*, from which it may be doubtfully distinct; used so far only for some species found on the Russian Platform.

1f. *C. (Pseudocadoceras)* BUCKMAN, 1918 [m] [including *Novocadoceras* SAZONOV, 1965 [m].]

The microconchs of all the subgenera of *Cadoceras*: the type species, *Px. boreale*, from the Koenigi Subzone of the Lower Callovian, is unusually involute and subcarinate. The dividing line between *Pseudocadoceras* and its predecessors, *Costacadoceras* Rawson, 1982 (type species *C. bluetgeni*, [m] of *Arcticoceras ishmae*) is arbitrary.

2. *Longaeviceras* BUCKMAN, 1918 [M] and [m]
Retaining the sharp umbilical edge of *Cadoceras* but developing the style of ribbing and incipient carina of the later Cardioceratinae. Upper Callovian in Europe and the Arctic.

Subfamily CARDIOCERATINAE Siemiradzki, 1891

The morphological variability of the family reaches its peak in *Cardioceras*. Past classifications have almost invariably been "vertical", in terms of morphological form-genera or subgenera of varying, overlapping ranges apparently evolving in parallel. These include *Verebriceras* (most strongly ribbed), *Subvertebriceras*, *Cawtoniceras*, *Maltoniceras* (with vestigial and strongly differentiated secondary ribbing), *Scottioceras* (smooth and discoidal), *Pachycardioceras* and *Golithiceras* (smooth and inflated). Precise ages are hard to pin down on the strength of only one or two specimens, but given sufficient material at any one level the range of forms found together usually spans two or more of these (sub)genera continuously in a way that can be highly diagnostic stratigraphically. As the classification of the American representatives of the subfamily raises no special problems, however, it need not be considered further in detail here.

Family STEPHANOCERATIDAE Neumayr, 1875 Subfamily STEPHANOCERATINAE Neumayr, 1875

1. *Parareineckia* IMLAY, 1962a [M] & [m]
A North American Cordilleran local group, probably derived from the otherwise quite ordinary Stephanoceratinae that lived on in the Pacific after they had vacated the western Tethys and Europe, where they were replaced by Cadomitinae. *Steph. (Normannites)* (alias *Determanites* Imlay, 1961a) occurs widely in the Cordilleran Upper Bajocian *Megasphaeroceras rotundum* Zone. *Parareineckia* [m] differs little from *Normannites* (cf. Imlay 1980b, PP 1091, PL10, Fig. 1). Westermann (1981, p.488), in contrast, considers it to belong to the Cadomitinae.

2. *Lupherites* IMLAY, 1973 [m] and *Domeykoceras* HILLEBRANDT, 1977 [M]

The systematic position of these forms has been discussed by Westermann and Riccardi (1979, p.174). *Lupherites* was described originally from Oregon but its occurrence together with *Domeykoceras* in the Andes suggests strongly that the two are merely a dimorphic pair. Their horizon must lie close to the Lower-Upper Bajocian boundary, for they occur both in Oregon and in the Andes in close proximity to the *Leptosphinctes-Spiroceras-Megasphaeroceras* fauna, at present taken as the lowest in the Upper Bajocian (see fauna B1, below). But no absolute association appears to have been recorded, so that their age could still be topmost Lower Bajocian.

Family KOSMOCERATIDAE Haug, 1887 Subfamily GOWERICERATINAE Buckman, 1926 [incl. Keppleritinae TINTANT, 1963]

In East Greenland the earliest forms appear suddenly in the Boreal Upper Bathonian, but in North America they may appear even somewhat earlier. The earliest forms in both regions are small, very finely and densely ribbed, and round-whorled at all stages of growth, with no trace of ventral flattening either in macro- or microconchs. Adult bodychambers are relatively inflated and short, little more than half a whorl, and the early forms could therefore be equally well

retained in the Cadomitinae of the Stephanoceratidae, from which they must certainly have been derived. No sharp dividing-line can be drawn on purely morphological grounds. The division appears to have been a biogeographical one, for at the same time as the early Kosmoceratidae colonized North America and East Greenland, there to evolve continuously into and throughout the Callovian, the original Cadomitinae persisted independently in the Tethys and its margins until well into the Upper Bathonian. At specific level coeval *Kepplerites* and *Cadomites* are quite distinct and there appears to have been no intercommunication.

Although regarded classically as members of the Boreal Realm *par excellence*, the Kosmoceratidae never in fact populated the truly northerly reaches of the Boreal Province proper. Thus, the Gowericratinae flourished in western North America, southern Alaska and East Greenland; but they became rare even in the northern Yukon, Spitsbergen and the Peshora and are unknown from the Boreal Bathonian of Siberia. Later, in the Middle and Upper Callovian, the Kosmoceratidae at times dominate the ammonite faunas of the Sub-Boreal Province of north-west Europe and the Russian Platform, but became minor elements in East Greenland and are absent now both from North America and the whole of the Arctic, their place there being taken by *Longaeviceras* of the Cadoceratinae. The southern margins of the distribution of the Kosmoceratidae are often very sharp. Isolated reports of their occurrence very much further south should therefore be treated with great caution, particularly in view of the ease with which they could be confused with more or less homocomorphic members of other branches of the Stephanoceratidae.

1. *Kepplerites* NEUMAYR and UHLIG, 1892 [M]

From their sudden first appearance in the Bathonian of North America or the Boreal Upper Bathonian of East Greenland these early Kosmoceratidae changed very little until nearly the top of the Lower Callovian. What changes did take place, e.g., the transition from round whorl-section to tabulate venter bordered by tubercles with concomitant coarsening of the secondary ribbing, occurred so gradually that no sharp boundaries can be drawn. Most of the many names of the past can therefore be abandoned, or retained at most at subgeneric level.

1a. *K. (Kepplerites)* [M] [= *Seymourites* (Kilian Reboul, 1909; *Cerericeras* Buckman, 1922; *Galliaeceras* Buckman, 1922; *Galliaeanus* Buckman, 1922; *Galliaes* Buckman, 1922; *Yakounites* McLearn, 1927; *Yakounoceras* McLearn, 1927)].

1b. *K. (Gowericeras)* Buckman, 1921 [M] [= *Toricellceras* Buckman, 1922]

1c. *K. (Toricellites)* BUCKMAN, 1922 [m]

Used for the microconchs of the whole genus. The earliest members are still round-whorled. Tabulate sections appeared in the Upper Bathonian, with flat venters which the secondary ribs cross undiminished (e.g., "*Kosmoceras*" *vigorosum* Imlay, *alaskanum* Imlay, see below); and ventro-lateral tubercles bordering a ventral furrow which may be smooth, *Kosmoceras*-like, appeared in the Lower Callovian.

Younger members of the family need not be considered further here.

Superfamily PERISPINCTACEAE Family PERISPINCTIDAE Steinmann, 1890 Subfamily LEPTOSPINCTINAE Arkell, 1950

1. *Cobbanites* IMLAY, 1962a [M] and [m], = *Leptosphinctes (Vertemphinctes)* Buckman, 1920

The type species, *C. talkettianus* Imlay, is morphologically so close to well-known European forms from the Garantiana Zone of the late Upper Bajocian (e.g., *L. (V.) meseres* (Buckman, 1927; pl.446A,B)

– itself probably a synonym of *L. (V.) pseudomartinsi* (Siemiradzki, 1899), that its age and affinities can hardly be in doubt. The name *Cobbanites* has come since to be applied to almost all other Perisphinctidae that have been found in the North American Middle Jurassic, but most of these can also be confidently reassigned to previously well-known genera, e.g., *Procerites* or *Choffatia* (see below under Zigzagiceratinae and faunas A3-A6, B7). It appears that the Middle Jurassic Perisphinctidae of North America are all representatives of rather general, pandemic groups and developed few if any local faunas. Conversely, they make useful indicators of age within the somewhat broad ranges characteristic of perisphinctids.

Subfamily ZIGZAGICERATINAE Buckman, 1920
[incl. *Siemiradzkiinae* Westermann, 1958, and
Gracilisphinctinae Besnosov, 1982]

1. *Epizigzagiceras* FREBOLD, 1973 [M] (in Frebold and Tipper, 1973).

This genus appears to have all the characteristics of the Zigzagiceratinae, particularly those of the earliest forms: compare *E. evolutum* Frebold, 1973, Pl. 1, Fig. 2, 4 with *Zigzagiceras (Franchia) arcelli* Sturani, 1967, Pl. 18, Fig. 2.3, from the basal subzone of the Bathonian of south-east France.

The only other forms from North America that have been assigned to Zigzagiceratinae close to *Zigzagiceras* itself are those described by Burckhardt (1927) from Oaxaca in Mexico as Middle Bajocian *Stephanoceras floresi* and *St. aff. brodiae* (Pl. 12, Figs. 10-16, Figs. 18-20). They were re-identified as Lower Bathonian *Zigzagiceras* by Arkell (1956, p.564) and this identification was recently upheld (Imlay, 1980; Westermann, 1981) until the present revision by Westermann (in Taylor *et al.*, this volume) based on new field work. "*S. floresi* and relatives are very early Upper Bajocian stephanoceratids as also classified by Sturani (1967, p.50). The material as a whole bears a very close resemblance to the early Upper Bajocian *Stephanoceras* from southern Alaska described recently by Imlay (1982a, PP. 1189, e.g., Pl.5, Figs.6.8; Pl.4, Fig.4). The perisphinctid nuclei (Burckhardt 1927, Pl.11, Figs.5-8) identified by Arkell as *Siemiradzki* or *Plantsphinctes* could equally well be *Leptosphinctes* (cf. Imlay 1982a, Pl.4, Figs.5-7). The forms developing the extremes of coronate ribbing found in *Zigzagiceras* are untypical of the Zigzagiceratinae as a whole and are otherwise known only from a quite restricted area of sub-Mediterranean (but not Tethyan) Europe. Reassignment of the Mexican forms to *Stephanoceras* s.s. would remove what otherwise is a serious anomaly, with its strong implications of a direct marine link between Oaxaca and the western Tethys via the proto-Atlantic in the Lower Bathonian (Westermann, 1981, p.476). In the more typical representatives of the Zigzagiceratinae such as *Procerites*, coronate ribbing rarely persists beyond the rudimentary state on the inner whorls. It is an unfortunate historical accident that the atypical *Zigzagiceras* should have given its name to a whole subfamily otherwise lying directly on the smooth evolutionary path of the Perisphinctidae between the more typical Leptosphinctinae and Pseudoperisphinctinae.

2. *Procerites* SIEMIRADZKI, 1898.

Some at least of the perisphinctids from North America seem to be safely assignable to this genus, e.g., *P. engleri* Frebold, 1957 (Pl.39; Pl.40, Fig.1) – the latter finding its closest match with *P. (Gracilisphinctes)* of the Middle Bathonian of Europe. The microconch is *P. (Siemiradzki)* Hyatt, (Frebold, 1957, Pl.40, Fig.1).

3. *Choffatia* SIEMIRADZKI, 1898.

This genus, too, appears to be represented in North America, e.g., *Ch. irregularis* Imlay, 1953 (PP 249-B, Pl.54) from Alaska. In Europe the transition from *Procerites* to *Choffatia* is gradual. *Choffatia* appears

as a minor element in the Middle Bathonian, and *Procerites* persists barely into the early Upper Bathonian.

Superfamily HAPLOCERATACEAE Zittel, 1884

Members of the family Opellidae are found occasionally in all three regions A-C in north America but are too rare and poorly understood to have much stratigraphical value at present. Lissoceratidae are moderately common in the Upper Bajocian of the Cordillera, but the same remarks apply.

Superfamily PHYLLOCERATACEAE Zittel, 1884
Family PHYLLOCERATIDAE Zittel, 1884

Members of this family occur widely in north America but beyond formal descriptions, their value for stratigraphical and palaeogeographical purposes tends to be dismissed as minimal indicating little more than the former extent of the Tethyan Realm latitudinally bounded roughly by the tropics. One of the discoveries of recent times, however, has been their barely diminished occurrence in parts of the world far removed from the tropics even during the Jurassic – sometimes associated with truly Boreal ammonites such as the Arceophalinitinae or Cadoceratinae in the northern hemisphere. From this and other evidence it seems more probable that the phylloceratids differed from most other ammonites in being pelagic ocean-dwellers rather than shelf-dwellers, and that the significance of their distribution today is as indicators of proximity to former oceans rather than of low palaeolatitudes. Their common occurrence in, for example, the Jurassic of Oaxaca, parts of the north American Cordillera and in southern Alaska reflected the presence nearby of the Pacific Ocean, then as now. Away from the oceanic margins their frequency diminishes rapidly, so that although they are still relatively common in the northern Yukon they have become rarities in north-eastern Siberia (Voronets, 1962) and the Western Interior of the U.S., and are practically unknown in the rest of the Arctic including East Greenland. Their rarity in the epicontinental deposits of, for example, Caracoles, Mendoza, and Neugen in the Andean Cordillera, now barely 200 km from the ocean, immediately suggests that these areas may have been considerably further from the Pacific during the Jurassic. A lot of continental crust appears to have been lost since. It seems that a general re-appraisal of the world-wide distribution of the whole sub-order Phylloceratina could be palaeogeographically illuminating.

THE AMMONITE SUCCESSIONS
IN NORTH AMERICA

The more important faunas that can be recognized are reviewed briefly. No attempt is made to use them to construct chronostratigraphical scales of zones; rather, they may be regarded as characterising faunal horizons of greater or lesser importance whose relations to each other remain in most cases to be clarified. Nevertheless, it is convenient to label each fauna/horizon with the name of one characteristic species as an index. Important accessory elements will be indicated and brief notes will draw attention to other points of interest. The faunal successions are summarized in Figures 3-5.

Region A. Western Interior
(Dakota-Wyoming-Utah-Montana-Alberta)

Fauna A1. Eocephalites primus IMLAY (1967)
+ *Megasphaeroceras* cf. and aff. *rotundum*
Spiroceras sp
Stephanoceratinae indet.

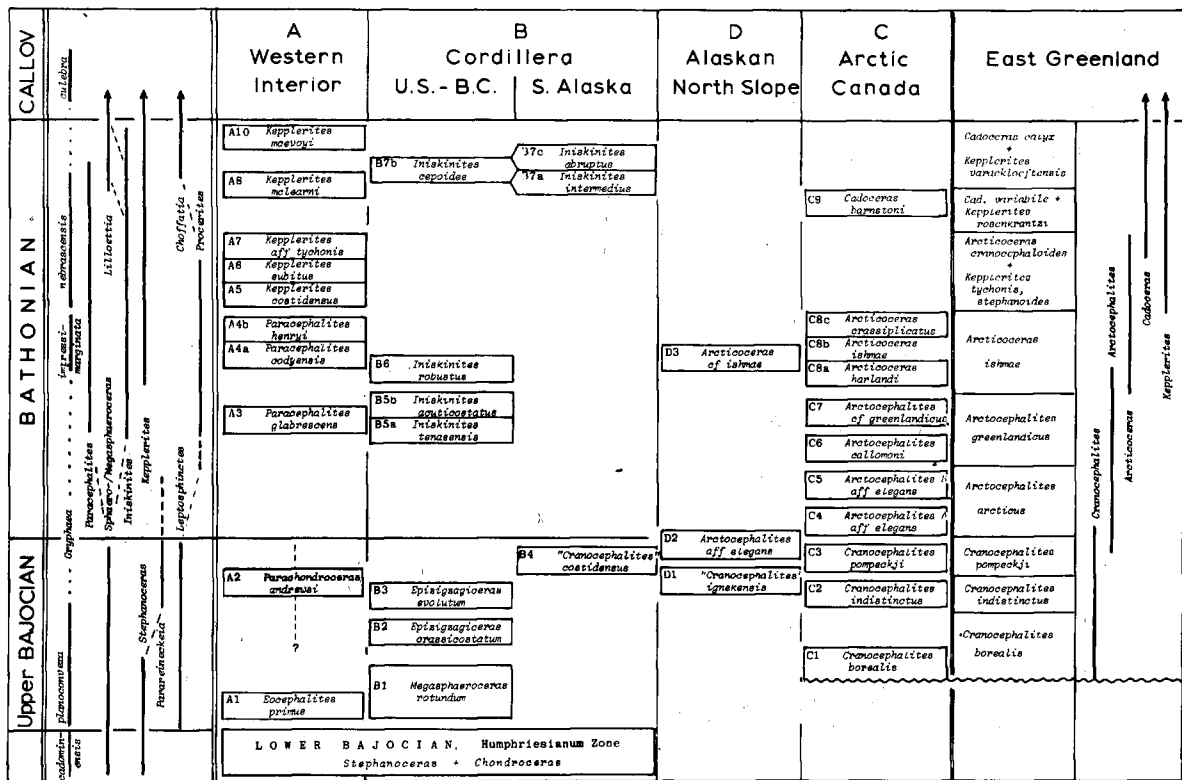


Figure 3. The successions of ammonite faunas in North America: Upper Bajocian - Bathonian. Note that the boxes represent no more than time-ordered sequences in any column; neither vertical widths nor spacings are proportional to time-durations. Boxes in adjacent

columns shown as partly or wholly overlapping are meant to suggest that their faunas probably differ little in age, although their precise order is usually not known. Correlations are discussed further in the text.

Utah-Idaho-Wyoming; Upper Bajocian; close if not exact equivalents of faunas with *Megaspheeroceras* in the Cordillera. A fauna of about this age has also recently been found in the foothills of south Alberta (Hall and Stronach, 1981).

Fauna A2. *Parachondroceras andrewsi* IMLAY (1967)

Utah-Wyoming-Idaho-Montana; possibly still Upper Bajocian, but no independent indicators for the fauna is known only from the Western Interior. *Parachondroceras* and *Sohlites* seem generically doubtfully distinct, but there is evidence to suggest that the forms may extend over some range stratigraphically; further horizons may, therefore, be recognizable one day.

The precise age of this fauna is conjectural. Imlay still favoured Upper Bajocian, largely because of the gradational transition between the Rich Member of the Twin Creek Limestone containing it and the underlying Sliderock Member with fauna A1. However, such evidence is not compelling, and fauna A2 could be younger, perhaps already Bathonian.

Fauna A3. *Paracephalites glabrescens* BUCKMAN (Frebald 1963; Imlay 1962) (= *P. sawtoothensis* Imlay, 1962)

+ *Xenocephalites saypoensis* Imlay [m]

Procerites ("Cobbanites") cf. or aff. *engleri* Frebald.

Montana, Sawtooth Formation and Alberta, *Corbula munda* Beds (lowest member of the Grey Beds), Fernie Group. This is the first of five more or less successive faunas that are closely related, characterized by large, smooth *Paracephalites* with its associated proportionally large *Xenocephalites* micronconchs (*Oligocadoceras* Meledina). They give the impression of spanning only a short interval of time, separated from the last fauna (A2) known below them, by a considerable gap. Age presumably Lower Bathonian.

Fauna A4(a) *Paracephalites* (*Warrenoceras*) *codyensis* IMLAY (1953; Frebald 1957, 1963) (incl. *P. rieronensis* Imlay, *imlayi* Frebald)

+ *Xenocephalites crassicostratum* Imlay [m]

Kepplerites sp. aff. *tychonis*

Procerites ("Cobbanites") *engleri* Frebald [M] and [m]

Montana, lower Rierdon Formation, and Alberta, middle Grey Beds of the Fernie, especially the *Gryphaea* Bed of Blairmore.

Fauna A4(b) *Paracephalites* (*Warrenoceras*) *henryi* (MEEK AND HAYDEN, 1865) (Imlay 1953; 1967, p.60)

South Dakota-Wyoming. Variants of fauna 4a are so close to the true *P. henryi* that they have been recorded as such by Frebald from the *Gryphaea* Bed.

Fauna A5. *Kepplerites costidensis* (IMLAY) (1953)

+ *Paracephalites muelleri*, *tetonensis*, *piperensis* (Imlay) [M]

Xenocephalites shoshonensis (Imlay) [m]

Procerites sp. [M]

P. (Siemiradzkaia) warmondensis (Imlay) [m]

These early, finely and densely-ribbed, small, round-whorled species of *Kepplerites* bear a strong resemblance to the first *Kepplerites* to occur in East Greenland, *K. stephanoides* sp. MS, in the lower Cranocephaloides Zone, which marks the beginning of the Boreal Upper Bathonian there. Montana, basal Rierdon Formation.

Fauna A6. *Kepplerites* ["*Gowericeras*"] *subitus* (IMLAY) (1948, 1953)

+ *K. (Toricellites?) costicrassum* (Imlay) [m] *partim*

Paracephalites muelleri, *tetonensis* etc. [M]

Xenocephalites shoshonensis [m]

Procerites [M] and [m] ("Grossouviria")

This fauna of *Kepplerites* is quite distinct from the finely-ribbed forms found below and above, unlike any known from elsewhere, and seems to be a local one. *Gowericeras* has strongly tabulate and tuberculate inner whorls, and is probably much younger. Montana, Rierdon Formation.

Fauna A7. *Kepplerites* aff. *tychonis* (RAVN) (Imlay 1953)

+ *Xenocephalites* sp.

Another small, densely ribbed species resembling the forms in A5, and the same remarks apply. Montana, middle Rierdon Formation, and Alberta, upper Grey Beds of the Fernie, 20 ft above the *Gryphaea* Bed (Frebald 1963, Pl.9, Fig.3)

If the resemblance of the *Kepplerites* of North America to those of east Greenland is not coincidental and indicates affinity, the ages of faunas A4-7, and perhaps A3 as well, are equivalent to early Upper Boreal Bathonian. Similarly, the Proceritids would indicate a correspondence to Middle-early Upper Bathonian of Europe.

Fauna A8. *Kepplerites mclearni* IMLAY [M] (1948, 1953) (incl.

K. rockymontanus, *planiventris*) (Imlay)

+ *K. (Toricellites) knechteli* (Imlay [m] (incl. *K. (T.) zortmannensis*, *vigorostus* (Imlay))

+ *Lilloettia* sp. [M]

Xenocephalites phillipsi Imlay [m]

These singular giant *Kepplerites* with their long bodychambers, occupying the last 1/4 whorls, would be readily mistaken if found in isolation with their almost perfect homocormorphs, *Stephanoceras* ex gr. *rhytum* of the Lower Bajocian: only their compressed tabulate-ventered *Kosmoceras*-like micronconchs reveal their true nature. Only known in North America from the upper Rierdon Formation of Montana and its equivalents in Jasper Park and sub-surface in Saskatchewan (Frebald, 1963), they give the impression of being yet another local fauna.

It seems once again more than coincidence that at a single precisely analogous level in Greenland a closely similar assemblage of giant *Kepplerites* occurs: *K. antiqum* Spath and *K. perampus* Spath (1932) with hitherto undescribed micronconchs very similar to those from America (cf. Callomon and Birkenlund, 1980, Pl.1 Fig.4). The position of this fauna in Greenland is in the lower Calyx Zone, the highest Zone of the Boreal Upper Bathonian.

Fauna A9. *Lilloettia* ? ["*Imlayoceras*"] *miettensis* (FREBOLD) (1963)

Found so far only in Alberta near Jasper Park, but allegedly above fauna A8 (Frebald, 1963, p.31)

Fauna A10? *Kepplerites mcevoyi* (McLEARN) (1928, Pl.4)

Only the holotype is known, from an unknown level in the Foothills of Ribbon Creek, southern Alberta (see Frebald, 1957, p.64). The generally fine ribbing and rounded venter suggests an age predating *K. keppleri* and its supposed American equivalents, *K. loganianus* of fauna B8(a) (q.v., below), and hence still Bathonian. It has close matches in the Keppleritids of the *Cadoceras barnstoni* fauna of the Yukon, C9, and in the Calyx Zone of east Greenland (cf. Spath, 1932, Pl.25,

		A	B		D	C	
Europe		Western Interior	Cordillera U.S.-B.C.	S. Alaska	Alaskan North Slope	Arctic Canada	
C A L L O V I A N	Upper	<i>Quenstedtoceras lamberti</i>	A11 <i>Quenstedtoceras collieri</i>				
		<i>Peltoceras</i> <i>utilata</i> + <i>Longaeroceras</i> <i>Kayserlingi</i>		B10 <i>Longaeroceras pomeroyense</i>	D6 <i>Longaeroceras stenolobum</i>		
	Middle	<i>Stenoceras</i> <i>constrictum</i>					
		<i>Stenoceras</i> <i>millersi</i>				C14 <i>Stenoceras canadense</i>	
		<i>Kaenoceras</i> <i>juvoni</i>	B8 <i>Stenoceras stenoloboides</i>			D5 <i>Stenoceras of canadense</i>	
	Lower	<i>Sigaloceras</i> <i>collipense</i> + <i>Cadioceras</i> <i>sublaense</i>				D4 <i>Cadioceras arectinum</i>	C13 <i>Cadioceras wronchetense</i> C12 <i>Cadioceras septentrionale</i> C11 <i>Cadioceras bodyletskyi</i>
		<i>Murchisoniella</i> <i>macrocephala</i> + <i>Cadioceras</i> <i>sluense</i>			B8g <i>Lilloestria stantoni</i> B8f <i>Kepplerites obliquus</i> B8e <i>Cadioceras wronchetense</i>		
			B8d <i>Lilloestria tipperi</i>				
			B8c <i>Lilloestria lilloestrensis</i>				
			B8b <i>Pavloviceras lomense</i>				C10 <i>Pavloviceras sp.</i>
		<i>Pavloviceras</i> <i>brevi</i> + <i>Kepplerites</i> <i>keppleri</i>	B8a <i>Kepplerites loganianus</i>				

Figure 4. Callovian (see captions and note for Fig. 1).

Fig.1), both of which are still placed in the Upper Boreal Bathonian. Its level relative to faunas A7 and A8 is not yet known.

— non-sequence

Fauna A11. *Quenstedtoceras collieri* (Reeside, 1919)

+ *Peltoceras* sp. (Imlay 1982, Pl.2, Figs. 3-6, 77,8, as *Quenst. cf. omphaloides*)

Perisphinctes (Prososphinctes) sp. (Imlay, 1982b, Pl.26, Figs.8-10)

Montana, basal Swift Formation; Upper Callovian, Lambert Zone, probably lower part.

— Oxfordian:

Faunas A12 - A16: *Quenstedtoceras* and *Cadioceras* spp.

The rich faunas of *Cardioceratidae* from the Western Interior described by Reeside (1919) and most recently by Imlay (1982b) have been discussed by Arkell (1956, p.549-50) who pointed out their remarkable resemblance to analogous faunas of northern Europe. Equally remarkable is the monogenic character of the faunas: unlike those of Europe, the *Cardioceratidae* occur almost without accessory elements of any other family, e.g., *Perisphinctidae* or *Oppelidae*. They have therefore a purely Boreal stamp, and this appears to apply wherever they

are found in the whole of North America. The shells occur at several levels in the Redwater Shales of the Sundance Formation of Wyoming and its correlatives from the Canadian border in Montana to northern Utah (see Imlay, 1982b). It is rare however that they are sufficiently abundant at any locality to establish the range of variability of an assemblage, much less to work out the succession. Descriptions have had to be primarily morphological, and the current classification is very much "vertical", expressed in range-charts of subgenera of *Cardioceras*. Stratigraphically Reeside's material was almost wholly unlocalized and unfortunately has to form the basis for the majority by far of the specific names available and in use today. It seems possible now to sort it into a rather few assemblages guided by the range of variability to be expected by analogy with the well-known faunas of Europe. The variability of *cardioceratid* biotopes is large, highly characteristic and almost unchanging from the Upper Callovian to the Middle Oxfordian: at every level one can find a morphologically continuous spectrum extending from compressed involute forms tending to be carinate (*Lambertoceras - Scotiocardioceras*), to highly inflated, more evolute, round-whorled forms (*Eboracoceras - Pavloviceras - Golithoceras*). Equally characteristic is the form of the dimorphism. In what follows, the names of species refer only to the type specimens in the first instance, and to what extent these

assemblages really are homogeneous in age remains to be seen. The four that are distinguished here correspond roughly to separate Zones or Subzones in Europe. By today's standards this is still very coarse, compared for instance with the twenty or so faunal horizons of cardoceratids that can now be recognized in the Lower to Middle Oxfordian of Europe. However, it is sufficient to provide a first frame of reference. The American faunas are as follows.

Fauna A12. *Cardioceras cordiforme* (MEEK HAYDEN, 1859) [M] (incl. *Quenstedoceras hoveyi*, *subtimidum*, *suspectum*, *tumidum* Reeside, *Card. albanense*, *auro-raensis*, *bellefourchense*, *crassum*, *incertum*, *russeli* Reeside, all [M])

+ *Cardioceras latum* Reeside [m].

Lower Oxfordian, Mariae Zone, Scarburgense Subzone. *C. cordiforme*, as exemplified by the lectotype, and the oldest name available, happens to be the compress end-member of the

series. The transition from "*Quenstedoceras*" to "*Cardioceras*" within the series is almost exactly as found in the Mariae Zone of England (e.g., Arkell 1939, Woodham: *Qu. omphaloides* - *Qu. mariae* - *Qu. woodhamense* - *Card. scarburgense* all imperceptibly intergrading). The variability in America is more striking because of the presence of abundant well-preserved macroconchs, which in Europe are rare. Several of the American forms are very close to *C. scarburgense*. Arkell regarded some of them as still belonging to *Qu.* (*Eboraceras*) of the Lamberti Zone, Upper Callovian, but the aspect of the assemblage as a whole favours the slightly younger age. Wyoming, Montana, Alberta.

Fauna A13. *Cardioceras martini* REESIDE, 1919 ([m]?), Alaska.

(a) *Cardioceras reesidei* MARIE, 1938 (= *C. cordiforme* Reeside 1919 *partim*, Pl. 8, Figs. 4, 5, holotype [m]; Figs. 6, [m]) (incl. *C. whitfieldi* Reeside?)

(b) *Cardioceras mountjoyi* Frebold, 1959 [M]

Europe		A Western Interior	B Cordillera U.S. - B.C. S. Alaska		D Alaskan North Slope	C Arctic Canada
Volgian & Kimmeridgian		?	?			↑↑ C20 <i>Quenstedites canadense</i>
		A18 " <i>Pisanites</i> " <i>occidentalis</i>	B16 <i>Amebooceras</i> <i>dubium</i>	B17 " <i>Subpisanites</i> " sp. ?		C19 <i>Dorsopisanites</i> - <i>Pastolus</i> spp.
O X F O R D I A N	Upper	<i>Amebooceras rosenkrantzi</i>		?	D10 <i>Amebooceras</i> spp.	
		<i>Amebooceras regulare</i>		B15 <i>Amebooceras aff</i> <i>transitorium</i>		
		A17 <i>Amebooceras</i> spp.		?		C18 <i>Amebooceras aff</i> <i>transitorium</i>
		<i>Amebooceras serratum</i>				
		<i>Amebooceras gloeense</i>			D9 <i>Cardioceras</i> - <i>Amebooceras</i> sp.	
	Middle	<i>Cardioceras tenuiserratum</i>	A16 <i>Cardioceras</i> <i>saxoniense</i>			
		<i>Cardioceras maltonense</i>	A15c <i>Cardioceras</i> <i>canadense</i>	B14 <i>Cardioceras</i> <i>whittoni</i>	D8 <i>C. (Maltonoceras)</i> sp.	
		<i>Cardioceras reddense</i>	A15b <i>Cardioceras</i> <i>reddense</i>			
		<i>Cardioceras vertebrale</i>	A15a <i>Cardioceras</i> <i>aff canadense</i>			
	Lower	<i>Cardioceras cordatum</i>	A14b <i>Cardioceras</i> <i>distans</i>			C17 <i>Cardioceras</i> <i>of distans</i>
	<i>Cardioceras eastiardi</i>	A14a <i>Cardioceras</i> <i>hyatti</i>	B13 <i>Cardioceras</i> <i>springiflorum</i>	D7 <i>Cardioceras</i> <i>of hyatti</i>		
	<i>Cardioceras bukowski</i>	A13c <i>Cardioceras</i> <i>methanopakensis</i>				
		A13b <i>Cardioceras</i> <i>mountjoyi</i>	B12 <i>Cardioceras</i> <i>martini</i>		C16 <i>Cardioceras aff</i> <i>alphanotense</i>	
		A13a <i>Cardioceras</i> <i>reesidei</i>				
	<i>Cardioceras praecordatum</i>		B11b <i>Cardioceras</i> <i>praecordatum</i>			
	<i>Cardioceras scarburgense</i>	A12 <i>Cardioceras</i> <i>cordiforme</i>	B11a <i>Cardioceras aff</i> <i>scarburgense</i>		C15 <i>Cardioceras aff</i> <i>scarburgense</i>	

Figure 5. Upper Jurassic (see captions and note for Fig. 1).

(c) *Cardioceras mathiaspeakense* Imlay, 1982b [M]
Lower Oxfordian, Cordatum Zone, Bukowskii Subzone. The resemblance of these forms to those of the Bukowskii Subzone of Europe so profusely illustrated by Maire (1938) and Arkell (1946) is very close. Some variants, especially among the microconchs, are indistinguishable. Whether *C. reesidei* and *C. mountjoyi* are of precisely the same age remains to be seen. In Europe such a pairing of micro- and macroconchs would be quite normal. The macroconchs of *C. mountjoyi* (from British Columbia) and of *C. martini* (from Alaska) do appear to be slightly different, although both can still be accommodated within the Bukowskii Subzone. *C. mathiaspeakense* gives the impression of being a little younger, and could already belong to the Costicardia Subzone. *Scarburgiceras*-like forms range well up into the Cordatum Zone in Europe. Wyoming (Reeside, 1919; Imlay, 1982b), Rocky Mountains of Alberta and British Columbia, in the Green Beds of the Fernie Group (Frebald *et al.*, 1959). Also in the Cordillera (q.v.): eastern Oregon, southern and central British Columbia, southern Alaska. Arctic Islands (Axel Heiberg Is., Frebald, 1961).

Fauna A14. *Cardioceras distans* (WHITFIELD, 1880) [m] (incl. *C. stantoni*, *hyatti*, *haresti* Reeside [m], and? *C. wyomingense*, *crookense* Reeside [m])
+ *Cardioceras schucherti* Reeside, *minnekahtense* Imlay [M]
Grossouvria cf. *trina* (Buckman) (Imlay 1982b)

Lower Oxfordian, Cordatum Zone, Costicardia and ?Cordatum Subzones; possibly divisible, 14(a), *C. hyatti*, and 14(b), *C. distans*. The microconchs again span a range from compressed (*C. hyatti*: cf. *C. persecan*, *anacanthum* Buckman in Europe) to depressed and coarsely-ribbed (*C. distans*, *haresti*: cf. *C. (Vertebriceras) quadrarium* Buckman in Europe). The macroconchs seem little known so far, but the characteristic style of ribbing of *C. schucherti* is the same as that of *C. studleyense* Arkell, 1946, also from the Costicardia Subzone. Wyoming and?Montana, southern Alaska.

Fauna A15. *Cardioceras (Cawtoniceras) canadense* WHITEAVES, 1903 [m]
+ *C. (Vertebriceras) whiteavesi* Reeside? [m]
C. (Maltoniceras) plattense Reeside, *bighornense* Imlay, *reddomense* Imlay [M]

Middle Oxfordian, Densiplicatum Zone. The holotype of *C. canadense*, from the Rockies near Fernie, B.C. (refigured by Frebald 1957, Pl.34, Fig.2a,b; 1964b, Pl.47, Fig.3a,b) resembles *C. (Cawtoniceras) cawtonense* from England so closely that its age can hardly be in doubt. None of the other specimens ascribed to this species by Reeside and Imlay from Montana and Wyoming exactly matches either the holotype or English material, and there may be small differences in age. Late Middle Oxfordian is suggested by the already strong differentiation of primary and secondary ribbing and a crenulate leaflet. The dense residual tertiary ribbing joining the secondary ventro-lateral tubercles to the crenulations of the keel is peculiar to the American faunas and at best rare in Europe.

Two slightly different faunas in sequence can be distinguished in at least one area - that of the Pryor Mountains of Montana (Imlay, 1982, P.3, Fig.2, extreme right-hand column = locality 17 of Fig.1 and Table 2):

A15(a) (the lower): Imlay, 1982, Pl.24, Figs.1,2,5-8,11,12; Pl.26, Figs.20-26, 29-31: all [m]; Pl.4, Figs.9,10,14, Pl.23, Fig.10, Pl.24, Figs.15-18,21: all [M] - described variously as *C. sundancense*, *reddomense*, *canadense* and *Goliathiceras tumidum*.

A15(b) (the upper): Imlay, 1982, Pl.24, Figs.3,4,13,14, Pl.26, Figs.32,33: all [m]; Pl.20, Figs.6,7 (type of *C. bighornense*), 1,3, Pl.23, Fig.16, Pl.24, Figs.9,10 (type of *C. reddomense*): all [M].

But the nearest approach to the true

A15(c): *C. canadense sensu stricto*

seems to lie in some of the forms described as *C. whiteavesi* (Imlay, 1982, Pl.22, Figs.14-21) from other localities also in Montana.

These assemblages still span the full range of variability typical of *Cardioceras* as found elsewhere up to about the middle of the Densiplicatum Zone, including inflated *Goliathiceras* and ultra-coarse *Vertebriceras* (Pl.26, Figs.32,33) in A15(a) and A15(b). These two may therefore still belong to the late Vertebrata Subzone. The true *C. canadense*, however, seems to fit securely into the higher Maltonense Subzone. These zonal names refer to the recently-established zonation of the Boreal Oxfordian (Sykes and Callomon, 1979) - *aluis* Plicatilis Zone, Vertebrata and Antecedens Subzones.

Fauna A16. *Cardioceras sundancense* REESIDE, 1919 [M] (incl. *C. stillwelli*, *americanum* Reeside)
+ *C. canadense* Reeside and Imlay *partim*, *non* Whiteaves [m] (Reeside, 1919, Pl.17, Figs.5-11; Imlay, 1982, Pl.26, Figs.14-19)

Middle Oxfordian, Tenuiserratum Zone. The differentiation of the keel is now virtually complete, as in *Amoeboceras*: inner whorls are characteristically smooth with well-spaced and wholly differentiated primary ribbing reappearing on the outer whorl of some microconchs as in *C. blakei* and *C. tenuiserratum* (see Sykes and Callomon, 1979), and the range of variability has shrunk to mainly compressed forms. The homogeneity of this fauna is supported by the fact that all the types of the species listed above came from a single locality (Reeside's no.22, Imlay's no.63) in north-east Wyoming, as did the microconchs cited, and that this locality did not seem to yield any of the other faunas. Many forms figured by Imlay under the names given above other than the types, and from other localities, belong to other faunas.

Fauna A17. *Amoeboceras* spp. (with *Buchia concentrica*) Said to be widespread in the Passage Beds of Alberta and adjacent British Columbia, but not yet well described (Frebald and Tipper, 1970). These Passage Beds are the highest fully marine deposits below the coal-bearing Kootenay Formation and its equivalents.

Fauna A18. "*Titanites*" *occidentalis* FREBOLD, 1957 (see also Arkell, 1956, Pl.26; Westermann, 1966; Frebald and Tipper, 1970).

This "fauna" is based on what must be the single most famous ammonite in Canada, lying in Ammonite Gully off Coal Creek, west of Fernie, B.C., where it was discovered by Newmarch

(1953) during mapping. Its fame derives from two sources. The first is its spectacular size, 147cm (5 ft) across. The second is its position, on the top surface of the Moose Mountain Member of the Morrison Formation (Gibson, 1979; the Basal Sandstone of the Kootenay Formation in the older literature). This is the last fully marine horizon underlying the coal-bearing Mist Mountain Formation, the principal coal-measures of the Blairmore coal-fields of southern Alberta and adjacent British Columbia, and thence thick non-marine Neocomian, etc. (dated by fossil flora), up to Albian, with ammonites, of the Alberta Group. Its dating is crucial to the question of the time of the onset in the area of the major non-marine cycle that has its equivalents in the Morrison Formation further south. There is no independent evidence of its age. Below it, the Green Beds of the Lower Oxfordian (fauna A13) are followed by the Passage Beds (100 m +) which were probably the source of the type of *Cardioceras canadense* Whiteaves (fauna A15), found not more than a mile or two from "T." occidentalis. The Passage Beds also yield sporadic *Amoeboceras* and *Buchia concentrica* (fauna A17), but so far none appear to have been reported from the immediate vicinity. The bed with "T." occidentalis contains no other macrofauna, nor has it yielded any microfauna. Besides the holotype, only one other fragment of a similarly huge ammonite has been found, 25 km to the east at more or less the same level (Hamblin, 1978; Hamblin and Walker, 1979). All that can be said independently therefore is that these big ammonites are post-Middle Oxfordian and probably pre-Valanginian in age. Any further conclusions must rest on the identifications of the ammonites themselves.

All previous opinions have been essentially in agreement. The ammonites are Perisphinctids, very large, and hence by analogy with what was then known of the classical successions of Europe, probably *Titanites sensu lato* of Portlandian/Middle Volgian/Upper Tithonian age. Since then a great deal more has been learned about *Titanites* itself, however, and the grounds for equating the Canadian form with it have largely disappeared. The difficulties are twofold: morphological and biogeographical.

The ammonite in Ammonite Gully is only partially preserved, mostly as an external mould of the outer 1/4 whorls that cannot be removed or easily photographed. While the coarse ribbing on the bodychamber could be matched perhaps by some members of the Dorsoplanitinae or Pavloviinae (of which *Titanites* is a member), a cast made by Westermann (1966) and photographed under appropriate oblique lighting brought out enough of the next inner whorl to show that the shell was strongly varicosate, i.e., dense fine ribbing on the inner whorls, with about 60 ribs per whorl, suddenly changes at the commencement of the adult bodychamber to coarse strong ribbing with less than 30 ribs per whorl. Such varicosation is unknown in the "Portland giants" - the Pavloviinae. Something approaching it can be found in some Dorsoplanitinae of the Middle Volgian, or Pectinatitinae of the Lower Volgian, but none of these attain a maximum size more than about a quarter that of the Canadian species.

Biogeographically, it has also become quite clear that the late Pavloviinae became more and more restricted in their distribution so that the last of them, the "Portland giants", were confined

to an ever-shrinking Anglo-Saxon Basin (later to become the non-marine Purbeckian) extending no further north than central east Greenland, if that, and no further east than the Moscow Basin on the Russian Platform, at most. All possible connecting-routes to British Columbia via the north were definitely populated by quite different faunas of Dorsoplanitinae, found i.a. in the Canadian Arctic; and all possible routes to the south were blocked by yet other faunas, largely Ataxioceratae and their decedents, found in the sub-Mediterranean Tithonian i.a. of the Caribbean, Mexico and southern California. Negative evidence includes the apparently total absence of the various forms of *Buchia* that are otherwise ubiquitous in western North America, Alaska, and the Yukon in beds of Portlandian/Middle-Upper Volgian/late Tithonian age.

It seems time, therefore, to abandon the assignment of the Canadian species to *Titanites sensu lato* or otherwise, and with it the implied time-correlation. The only alternative that comes to mind is that the species represents yet another local or Pacific fauna of perisphinctids whose closer affinities to others are still unknown - certainly not a member of the Pavloviinae, and probably not of the Dorsoplanitinae, but perhaps an independent descendent of some Oxfordian Perisphinctinae. Its age is presumably not later than Hauterivian, the youngest stage to have yielded Perisphinctids anywhere, including the Cordillera of North America. It could still be just Upper Oxfordian or Lower Kimmeridgian, in which case the onset of non-marine sedimentation in the Fernie Basin would have been roughly synchronous with the base of the Morrison Formation. It could even be "Portlandian" as has always been assumed - but not for the reasons given.

The paucity of Upper Jurassic perisphinctids in the northern Pacific as a whole continues to be a mystery, in great contrast to their abundance almost everywhere else, including the Boreal Province (Dorsoplanitinae), the Tethys and its margins, and even the Andes in the south Pacific. There is just no general framework within which isolated finds such as the one at Fernie can be discussed. Clues are sparse. Perhaps two specimens recently described by Imlay may belong to the same group: "*Subplanites* sp." [M] (Imlay, 1981, Pl.8, Fig.15), and "*Aulacosphinctoides* sp." [m] (Imlay, 1981, Pl.7, Fig.1-3), both from the same locality on the Alaska Peninsula and associated with *Buchia mosquensis* and *B. rugosa* indicating roughly a Lower Volgian age. (For the ranges of *Buchia* and the approximate equivalence between Lower Volgian and Lower Tithonian, see Imlay, 1980a, Figs.15,16).

Region B. North American Cordillera

Fauna B1. Megasphaeroceras rotundum IMLAY [M] (1962)

+ *Sphaeroceras talkeetnanum* Imlay [m]

Normannites vigorosus (Imlay) [m]

Leptosphinctes cliffensis and *delicatula* Imlay

Oppelia kellami Imlay

Lissoceras bakeri Imlay

Spiroceras sp.

South Alaska, Cook Inlet. Unmistakably Upper Bajocian, probably upper Subfurcatum or lower Garantiana Zone in the European standard zonation. The *Leptosphinctes* could prob-

ably be matched exactly with European forms. Equivalence of this fauna to that of the Subfurcatum Zone was already clearly pointed out by Imlay (1954a, p.7); made the basis of a Rotundum Zone by Hall and Westermann (1980).

Fauna B2. *Epizigzagiceris crassicosatus* FREBOLD (Frebald and Tipper, 1973)

- + *Megasphaeroceras* aff. *rotundum* Imlay
- Leptosphinctes* sp. (as "*Cobbanites talkeetnanus*")

Central British Columbia; Smithers Formation, lower fauna.

Fauna B3. *Epizigzagiceris evolutum* FREBOLD (Frebald and Tipper, 1973)

- + *Megasphaeroceras* ["*Morrisiceras*"] *dubium* Frebald
- ?*Megasphaeroceras* ["*Arctocephalites*?"] *multicostatum* (Frebald)
- "*Cranocephalites*" aff. *costidensus* Imlay
- Leptosphinctes* sp. [M] and [m] cf. *subdivisus* (Buckman) (as "*Cobbanites talkeetnanus*")
- Parareineckeia* cf. *shelikofana* Imlay

Central British Columbia; Smithers Formation, upper fauna. Faunas B2 and B3 found in sequence, presumed to follow B1. Alaska Peninsula, unlocalized (the type of *Parareineckeia shelikofana*)

Fauna B4. "*Cranocephalites*" [*Iniskinites*?] *costidensus* IMLAY [M] (1962, 1980)

- + "*Cranocéphalites*" *globosus, alaskanus* Imlay [M]
- Talkeetmites cadiformis* Imlay [M]
- Tuxedinites alticosatus* Imlay [m]
- Parareineckeia hickersonensis* Imlay
- *nelchinensis* Imlay
- sp. nov.? (*Cadomites cf. deslongchampsii* in Imlay, 1980b)

Cobbanites talkeetnanus Imlay [M] and [m]
Oppelia sp.

Southern Alaska: Cook Inlet, Talkeetnas, Wrangells, widespread and abundant. Of all the forms found in the Cordillera, those described here as "*Cranocéphalites costidensus* and *alaskanus*" are certainly the ones bearing the closest resemblance to any of the true Boreal Arctocephalitinæ. Nevertheless, there are some important differences between "*C.*" *costidensus* and *C. pompeckiji* Spath - the species it most closely resembles: the ribbing in the former is denser, finer and more flexuous, and the apertural constriction is always deeper and narrower, most pronounced on the lower whorl-side in *costidensus* as in *Sphaeroceras* and not as in *Cranocéphalites* s.s. Taken in isolation, such differences need hardly be more than specific; but in the context of two lineages of recently common origin now evolving separately in adjacent faunal provinces the possibility of transitory convergent homocormorphism should not be ruled out. "*Cranocéphalites costidensus*" [M] (and its microconch *Tuxedinites alticosatus*) would certainly fit into the Pacific succession from *Megasphaeroceras* to *Iniskinites* as well as, or even better than, it would fit into the Boreal Arctocephalitinæ as a temporary emigrant. Which of these interpretations is correct remains to be seen, but in the meantime it is important not to assume a close time-correlation between the *costidensus* fauna of the northern Pacific and the Pompeckji Zone of the

Arctic that an assignment of the former to *Cranocéphalites* might imply.

Fauna B5(a). *Iniskinites tenasensis* FREBOLD (1978)

+ *Kepperlites* sp. (? - cited, but not described: Frebald, 1978) Central British Columbia; Ashman Formation, lower fauna (section XX, beds 1-5, in Tipper and Richards, 1976), in sequence above B3.

Fauna B5(b). *Iniskinites acuticosatus* IM1.AY (1981a) [M]

+ *Xenocephalites vicarius* Imlay [m]
Iniskinites acuticosatus seems hard to distinguish from *I. tenasensis*. Eastern Oregon, upper part of the upper member of the Snowshoe Formation (450 m). According to Imlay (1981a, p.7), the top member of this formation is divisible into three parts: basal, middle (ca. 250 m) and upper (ca. 200 m). The basal part yielded a fragment of *Leptosphinctes* sp. [?, indet.] and hence was assigned to the basal Upper Bajocian. The middle part was unfossiliferous; and the species listed above came from the upper part. Numerous additional forms from these beds were assigned to *Kepperlites*, *Toricelliceras*, *Parareineckeia*, *Cobbanites*, *Bullatimorphites* and *Choffatia*. On the strength of these the whole of the upper part of the Snowshoe Formation was assigned to late Bathonian - early Callovian. Some of them appear however to have been misidentified. Thus, the type of *Toricelliceras izeense* Imlay (1981a, Pl.3, Fig.6) has a lappet and is a large microconch; this, together with the style of tuberculation of the inner whorls, points strongly to a *Stephanoceras (Normanites)* aff. *vigorosum* (Imlay), early Upper Bajocian. Its macroconch may well be the very large "*Kepperlites cf. plenus*" on Plate 2, Figure 9 (shown reduced x 0.73), whose inner whorls are hard to distinguish from those of *Kepp. mclearni* of fauna A8 but whose outer whorl, apparently still at least partly septate, is quite different and again typical of *Stephanoceras*. *Parareineckeia cf. hickersonensis* (Imlay, 1964 Pl.4, Figs.1-6) and *Toricelliceras izeense* pars (1981, Pl.3, Figs.7-10) both strongly resemble Upper Bajocian *Stephanoceras* from Alaska (Imlay, 1982a, Pl.4, Fig.4, Pl.5, Figs.6,8). *Cobbanites ochocoensis* Imlay seems at least in part (1981, Pl.5, Fig.6) close to *Caumontisphinctes* (cf. *C. aplous dimiensis* Pavia, 1973, Pl.21, Fig.5) or *Leptosphinctes* (cf. *L. schmiereri* (Bentz) Dietl, 1980, Pl.2, Fig.1) from the Subfurcatum Zone. Some of the uppermost beds of the Snowshoe Formation appear therefore to be still of Upper Bajocian age. This is not to deny that Bathonian and Callovian may also be represented: the identification of the most interesting *Bullatimorphites (Tryptoceras)* [Enay, 1960, non Flowers, 1942?] sp. [m] is not in doubt and its closest resemblance is to European forms of about Middle Bathonian age. But attempts to subdivide the faunas of the upper Snowshoe formation further must await more stratigraphical evidence.

Fauna 5(a) was collected from a single well-defined succession of beds spanning only 19 m and seems to be nearly homogeneous. It apparently marks the first appearance of *Kepperlites* in the Cordillera.

Fauna B6. *Iniskinites robustus* FREBOLD (1978) [M]

- + *Xenocephalites vicarius, hebetus* Imlay [m]
- "*Lilloettia*" [*Iniskinites*] aff. *lilloetensis* Crickmay

Keplerites cf. *tychonis* Ravn (as "aff. *ingrahami*, cf. *chisikensis*" Frebald; *snugharborensis* Imlay, 1981, Oregon, here?)

Central British Columbia, Ashman Formation, upper fauna (Section XX, beds 8-11, 25 m). This fauna, if present at all, is not conspicuous in Oregon. There may be traces of it in southern Alaska ("Cranocephalites" *pompeckji*, Imlay, 1962, Pl. I, Figs. 11-13). The *Keplerites* are in the same style - relatively small, evolute, very densely and finely ribbed - as the first ones to appear in the succession both in the Western Interior (*K. costidensus*, fauna A5) and in East Greenland (*K. tychonis* var. *fasciculata* Spath, 1932, and *K. tychonis* Ravn s.s.). In Greenland they mark the lowest Zone of the Boreal Upper Bathonian.

Fauna B7. *Iniskinites intermedius* (IMLAY) (1953, 1975)
Iniskinites s.str. ranges over a number of horizons.

Fauna B7(a). *Iniskinites intermedius* (IMLAY) [M]
+ *I. magniformis, martini* Imlay [M]
Chinitites chinituensis, parviformis Imlay [m]
Keplerites chisikensis Imlay [M]
K. cf. abruptus (McLearn) [M]
K. (Torticellites) alaskanus (Imlay) [m]
Cadoceras moffitti Imlay [M]
Choffatia irregularis Imlay [M]

Southern Alaska: Talkeetnas and Cook Inlet (e.g., Imlay, 1975, p.5, first and last columns, basal 100 ft of Tonnie Silstone Member). Characterized by the spectacularly globuliform, finely ribbed spherocoelic *Iniskinites*. The original identification as *Kheraicerus* gave support to the assignment of these beds to the Lower Callovian. The two genera are however easily distinguished, i.e., by the form of their dimorphism: only the macroconchs are homocomorphic, the microconchs (*Chinitites* and *Kh. (Bomburites)*) bearing little resemblance to each other. The sphaeroceatid ancestry of *Iniskinites* is also clearly revealed in the form of its peristome, marked by deep lateral constrictions unfolding ventrally into a projected hood resembling the peak of a cap exactly as in *Sphaeroceus* itself (see Imlay, 1975, Pl. 3, Figs. 8,9).

The precise ranges of the various genera and species described from this part of the succession appear to be very uncertain and further separate faunal horizons may come to be distinguished. The *Keplerites* seem to be characteristic, however, consisting still of densely and finely-ribbed forms resembling the true *K. tychonis* but compressed and involute in both macro- and microconchs. Such forms occur in Greenland in the upper Variable Zone and lower Calyx Zone of the Upper Boreal Bathonian. This fauna apparently also sees the first appearance of *Cadoceras* in the coarsely-ribbed forms with open, round-shouldered umbilici of *C. moffitti* (Imlay, 1953, Pl.42, Figs. 3,4,9) whose position at these levels seems to be established in the Talkeetnas (Imlay, 1975, p.9, second column from the right, USGS Mesozoic locs. 24151, 24147, 24224). In East Greenland such early forms of *Cadoceras* also occur in the lower part of the Calyx Zone. Imlay also records *C. catostoma* Pompeckj, but the principal occurrence of the forms ascribed by him to this species is higher and is further discussed below (fauna B8(f)).

Fauna B7(b). *Iniskinites cepoides* (WHITEAVES, 1884)
(Frebald, 1979)

Queen Charlotte Islands, top member of the Yakoun Formation. Apparently found in isolation without any other groups. Exact stratigraphic position conjectural, placed here on grounds of morphological resemblance to *Iniskinites* of fauna B7(a).

Fauna B7(c). *Iniskinites abruptus* (IMLAY) (1953, 1975) [M]
+ *Keplerites chisikensis* Imlay 1975 [M] (holotype, Pl. I, Figs. 1,5)

K. alticostatus Imlay [M] (incl. *K. cf. abruptus* (McLearn) - Imlay, 1953, Pl.52, Fig. 6; *K. cf. ingrahami* (McLearn) - Imlay, 1953, Pl.49, Fig. 21)

K. (Torticellites) cf. alaskanus (Imlay) (Imlay, 1953, Pl.48, Figs. 12,13) [m]

Cook Inlet, localities 9, 77, 78; Peninsula, Wide Bay, locality 125; Talkeetnas, localities 18, 32, 34. The *Keplerites* differ little from the ones found below and above, but the *Iniskinites* is distinct and unmistakable. The association, apparently always free from *Cadoceras*, seems to be so widespread as to be characteristic of a distinct horizon. The evidence from Cook Inlet indicates that it lies higher than that with fauna B7(a) (see Imlay, 1975, p.5, right-hand column, 350-750 ft above base).

Fauna B8. *Cadoceras comya* IMLAY, 1953 (1975)

This index is used here for the faunas of what is roughly the "Cadoceras catostoma Zone" of Imlay (1975), best known from the famous "Cadoceras-beds" of the Chinitina Formation in southern Alaska. The reasons for abandoning *C. catostoma* Pompeckj, 1900, as index are twofold. Firstly, the species as defined by its type series is only barely interpretable. It was based on two syntypes of which only one is at all identifiable (Pompeckj 1900b, Pl.5, Fig. 1), a complete microconch only 23 mm in diameter and here designated lectotype. Such microconchs of *Cadoceras* change little from their first appearance in the Upper Bathonian up to the top of the Lower Callovian; and whether the various "species" named by Pompeckj (*C. catostoma, grewingki, narseni, petelini* and *schmidtii*), as represented by their microconch type series, really are distinct and of different ages, or whether they are merely variants of a single species, may never be determined. The type localities are not well enough localized to be able to recollect topotypes. Secondly, the material described by Imlay (1953, Pl.34) consists of a mixture of forms also from poorly known horizons, so that even if one of them were chosen as basis for re-interpretation of the name, e.g., the macroconch from Iniskin Bay shown on Pl.34, Figs. 12,14, little would have been gained for stratigraphical purposes. Neither would a precisely known level have been characterized, nor would an identifiable fauna have been labelled. The name *catostoma* seems best left as a *nomen dubium*, and the labelling of faunal horizons restricted to well-defined nominal species.

Stratigraphic uncertainties reach their peak here. The ranges of the rich Callovian faunas in southern Alaska given by Imlay (1953, 1975) indicate long and largely overlapping ranges of many species of *Cadoceras, Lilloettia* and *Keplerites*. Yet the figured material includes forms that resemble species found elsewhere in isolation or in succession over ranges of strata

representing considerable intervals, extending over several ammonite zones. The range-charts for Alaska must inevitably depend very much on the systematic classification adopted for the material available; and as the bulk of this consists of small lots made by various collectors at many localities, the classification has to be primarily morphological. What follows is an attempt to identify what might be separable faunas on the strength of the material that has been figured, and to suggest some possible ages and correlations.

Fauna B8(a). *Keplerites loganianus* (WHITEAVES, 1884) (McLearn, 1929; Imlay 1953, 1975, *PP836*) (incl. *K. plenus*, *multus*, *githini*, *abruptus*, *ingrahami*, *torrensi* (McLearn) [M])

K. (Toricellites) newcombii (Whitcaves, 1900) [m]

K. (Toricellites) penderi (McLearn) [m]

Queen Charlotte Islands, top member of the Yakoun Formation; apparently monogenic, free of *Cadoceras*.

This fauna is very close to the Kepleritids of the zone of *Cadoceras apertum* sp. nov. MS in East Greenland and of the immediately overlying beds, both in the macro- and microconchs. One of the former is *Kepp. trailiensis* Donovan, 1953. Compared with the earlier forms of *Keplerites*, the ribbing on the inner whorls has become stronger and coarser, and the innermost whorls of the macroconchs have flattened venters. The microconchs are also more evolute, strongly and coarsely ribbed. Both the American and Greenland faunas in turn are very close to, if not quite identical with, the fauna of *Keplerites keppleri* (Oppel) in northwest Europe: there are individual variants in all three faunas that are morphologically indistinguishable. The *K. keppleri* fauna was first described from Württemberg in southern Germany (Oppel, 1862; Buckman, 1922, Pls. 289 [M], 310, 318-9 [m]; Quenstedt, 1886, Pl. 77, Figs. 1-5 [M], Pl. 76, Fig. 9 [m]) where it occurs at the base of the "Macrocephalus noolith" (Dietl, 1981). This condensed ironshot oolite is regionally the lowest bed of Callovian age, but its time-duration within the Callovian is highly variable. Its upper boundary is demonstrably diachronous, and the precise age of its base relative to the base of the Callovian Stage as defined in England (Callomon 1964) has not yet been established independently. Fortunately the level at which the *K. keppleri* fauna occurs in England is known rather more precisely (Callomon, 1959). Two stratigraphically not closely localized specimens have been figured ("Cerericeras" cereale Buckman 1922; Arkell, 1954, p. 118, Text-fig. 42), but several others in the Oxford University Museum came from Swan Inn quarry, Long Handborough, 12 km northwest of Oxford, Upper Cornbrash (Douglas and Arkell, 1928, p. 129, bed 4), *Ornithella sidingtonensis* brachiopod zone. This is the lowest brachiopod zone in the Macrocephalus Subzone of the Macrocephalus Zone in England, and hence of the Callovian Stage by definition. *K. keppleri* appears to occur at only a single horizon in the Macrocephalus Zone both in England and Swabia, so it seems safe to assume that these occurrences reflect but a single brief and closely isochronous southerly invasion of northwest Europe by what was at the time still a strictly Boreal group. Conversely, these occurrences provide the crucial key to the correlation of the standard northwest European, Boreal and northwest Pacific ammonite provinces at the base of the Callovian, and make it

possible to locate the Bathonian-Callovian boundary there as well as can be done, to within half a standard ammonite Zone, say. Fauna B8(a) may therefore be taken to mark the base of the Callovian in the Cordillera. In the Queen Charlottes it occurs immediately above fauna B7(b). In Greenland its analogues occur some distance above the analogues of fauna B7(c). Its position elsewhere in the Cordillera remains somewhat uncertain, however. It has also been recorded from southern Alaska, e.g., localities 85-87 on the east shore of Iniskin Bay (Imlay, 1953b), but the assemblage from this area seems slightly different and is assigned a separate horizon, discussed further below (fauna B8(f)).

Fauna B8(b). *Cadoceras (Paracadoceras) tonniense* IMLAY, 1953 [M]

+ *C. glabrum* Imlay, partim, including

? *C. (Paracadoceras) harveyi*, brooksi Crickmay

C. wosnessenskii (Grewingk) *sensu* Imlay partim

This appears to be the lowest fauna in which *Cadoceras* predominates. The problems of classifying the Alaskan representatives of the genus have already been discussed in the systematic introduction. Although the range-charts show many species extending over long intervals of strata in parallel, the faunas as a whole give the impression of changing little, implying that they represent only a short time-interval - perhaps the equivalent of no more than a single standard ammonite zone altogether. Most of the collections are small lots from scattered localities, but when occasionally a single locality did yield more extensive collections (e.g., USGS Mesozoic loc. 2921, no. 87 in Imlay, 1953) the impression is very strongly one of all the "species" blending into each other in a single homogeneous assemblage. The characteristic features almost all the forms have in common are open, conical umbilici, only moderate inflation, and small size as *Cadoceras* goes. In Alaska the *C. tonniense* fauna ("Paracadoceras") appears to be well localized in the Iniskin Peninsula near Tonnie Peak, at about 450 ft above the base of the Chinikna Formation (Imlay, 1975, p. 5, second column from the right).

The type and only specimen of *Paracadoceras harveyi* came from Crickmay's "Zone of *Cadoceras brooksi*" near Harrison Lake in southern British Columbia, which yielded in addition *C. catostomu* (*teste* Crickmay and Frebold), *C. (Pseudocadoceras) schmidii* and *grewingki* Pompecky (see Frebold and Tipper, 1967). The position of this horizon relative to others could not however be firmly established, and there seems no point in separating "a horizon of *C. harveyi/brooksi*" in any other than the most local sense.

In East Greenland *Paracadoceras* occurs commonly in beds immediately above the levels with *Kepp. trailiensis* and *K. cf. keppleri* and then ranges upwards as a minor element in the Zone of *Cadoceras nordenskjoldi* sp. nov. MS. *Paracadoceras* occurs also very rarely in the Cornbrash of southern England (*Cadoceras breve* Blake, 1905, Pl. 5, Fig. 1), in beds taken to be Upper Cornbrash (*teste* Blake) and hence of Macrocephalus Zone and Subzone age. The only other known specimen, in the British Museum (C.7331), is from an old collection without locality, but its matrix points strongly to the Upper Cornbrash of the Malmesbury area of Wiltshire.

All the evidence strongly and consistently indicates an early Lower Callovian age for this fauna, equivalent to the Macrocephalus Zone of Europe and probably also still the Macrocephalus Subzone.

Fauna B8(c). *Lilloettia lilloetensis* CRICKMAY, 1930 (incl. *L. ("Buckmaniceras") buckmani* and *L. mertonyarwoodi* Crickmay – all [M])

Xenocephalites vicarius Imlay [m]

Southern Alaska, Tonnie Siltstone Member of the Chinatina Formation; southern British Columbia, "Zone of *L. lilloetensis*" of Crickmay, eastern Oregon, Trowbridge Shale (Imlay, 1964, 1981). The three "species" of *Lilloettia* appear to represent no more than the partial range of variability of a single biospecific assemblage; *L. milleri* Imlay may be the spheroconic end-member.

The precise age of *Lilloettia* was for a long time uncertain, for it had been recorded from many scattered localities at few of which, if any, it was associated or found in succession with other genera. In Alaska it is recorded as ranging over almost the whole of the *Cadoceras*-beds, but its precise levels within these beds seems now securely established in at least two places on the Iniskin Peninsula: USGS Mesozoic loc. 21322 (no. 38 in Imlay, 1953, and second column from the right in Imlay, 1975, p.5); and USGS Mesozoic locs. 21340, 22556 (nos. 35 and 36, and third column from the right). In both places it succeeds *Cadoceras* but is not associated with it. At the first locality it thus directly overlies fauna B8(b), which puts it in the same relation to *Paracadoceras* as Crickmay thought it did at Harrison Lake, although he had not proof. At the second locality the *Cadoceras* does not seem to be quite abundant enough to tell whether it belongs to fauna B8(b) or to a higher one, B8(f), described below. Either way, the early Lower Callovian age of these species of *Lilloettia* now seems firmly established.

This is of great importance in the wider context of the Pacific Realm as a whole, for very closely related, possibly identical faunas occur further south, e.g., in the material from Cualac, Province of Guerrero, Mexico, described by Burckhardt and discussed in a preliminary revision elsewhere (Westermann *et al.*, this volume)

Macrocephalites boesii Burckhardt [M] (1927, Pl.15, Figs. 1-4, = *Lilloettia* cf. *buckmani* (Crickmay, 1930))

Macrocephalites aff. *macrocephalus* (Schlotheim) [M] (1927, Pl.16, Figs.1-3, = *Lilloettia* cf. *lilloetensis* Crickmay)

Macrocephalites nikitini Burckhardt [m] (1927, Pl.16, Figs. 4-9, = *Xenocephalites* aff. *vicarius* Imlay, 1953)

The close homoeomorphism between macroconchs of *Lilloettia* and of *Macrocephalites* is neatly resolved by means of the microconchs. It should be possible to follow these correlation further, into the Andes (Riccardi, in progress) and hence finally to settle the question of the Bathonian-Callovian boundary there.

Fauna B8(d). *Lilloettia tipperi* FREBOLD (1967) [M] (in Frebold and Tipper, 1967)

Southern British Columbia: isolated horizon and locality. Listed separately here to emphasize the point that *Lilloettia* ranges over several horizons. The material is also sufficiently

plentiful and well preserved to show that at some horizons, at least, the biospecific variability of *Lilloettia* can be quite small.

Fauna B8(e). *Cadoceras wosnessenskii* (GREWINGK, 1850) *sensu* Imlay 1953 [M]

+ *Cadoceras catostoma* Pompeckj, 1900, *sensu* Imlay [M]

Cadoceras glabrum Imlay [M]

Cadoceras comma Imlay *partim* [M]

This label is applied to the two collections from the east shore of Iniskin Bay at USGS locs. 2921 and 3029 (nos. 87 and 86 in Imlay, 1953, respectively) which, to judge from the admittedly scanty indications, came from the lower part of the Paveloff Siltstone Member of the Chinatina Formation (Imlay, 1975, p.5, right-hand column). Although there may be some mixing of horizons, much of the fauna gives the impression of homogeneity. If the correlations given by Imlay are correct, this upper *Cadoceras* fauna lies considerably higher than the lower *Cadoceras* fauna B8(b) and above the *Lilloettia* fauna B8(c).

It includes good macroconchs described under two of the old Russian names revised by Imlay. One of these, *C. catostoma*, has already been discussed above. The case for the other one, *C. wosnessenskii*, is more hopeful. The type series seemed to consist of the single specimen figured by Grewingk (1850, Pl.4, Figs. 1(a)-(c)). It is the inner part of a phragmocone of a macroconch that does resemble the forms described by Imlay under the name quite closely, as far as it goes, although it could have belonged probably equally well to several other of Imlay's species. If the name is to be revived it should be firmly tied to a reference specimen, a possible neotype, should the holotype be lost. The holotype came from the Shelikoff Formation near Katmai Bay on the Alaskan Peninsula (not from Chignik Bay as stated by Imlay). No new material seems to have been collected in this area and hence there are no topotypes. For the next best candidate there is not much to choose between the fine specimens described by Imlay from Wide Bay, 100 km south-west, or Iniskin Bay, 200 km north-east, and hence the specimen suggested here is Imlay's (1953, *PP 249-B*) Plate 40, Figures 9 and 12. This closely matches Fig. 1 on the same plate from Wide Bay, and this in turn seems to have come from the same level and locality as the type of *C. glabrum* (Imlay, 1953, Pl.37, Figs.5,6,8,9). In this way a picture of the fauna can be built up. It still resembles the lower *Cadoceras* fauna B8(b) very closely and the time-gap between them must have been very short.

One or both of these *Cadoceras* faunas are also present in northern Siberia (e.g., *C. anabarense* Bodylevsky, 1960, Pl.4, Fig.3; Meledina, 1977, Pl.21, Fig.1, Pl.22, Fig.1, Pl.23, Fig.1, Pl.24, Fig.1; *C. cf. multiforme* Imlay – Bodylevsky 1960, Pl.8; Meledina, 1977, Pl.19, Fig.1), but it has so far been described neither from the Alaskan North Slope, nor the Arctic Islands, nor East Greenland. In Greenland the reason may be that at the time the area was occupied by a peculiar local fauna, *C. nordenskjoldi* sp. nov. MS (cf. Madsen, 1904, Pl.10, Fig.2), between the Apertum Zone of the basal Lower Callovian and the Septentrional – Calloviense Zones of the late Lower Callovian.

Fauna B8(f). *Kepplerites* cf. *abruptus* (McLEARN)

Southern Alaska, localities 85-87 on the east shore of Iniskin

Bay, figured by Imlay under various of McLearn's names (1953, Pls. 50-51, and including *Kepp* (*Toricellites*) cf. *newcombii*, Pl. 53, Figs. 4,5 [m]). Those from locality 85 at least (USGS Mesozoic loc. 20763) were confidently placed into the upper part of the Chinitta Formation by Imlay (1975, P. 5, right-hand column) and said to be associated with *Cadoceras*, including *C. wosnessenskii*, *C. doroschini* and *C. kialagvikense*, suggestive of fauna B8(c). Morphologically these forms differ little from the ones both from the Queen Charlotte Islands (B8(a)) and from some of the others described by Imlay from beds with *Iniskinites* in Alaska. There is, perhaps, a more persistent tendency for the venters to become tabulate as far as the bodychamber (cf. Imlay, 1953, Pl. 50, Figs. 1,3) which is rare in the true *Kepp*, *keppleri* and, according to McLearn, in the *Kepp*, *loganiamus* fauna. It may well be that faunas B8(a) and B8(f) merely reflect temporary predominances in the fluctuating abundance of *Kepplerites*, ranging with little change in Alaska from the latest *Iniskinites* beds throughout the *Cadoceras* beds as Imlay's range-charts suggest. This would support the impression given by *Cadoceras* of a relatively short time interval.

Fauna B8(g). *Lilloettia stantoni* IMLAY
+ *Lilloettia buckmani* (Crickmay)

There is consistent evidence of a higher assemblage of *Lilloettia* differing somewhat from that in fauna B8(c) at the very top of the *Cadoceras* beds with the *C. wosnessenskii* - *comma* group (e.g., Imlay, 1975, p. 7; p. 5, right-hand column, USGS Mesozoic loc. 22434; third column, loc. 22556). Also eastern Oregon, Trowbridge Shale? (Imlay, 1981).

Fauna B9. *Stenocadoceras stenoloboide* POMPECKJ, 1900 [M] (Imlay 1953, 1975) (incl. *C. (S.) multicoatum*, *bowsersense*, *straitum*? Imlay [M]
+ *C. (Pseudocadoceras) petelini* Pompeckj [m] (Imlay, 1953, Pl. 44, Figs. 6-8, 12; Pl. 47, Figs. 7, 8; Pl. 48, Figs. 1-6; Pl. 49, Figs. 1, 2, 8 - under various names)

Southern Alaska: Peninsula, Cook Inlet, Talkeetnas (Imlay, 1953, 1975); central and southern British Columbia (Frebald and Tipper, 1967). Canadian Arctic: northern Yukon, Babbage River and Aklavik Range (Frebald, 1964). Northern Siberia: eastern Taimyr (Meledina, 1977). *Pseudocadoceras* spp. recorded from a number or other localities, including Vancouver Island, eastern Oregon, and possibly as far south as the Sierra Nevada of northern California (Imlay, 1961, Pl. 2, Figs. 6, 7 only) may belong to this horizon. The use of the name *stenoloboide* to label this fauna again follows Imlay's interpretation, for the type series (4 syntypes) seemed to consist mainly of microconchs and is also barely interpretable.

The age of fauna appears to be Middle Callovian although there is no direct proof. *Stenocadoceras* [M] is known neither in Europe nor in East Greenland. *Cadoceras* are relatively common in the lower part of the Middle Callovian of Britain (Jason Zone), but the macroconchs are still typical *Cadoceras* s.s. Higher, in the Coronatum Zone, they are exemplified by the group of *C. ("Rondiceras") milaschewici* (Nikifor) [M] (see illustrations by Sazonov, 1957) whose inner whorls do resemble *Stenocadoceras* but whose outer whorls revert to the style of ordinary *Cadoceras*. The Alaskan microconchs, however, closely resemble those from the Middle Callovian of Europe,

e.g., *Pseudocadoceras concinnum, laminatum* Buckman (1927, Pls. 727, 735) from around the Middle-Upper Callovian boundary; but they also resemble some earlier forms, including *Pseudocadoceras boreale* Buckman itself (1919, Pl. 121B), from the Koenigi Subzone of the Calloviense Zone (not Upper Callovian, as Buckman thought), and *Ps. mundum* (Sazonov, 1957, Pl. 6, Figs. 2-4) from the Elatmae Zone (pre-Koenigi) of the Russian Platform. The main argument in favour of a Middle Callovian age is indirect, based on the morphologically intermediate position of *Stenocadoceras* [M] and [m] between the undoubtedly Lower Callovian faunas B8(a)-(f) below, and the Upper Callovian fauna B10 above.

The correctness of this assignment would, however, raise another problem. As argued above, all the *Cadoceras* in the horizons below, B8, indicate an early Lower Callovian age, rising no higher than the Macrocephalus Zone. Of the large cadicone *Cadoceras* ex gr. *sublaeve* typical of the late Lower Callovian, Calloviense Zone, there is no sign. Yet such forms are present not far away, in the northern Yukon and the Arctic Islands (*Cad. arcticum, voronetsae, septentrionale* var., Frebald, 1964) and on the North Slope. The implications would be a considerable non-sequence in southern Alaska between the *Cad. comma* (B8) and *Stenocadoceras* (B9) horizons in the Chinitta and Shelikoff Formations. This would not in itself be at all surprising, considering the other non-sequences that can be recognized. The difficulty would lie in the reports of admixture or overlap of the two faunas. These should be carefully re-examined. If confirmed, it would become necessary to consider the possibility that *Stenocadoceras* is also still Lower Callovian, perhaps a local genus.

Fauna B10. *Longaeviceras pomeroyense* IMLAY [M] (1953, Pl. 43, Figs. 1-3)
+ *Pseudocadoceras crassicoatum* Imlay *parim* [m] (1953, Pl. 49, Figs. 19, 20)

Pseudocadoceras chinitense Imlay [m] (Pl. 48, Figs. 7-10) Southern Alaska, Cook Inlet. These forms are unmistakably of early Upper Callovian age, lower Athleta Zone. They occur near the top of the Chinitta Formation.

- regional non-sequence -

Oxfordian

Fauna B11(a). *Cardioceras* aff. *scarburgense* (YOUNG and BIRD) (Frebald and Tipper, 1975) (= *Quenstedoceras (Lamberticeras) henrici, intermissum* and sp. aff., Frebald and Tipper)

Central British Columbia: Smithers area, GSC locality 85376. Although a general resemblance to *Quenstedoceras* of the Lambert Zone cannot be denied, the sharpness of the ribbing and rather involute coiling points strongly to a somewhat later age, probably in the Mariae Zone of the Lower Oxfordian.

Fauna B11(b). *Cardioceras* cf. *praecordatum* DOUVILLÉ Frebald and Tipper 1975, Pl. 2, Figs. 8, 9, 12, GSC locality 90821, central British Columbia; top Mariae Zone, Praecordatum Subzone.

Fauna B12. *Cardioceras marini* REESIDE [M] + [m] (Reeside 1919; Imlay 1964, 1981)

Very close to, if not identical with, *C. reesidei* Maire, fauna A13, Eastern Oregon (Imlay 1964); central British Columbia (Frebold and Tipper 1975, Pl.2, Figs.7,10; GSC locality 90824); southern Alaska (Imlay). Cordatum Zone, Bukowskii Subzone.

Fauna B13. *Cardioceras spiniferum* REESIDE [M] (Reeside 1919; Imlay 1981)

- + *C. alaskense* Reeside, cf. *stella* Arkell – Imlay [M]
- + *C. distans* (Whitfield) – Imlay, cf. *lillooetense* Reeside – Imlay [m]

Southern Alaska, Lower Oxfordian, Cordatum Zone, upper Bukowskii or lower Costicardia Subzone. In Europe, where many successive faunas can be collected even within a single Subzone, each one differs slightly in aspect from the others as the *Cardioceras* lineage evolved and the boundaries between Subzones are arbitrary and not always easy to recognize. Individual morphs can range over several faunas or even Subzones. It is not surprising therefore that Imlay records similar overlaps in Alaska (1981, p.14-15, Tables 2,3).

The precise position of *Cardioceras lillooetense* Reeside as exemplified by its type from southern British Columbia requires confirmation, but it could well belong here.

Fauna B14. *Cardioceras whiteavesi* REESIDE [m] (Imlay, 1981)

- + *Perisphinctes* cf. *muehlbachi* Hyatt ? [m] (Imlay, 1981, Pl.7, Fig.9)

Southern Alaska. The *Cardioceras* does strongly resemble the type which came from Wyoming, fauna A15, assigned there to the Middle Oxfordian, Densiplicatum Zone. The *Perisphinctes* came from the same area, and it is not unlikely that it may have come from beds of the same age. It is certainly very close to *Per. antecessans* Salfeld or *Per. buckmani* Arkell from the Plicatilis – Tenuiserratum Zones of Europe, and it could be significant that this horizon, about the only one at which a more southerly faunal element ever penetrated into the northerly territory of the Cardioceratinae in America, has the same age as those zones in the Oxfordian of Europe in which the Perisphinctidae similarly achieved their maximum northerly extent.

Fauna B15. *Amoeboceras* aff. *transitorium* SPATH (Imlay, 1981, Pl.12, Figs.2-15) + *Buchia concentrica*

Alaska, Wrangell Mountains. This fauna is not easy to place. The macroconchs (Imlay, 1982, Pl.12, Figs. 12,15) resemble *Amoeboceras schulginae* Mesezhnikov, 1967 (Pl.3, Fig.1) in the straightness and coarseness of the primary ribs with their ventrolateral tubercles; but the general resemblance of the inner whorls and microconchs (Figs.5-11) seems closer to *A. glosense* and *transitorium* (see Sykes and Callomon, 1979). The most likely ages are therefore either Upper Oxfordian, Glosense Zones (*A. transitorium*) or Regulare Zone (*A. schulginae*).

Fauna B16. *Amoeboceras dubium* (HYATT, 1894) [m] (Reeside, 1919, Imlay, 1961)

Northern California. These seem to be the only indisputably Lower Kimmeridgian Boreal ammonites so far described. They are close to *A. elegans* Spath (1935) and their age is Eudoxus Zone.

Fauna B17. "*Subplanites* [M]/*Aulacosphinctoides* [m] spp." IMLAY (1981)

+ *Buchia* sp.

Southern Alaska. These forms are entirely strange and new. They were accompanied only by *Buchia mosquensis* and *B. rugosa*, indicating about a Lower Volgian age (Middle Kimmeridgian *sensu anglico*).

Higher Jurassic strata appear to be widely represented in the Cordillera but have yielded no ammonites, only *Buchia*. A number of ammonites from various localities have not been considered here, because they are not closely identifiable or because they are stratigraphically not very significant at present. This includes numerous Phylloceritidae and Lytoceratidae, some Poppelidae, and some Perisphinctaceae of southerly affinities found in California and southwestern Oregon, such as the Upper Tithonian faunas described by Imlay and Jones (1970, p.B5-11).

Region C. Arctic Canada: Northern Yukon (excluding British Mountains) – Richardson Mountains – Arctic Archipelago

Due largely to the intensive exploration for hydrocarbons in the last 30 years, the Jurassic stratigraphy of this region has become rather well known. Emerging in the Keele Range near the Alaskan border at about 67°N, the outcrop sweeps in a broad band northeastwards via Prince Patrick Island into the Sverdrup Basin as far as Axel Heiberg and Ellesmere Islands (80°N) before being lost into the Arctic Ocean (cf. Poulton *et al.*, 1982, Fig.3; Poulton, 1982, Fig.3). It is bounded to the northwest by a fault belt that runs northeastwards from the Brooks Range into the Beaufort Sea at the mouth of the Mackenzie Delta and is said to be associated with the Kaltag Fault of western Alaska, dividing it from the Brooks-Mackenzie Basin occupying the North Slope and British Mountains which are discussed separately as region D below. The overall distribution of ammonites in region C is so uniform that its evolution as a single coherent pericratonic basinal entity can be in little doubt (see Poulton *et al.*, 1982). The major features of the ammonite faunas are almost identical with those of East Greenland. There are lesser differences, in the form of clearly discernible faunal gradients, that are of great significance. It is useful, therefore, to distinguish three subregions, from southwest to northeast:

(i): Keele Range – Old Crow – upper Porcupine River. This arcas contains what must be the finest single section through the Middle Jurassic in the whole of the Arctic at Salmon Cache Canyon on the Porcupine River, at the "Big Bend" where its flow changes direction from northwards to westwards (67½°N, 138°W) 60 km east of Old Crow settlement (cf. Poulton, 1978b, Pl.II). Some 70 beds can be distinguished in succession (cf. Poulton and Callomon, 1976, Poulton, 1978a,b for preliminary descriptions) of which at least 35 have yielded ammonites that are in course of being described (Poulton, 1983).

(ii): Richardson Mountains. Jurassic rocks are seen in many fine exposures from the Mackenzie Delta westwards to the White Mountains and their surroundings. Over 30 detailed sections have been recently described (Poulton *et al.*, 1982). They reveal very rapid lateral changes of thickness and facies, reflecting syndesimetary tectonic movements; yet the ammonites that occur tend always to belong to the same rather limited

set of faunas. This suggests that the limitations were imposed by sporadic faunal colonization rather than by gaps in the sedimentary record, and that with some exceptions, the succession of faunas as we now know it may be regionally fairly complete.

C(iii): Sverdrup Basin, from Prince Patrick to Ellesmere Islands. Ammonites have been found at widely scattered localities and only rarely has any one locality yielded much of a faunal succession. The evidence for relative dating, therefore, is sometimes indirect.

The early Middle Jurassic is represented by all but one member of what appears to be a standard Boreal - North Pacific succession defining a distinct, Bering Province (see Taylor *et al.*, this volume) shared by regions B, C and D and extending without modification into eastern Siberia, from the Chukhotsk Peninsula via Kolyma to the southern shores of the Sea of Okhotsk and the Bureya basin (cf. Saks, 1976).

Be-1: *Pseudolioceras mcIntocki* (HAUGHTON, 1858)
Prince Patrick, Mackenzie King and Melville Islands (Frebold, 1958, 1960); northern Yukon (Poulton, 1978b); northern Alaska (Imlay, 1976); Okhotsk: Tugur and Bureya (Sey and Kalacheva, 1980).

Be-2: *Leioceras opalimum* (REINECKE)
Prince Patrick and Melville Islands (Frebold, 1958, 1960); northern Yukon (Poulton, 1978); Spitzbergen (Wierzbowski *et al.*, 1981); northern Siberia, Lena basin (Bidzhyev, 1965).

Be-3: (a) *Eryctoides howelli* (WHITE, 1889) [M]
+ *E. (Kialagvikites) kialagvikensis* (White, 1889) [m]
(b) *Pseudolioceras whiteavesi* (White, 1889)
(c) *Pseudolioceras* ["*Tugurites*"] *tugurense* (Kalacheva and Sey, 1970; see 1980)
(d) *Pseudolioceras spitsbergenense* Frebold, 1975
(e) = *Pseudolioceras* ["*Canavarella*"] *crassifalcatum* (Imlay, 1976) ? (PP854)
(f) *Tmetoceras* spp.

Ellesmere Island [(d), Frebold, 1975]; northern Yukon [(a), (b)?, (e)?, Poulton, 1978b]; northern Alaska [(a), (c), Imlay, 1955]; southern Alaska [(a), (b), (d), (f), Westermann, 1964a, the basis in part of his *E. howelli* Zone]; Okhotsk: Tugur and Bureya [(a), (b), (c), Sey and Kalacheva, 1980]; Japan [(b), as *Graphoceras*, (f), Sato, 1954, 1957, 1958].

Be-4: *Pseudolioceras fastigatum* WESTERMANN, 1969
Southern Alaska (Westermann, 1969); Okhotsk: Bureya (Sey and Kalacheva, 1980).

Be-5: *Arkeloceras tozeri* FREBOLD, 1958 [M]
+ *A. mclearnii* FREBOLD, 1958 [m]
Axel Heiberg, Melville and Prince Patrick Islands (Frebold, 1958, 1961, 1964); northern Yukon (Poulton, 1978b); southern Alberta (Westermann, 1964b). Southern Alaska (Imlay, 1964); northern Alaska, Canning River (Imlay, 1955). Siberia: Chukotsk Peninsula, Anadyr (Efimova *et al.*, 1968, p.80); Kolyma Plateau (Efimova *et al.*, 1968, pl.79); Bureya basin (Sey and Kalacheva, 1980).

There is no sign of the rich accessory faunal elements found in the Alaska Peninsula. The abundant *Stephanoceras* faunas of the south, of the Humphriesianum Zone and early Upper

Bajocian, are similarly absent, with the possible exception of a single specimen from the Big Bend section on the Porcupine. Instead, there follows abruptly everywhere the first of the purely Boreal faunas, unknown further south in regions A and B, that then held sway during the rest of the Jurassic. Yet some Pacific elements from region B did penetrate a little distance into the Arctic as far as Salmon Cache Canyon. These include *Phylloceras*, relatively common there at several horizons; *Iniskinites*, not rare in the Upper Bathonian; *Choffatia*; and even a single specimen, unfortunately not in place, of the very local North Pacific *Parareineckea*. Yet hardly any of these seems to have got as far even as the Richardsons [C(ii)] and with the exception perhaps of very rare *Phylloceras* in Prince Patrick Island, none reached the Sverdrup Basin [C(iii)]. Old Crow was thus very much at the gateway between Pacific Ocean and Boreal Sea during the Jurassic as far as the ammonites were concerned.

Fauna C1. *Cranoccephalites borealis* (SPATH) (incl. *C. warreni* Frebold, 1961).

Salmon Cache Canyon; Richardsons, widespread; East Greenland; northern Siberia. As in Greenland, the duration of this fauna seems to have been rather short and all the material that has been collected probably can be safely regarded as effectively isochronous. The ranges of variability of the Canadian and Greenland assemblages then largely overlap but do not quite coincide. The small differences could well represent geographical subspeciation. If due to differences of age, this could only have been very slight. No other genera have been found so far in association and the question of precise age and correlation with Europe and the rest of North America remains open. The similarities in both dimorphs with the Pacific Sphaeroceratinae of the Humphriesianum Zone have already been noted in the systematic introduction above (see Fig. 2) suggesting a close phyletic and temporal relation, and the best guess for the age of *C. borealis* remains early Upper Bajocian as suggested previously (Callomon, 1959).

Fauna C2. *Cranoccephalites indistinctus* CALLOMON, 1959. Richardsons (Poulton *et al.*, 1982, p.84); Prince Patrick Island (Frebold 1958, Pl.8); East Greenland. In Greenland there are at least two slightly different assemblages in the Indistinctus Zone.

Fauna C3. *Cranoccephalites pompeckji* (MADSEN, 1904) and spp. aff.

Richardsons (Poulton *et al.*, 1982); Prince Patrick Island (Frebold, 1958); East Greenland; Novaya Zemlya (Sokolov, 1913); northern Siberia (Voronets, 1962). In East Greenland the Pompeckji Zone is subdivisible, encompassing at least six distinct faunas; and some of the forms from Siberia (e.g., *C. nordvikensis* Voronets) are different again. Close correlation of the Canadian material is not yet warranted either by the quality or quantity of material available.

Fauna C4. *Arctoccephalites* sp. *A. aff. elegans* SPATH, 1932. Small, compressed, fine-ribbed species of *Arctoccephalites* that resemble *A. elegans* Spath (1932, Pl.10, Fig.4) in these respects were recorded as such from various localities by Frebold (1961). Salmon Cache Canyon, 1964a, Axel Heiberg (s.). New collections *in situ* both at Salmon Cache Canyon and in East Green-

land show that the resemblance is close only between the peripheral variants of what are quite distinct assemblages although the ages are probably not very different. The Greenland fauna from the lower Arcticus Zone includes *A. nudus* Spath, *A. ornatus* Spath, *A. sphaericus* Spath as well as the Franz Josef Land species *A. koettlitzii* (Pompeckj, 1900a), *A. ellipticus* Spath, *A. pilaeformis* Spath and the true *A. arcticus* (Newton and Teall, 1897), all in the same metre thick concretionary bed. The assemblages from the Porcupine are being fully described by Poulton (1983). Porcupine and Richardsons, various localities (Poulton *et al.* 1982); ?Axel Heiberg Island.

Fauna C5. *Arctocephalites* sp. nov. B

At Salmon Cache Canyon the beds with fauna C4 are succeeded by horizons yielding even smaller forms of this genus, the macroconchs, with minute umbilici, barely exceeding 50 mm in diameter. Fragmentary material may be hard to distinguish from the small *Phylloceras* or *Partisiceras* that occurs in the same beds (cf. Frebold *et al.*, 1967, Pl.2, Figs. 1.2?). Also on the Old Crow River near its junction with the Porcupine. These forms are also being described by Poulton. In East Greenland, higher parts of the Arcticus Zone yield similarly fine-ribbed smoothish forms with minute umbilici, but they are not as small as those of fauna C5.

Fauna C6. *Arctocephalites callomoni* FREBOLD, 1964a.

Axel Heiberg Island, in a well-defined bed; and Salmon Cache Canyon on the Porcupine. ? Northern Siberia (*A. voroneisae*, *kigilakhensis* Meledina, 1973, Pls. 13,14,16). Occasional variants resembling these species occur in East Greenland in the Greenlandic Zone, but the assemblage as a whole is distinct.

Fauna C7. *Arctocephalites* cf. or aff. *greenlandicus* SPATH, 1932

Porcupine and Richardsons, widespread. In East Greenland the Greenlandic Zone is divisible into at least three Subzones. It therefore represents a considerable time-span and although the general correspondence to the faunas from the Yukon is clear, an exact match may not be possible. There are also a number of levels at Salmon Cache Canyon yielding faunas of this general aspect. They include inflated variants comparable with *A. crasus* (Madsen) and *A. freboldi* Spath found in East Greenland mainly in the higher parts of the Zone.

Fauna C8. *Arcticoceras ishmae* (KEYSERLING, 1846).

In East Greenland the Ishmae Zone (formerly Kochi Zone: see Callomon, 1972) is clearly divisible into three Subzones: of *A. harlandi* Rawson, 1982 (type from Spitsbergen) (lowest); *A. ishmae* (lectotype from the Petchora); and *A. crassiplicatum* sp. nov. MS (type from Jameson Land) (highest). Copious new collections from the Ishmae Subzone match the lectotype of *A. ishmae* and the topotypes in the British Museum (cf. Spath, 1932, Pl.15, Fig.7) perfectly, and show that the poorly-preserved holotype of *A. kochi* Spath came from this assemblage. In *A. harlandi* the ribs are straight and reticulate, in *A. ishmae* somewhat curved and moderately projected on a more sharply curved venter, and in *A. crassiplicatum* the coarse and ventrally strongly projected ribs persist almost undiminished to the adult peristome on whorls of almost carinate section. All three Subzones can be recognized in the Porcupine - Old Crow area of

the northern Yukon but seem to have been cut out at least in the eastern Richardsons.

Fauna C8(a). *Arcticoceras harlandi* RAWSON, 1982

Salmon Cache Canyon, Porcupine (cf. Frebold, 1961, Pl.12, Pl.16, Fig.1).

Fauna C8(b). *Arcticoceras ishmae* (KEYSERLING, 1846)

+ *Iniskinites* sp. nov.

Opellia (?) *Oxyerites* sp. cf. and aff. *undata* and *jugata* Ershova and Meledina, 1968

Choffatia sp.

Salmon Cache Canyon. It seems significant that this is precisely the same horizon as the only one to have yielded Opellids in East Greenland (Birkclund, Hakansson and Surlyk, 1971). The forms from northern Siberia appear to be slightly older, said to be from beds with *Arctocephalites*. *A. ishmae* has a wide distribution, including northern Russia (Keyserling, 1846), Novaya Zemlya and northern Siberia (Meledina, 1973).

Fauna C8(c). *Arcticoceras* cf. *crassiplicatum* sp. nov. MS

A spot locality north of the Porcupine, between Old Crow and Ramparts House: D.K. Norris collection, 1981 (1409 NC; 1 am indebted to Dr. Norris for showing me this material).

Fauna C9. *Cadoceras barnstoni* (MEEK, 1859)

+ *Iniskinites* aff. *varicostatus* (tmlay, 1953)

Keplerites cf. or aff. *rosenkrantzi* Spath

Porcupine: Salmon Cache Canyon (almost certainly the source of the type of *C. barnstoni*, refigured by Frebold, 1964a), abundant; Axel Heiberg Island, "lower *Cadoceras* beds" *partim* ? (Frebold, 1964a, Pl.10, Fig.2); Ellef Ringnes Island ? (Frebold, 1964a, Pl.11, Fig.2). Individual variants are close to *C. variable* Spath, although the assemblage as a whole is distinct. Both *Cadoceras* and *Keplerites* are so close to those of the Variable Zone of East Greenland that a very similar age cannot be in doubt - it is still Boreal Upper Bathonian. In Greenland there are several further faunas between Ishmae and Variable Zones indicating a considerable time gap between faunas C8 and C9, but the absence, so far, of any evidence of these faunas or their equivalents in the Yukon may well be merely collection-failure. At Salmon Cache Canyon there is a considerable thickness of poorly exposed shales in the interval in question.

Fauna C10. *Cadoceras* (*Paracadoceras*?) sp. indet.

A single layer of concretions at about the middle of some 50 m of very poorly exposed beds in the upper part of the Salmon Cache Canyon section, between faunas C9 and C11, contains rather badly preserved crushed specimens of what appeared to be *Paracadoceras* (pers. observation, 1975). If correct, it is unfortunate that it would be just this sparsely-documented part of the north Canadian succession in which the equivalents of the rich *Cadoceras*-beds of southern Alaska should be sought.

Fauna C11. *Cadoceras bодylevskiyi* FREBOLD, 1964

The type material came from the "lower *Cadoceras* beds" of Axel Heiberg Island (Frebold, 1964a). A closely similar, if not identical, assemblage occurs in great profusion in the top beds at Salmon Cache Canyon and analogous levels at other localities in the vicinity.

Fauna C12. *Cadoceras septentrionale* FREBOI, D. 1964.

Axel Heiberg Island, "upper *Cadoceras* beds" (Frebald, 1964a). These forms retain vestigial primary bullae on the umbilical margin to fairly late stages, reminiscent of earlier species, but begin to assume the globular shape and depressed whorl section characteristic of the later Lower Callovian forms like *C. sublaeve*. Extreme variants can become almost spindle-shaped. What appears to be an identical assemblage occurs in East Greenland between *Paracadoceras* and *Cadoceras sublaeve* and forms the basis there of the Septentrionale Zone which is assumed to lie immediately below the Koenigi Subzone of the Calloviense Zone.

Fauna C13. *Cadoceras voronetsae* FREBOLD, 1964 (incl. *Cad. septentrionale* var. *latidorsata* Frebold *partim*, 1964a, Pl.7, Fig.1, Pl.8, Fig.1; *Cad. arcticum* Frebold, 1964a?)

Large spherocones with smooth steep-walled conical umbilici as in the group of *C. sublaeve*. Richardsons, not closely localized and not in sequence; Cornwall Island? (type of *C. arcticum*). The relative sequence of faunas C12 and C13 is conjectural.

Fauna C14. *Cadoceras (Stenocadoceras) canadense* FREBOLD, 1964a.

Richardson Mountains, not closely localized. The finer and ventrally more strongly projected ribbing gives the impression that this species may be somewhat younger than those of the *Stenocadoceras stenoloboides/multicostatum* assemblage (B9) of southern Alaska, intermediate between it and early *Longaeviceras*, e.g., *L. filarum* Meledina (1977, Pl.24, Fig.3). This suggests a late Middle Callovian age.

Faunas C15 - C18: Oxfordian, *Cardioceras* and *Amoeboceras* spp.

Small collections have been made from widely scattered localities. The material is rarely well preserved and almost never found in faunal succession. As a whole it indicates that almost all the Oxfordian is represented at one place or another and that the ammonites are essentially the same as those found elsewhere in North America.

Fauna C15. *Cardioceras* cf. or aff. *scarburgense* (YOUNG and BIRD).

Richardsons, Berry Creek (see Poulton *et al.* 1982, Fig.1; new collection, locality Pu-2-81). ? Tombstone area, central Yukon (recorded as *Cadoceras*? sp. in Frebold *et al.*, 1967, Pl.2, Figs.3-6). Lower Oxfordian, Mariae Zone, Scarburgense Subzone.

Fauna C16. *Cardioceras* cf. or aff. *alphacordatum* SPATH or *mountjoyi* FREBOLD

Richardsons, various localities (Poulton *et al.*, 1982, p.33,37,91) including the one cited previously, in sequence above fauna C15. Axel Heiberg Island (Frebald, 1961, Pl.18, Fig.2). Lower Oxfordian, upper Mariae or lower Cordatum Zones.

Fauna C17. *Cardioceras* cf. or aff. *distans* (WHITFIELD)

Tombstone area, central Yukon (Frebald *et al.*, 1967, Pl.2, Figs.8,9, Pl.3, Fig.4; Poulton and Templeman-Kluit, 1982). Lower Oxfordian, Cordatum Zone.

Fauna C18. *Amoeboceras* sp. cf. or aff. *transitorium* SPATH

Richardsons, Martin Creek, near base of Husky Formation (recorded as *Cardioceras* sp. in Poulton, 1978b, p.464). Enough of the diagnostic serrated keel and lateral tubercles are preserved to make the identification as *Amoeboceras (Prionodoceras) firm* (see Sykes and Callomon, 1979). Early Upper Oxfordian, Serratium Zone. The specimen is important because it dates the onset of the *Buchia* facies that spread over so much of North America and displaced the otherwise ubiquitous ammonites during the Upper Jurassic.

Fauna C19. *Dorsoplanites* aff. *maximus* SPATH + *Pavlovina* (? *Paravirgatites*) sp.

Ellesmere Island (Frebald, 1961), Middle Volgian. The general resemblance to the well-known Volgian faunas of East Greenland (see Callomon and Birkelund, 1983, for a recent review), the Barents Shelf and northern Siberia (Zakharov and Meezhnikov, 1974) is obvious but a more precise match remains elusive. It is not clear whether the two specimens are strictly associated and of precisely the same age. Their closest matches in Greenland would be of somewhat different ages. The reluctance of these otherwise prolific ammonites to penetrate further than the northern end of the Sverdrup Basin during the late Jurassic and early Cretaceous remains mysterious (see also discussion below, under fauna A18).

Fauna C20. *Craspedites canadensis* JELETZKY, 1966

Ellesmere Island, a prolific fauna from a single concretion at an isolated level in the Deer Bay Formation; Upper Volgian.

The relatively rich succession of ammonite faunas in the Neocomian is summarized by Jeletzky (1973), but with rare exceptions it, too, is confined to the northern Sverdrup Basin.

Region D. Alaskan North Slope - British Mountains

The Jurassic rocks of the Brooks-Mackenzie Basin north of the "disturbed belt" attributed to the Kaltag Fault are poorly exposed and ammonites are known from only a few horizons. The Aalenian - Lower Bajocian succession has already been described in the previous section and is essentially the same as in regions B and C; faunas Bel, Be3 and Be5 have been recognized. They are succeeded by the following horizons.

Fauna D1. "*Cranocephalites*" [*Iniskinites*?] *ignekensis* IMLAY (1976)

The identity of this fauna is subject to the same doubts as is that of "*Cranocephalites*" *costidensus*, B4, from southern Alaska. It does not fit very readily into *Cranocephalites sensu stricto*, having equally close affinities with the Pacific genus *Iniskinites*, as discussed above under fauna B4, to which it bears a very close resemblance. True *Cranocephalites* occurs not far away, in Prince Patrick Island (fauna C3; Frebold, 1958, Pl.7).

Fauna D2. *Arctoccephalites* aff. *elegans* SPATH + IMLAY (1976)

Undoubtedly this is a member of the true Boreal *Arctoccephalites* close to the forms from the northern Yukon described above under fauna C4. The exact stratigraphical relations between faunas D1 and D2 still seem somewhat uncertain. At some localities D2 lies above D1, as it should if both are correctly identified. At others they appear to occur together

(Imlay, 1976), which would be simply explicable only if D1 were an *Inshikinites* rather than a *Cranoccephalites*. Boreal Bathonian, Arcticus Zone.

Fauna D3. ? *Arcticoceras* cf. *ishmae* (KEYSERLING)
Canning River (Imlay, 1976 Pl.3, Figs.22,?17,18. For the remaining material figured as *A. ishmae*, see fauna D6 below).

Fauna D4. *Cadoceras* cf. *arcticum* FREBOLD, 1964
Babbage River (eastern boundary of the British Mountains, northern Yukon; Frebold, 1964a). Aichillik River (western end of British Mountains, north-eastern Alaska; U.S.G.S. Mesozoic loc.31274, Dettnerman coll. 1976). The specimens from the Babbage River are paratypes of *C. arcticum*, although the holotype came from Cornwall Island. The scanty material most closely resembles the late *Cadoceratids* of the Calloviense Zone (cf. fauna C13), but it is not well-enough preserved for closer comparisons.

Fauna D5. *Cadoceras* (*Stenocadoceras*) cf. or aff. *canadense* FREBOLD, 1964.

Babbage River (Frebold, 1964a); cf. faunas B9, C14. Middle Callovian?

Fauna D6. *Longaeviceras* cf. *stenolobum* (KEYSERLING, 1846)

(= *Pseudocadoceras grewinkii*, Imlay, 1955, Pl.12, Fig.1; *Arcticoceras ishmae* and sp. juv., Imlay, 1976, Pl.3, Figs.1-4,7-16,19-21; *Cardioceras dettermanni* Imlay *partim* (not the holotype), 1981, Pl.10, Figs.1-4,8-11, = 1976, pp.3,5 as *Card.* (*Scarburgiceras*) sp.)
+ *Grossouvreia* sp.

Longaeviceras has a wide distribution in the Boreal Realm, and many of the Alaskan forms can be matched elsewhere. Imlay's macroconch (1976, Pl.3, Figs.7,8) is close to the true *L. stenolobum* itself, as represented by Sokolov's (1912) Plate I, Figure 4 from the Petchora [neither "the" type specimen, as claimed by Sokolov, nor even a syntype, according to Bodylevsky (1960, p.78) who renamed it *Cad. lahuseni*, but probably a topo- or chorotype]. This probably includes *L. nikitini* (Sokolov) (1912, Pl.1, Fig.3), and Newton and Teall's *Cad. modiolare* from Cape Flora. Franz Josef Land (1897, Pl.39, Fig.10, Institute of Geological Sciences Collection, London, *For 964*; cf. Clark, 1982). Imlay's Figures 9 and 10 show the onset of the characteristic shallow conical umbilicus to be seen i.a. in *L. bodylevskii* Meledina (1977, Pl.30, Fig.2), from Anabar Bay in northern Siberia. The Alaskan microconchs include some (Pl.3, Figs. 1.12, 16) that match Pompeckj's *Cad. nanseni* (1900a, Pl.2), also from Cape Flora; and others (Pl.3, Figs.14,20) that are close to *L. holdedahli* (Salfeld and Frebold, 1924, Pl.1, Figs.3,4), from Novaya Zemlya. In the Boreal Province proper (northern Alaska; northern Siberia: Lena, Olenek, Anabar; northern Russia and Barents Shelf: Petchora, Novaya Zemlya, Franz Josef Land, Spitsbergen) *Longaeviceras* dominates and occurs free of *Kosmoceras*. A little further south on the borders of the Sub-Boreal Province (e.g., in East Greenland), *Longaeviceras* and *Kosmoceras* are found in comparable numbers; while in the Sub-Boreal Province proper [e.g., England (*L. longaevum* and *placenta* (Leckenby, 1859) in Buckman, 1919-20, Pls.121, 148) and the Moscow Basin (Nikitin, 1881)], *Longaeviceras*

occurs only as a minor constituent of the faunas, which now includes abundant more southerly elements, such as *Perisphinctidae* and *Peltoceras*. Upper Callovian, Athleta Zone, probably middle part, a little younger than fauna B10 of southern Alaska; *Longaeviceras keyserlingi* Zone of Soviet authors.

Fauna D7. *Cardioceras* cf. *hyatti* REESIDÉ *sensu* IMLAY, 1982

British Mountains, Babbage River (Frebold *et al.*, 1967, Pl.3, Figs.2,3). The scanty material seems to match some of the forms figured by Imlay (1982, Pl.15), from fauna A14, q.v. Lower Oxfordian, Cordatum Zone.

Fauna D8. *Cardioceras* (*Maltoceras*) sp.
British Mountains, Babbage River (Frebold, *et al.*, 1967, Pl.2, Fig.10, Pl.2, Fig.1). Middle Oxfordian, upper *Densiplicatum* Zone.

Fauna D9. *Cardioceras* - *Amoeboceras* sp. nov. + *Buchia concentrica*

Canning River (Imlay, 1976 p.4, Text-fig.1; 1981, Pl.12, Figs.16-21). Hard to place closely; the macroconch (Pl.12, Figs.19-21) still resembles late *Card.* (*Maltoceras*) in the crenulation of the keel (cf. Arkell, 1941, Pl.51, Figs.3b,7b) but *Amoeboceras* (*Prionodoceras*) in-ribbing and coiling, whereas the microconch (Fig.16) resembles *Amoeboceras* s.s. in its keel but *Card.* (*Vertebriceras*) in ribbing (cf. de Riaz, 1898, Pl.16, Fig.8; Gygi and Marchand, 1982, Pl.13, Fig.2) of the Blakci Subzone of the Tenuserratum Zone. Hence the age is probably earliest Upper Oxfordian, basal Glosense Zone.

Fauna D10. *Amoeboceras* spp. + *Buchia concentrica*
Canning River (Imlay, 1955, Pl.12, Figs.2-6; 1981, Pl.12, Fig.1) and Babbage River (Frebold *et al.*, 1967, Pl.3, Figs.5-7). These barely determinable fragments suggest a late Upper Oxfordian age, perhaps Rosenkrantz Zone.

Higher Jurassic beds are indicated by further *Buchia* spp., but ammonites first reappear in the Albian (see Imlay, 1961, *PP* 335).

CORRELATION

The ammonite faunas and their supposed successions in regions A to D are shown in Figures 3, 4 and 5. It must be stressed that these tables represent no more than time-ordered sequences and that vertical spacing are not proportional to time-intervals. Neither are the thicknesses of the boxes representing the faunas meant to suggest equal time-durations. The effective time-durations of the faunas as catalogued in this review must have varied enormously, from the instantaneous to periods comparable to that represented by the whole of an average standard ammonite Zone. Boxes in adjacent columns shown as partly or wholly overlapping are meant to suggest that their faunas probably differ but little in age, although their precise order is usually not known.

Upper Bajocian - Bathonian (Figure 3)

The relevant part of the standard Boreal Middle Jurassic ammonite zonation is indicated as a reference scale on the right. Standard European Stages are named on the left, but their

ammonite Zones are not included because correlation of the American faunas with them at this level of precision is still quite impossible. Ranges of some important genera are also shown.

The boundary between Bajocian and Bathonian has been drawn to lie above faunas B2 - B4 with *Leptaspinctes* ("Cobbanites" s.s.) and below fauna A4 with (fairly late) *Procerites*. If the interpretation of "*Cranocephalites costidensis* (B4) and "*C. ignekensis* (D1) suggested in the text is correct, the proximity of the latter to the earliest *Arctocepalites* of D2, which in turn correlates closely with C4, would indicate that the Bajocian - Bathonian boundary in the standard Boreal succession lies somewhere around the Pompeckji - Arctician boundary. This would be new. Hitherto, except for a suggestion that the Borealis Zone might still be Upper Bajocian, no attempt has been made to indicate this boundary more closely. There has just been no evidence, and everything from the *Cranocephalites indistinctus* Zone to the *Cadoceras calyx* Zone inclusive below the beds with *Keplerites kepleri*, has been simply referred to as "Boreal Bathonian". The closeness of the resemblance between *Cranocephalites borealis* (C1) and *Chondroceras oblatum* of the North American Oblatum Zone, correlated with the European Humphriesianum Zone, that has become apparent in recent times strengthens the idea that all the true *Cranocephalites* beds of the Arctic may still be Upper Bajocian.

Faunas A4 and B6 are shown close together because both appear to mark the lowest appearance in their regions of *Keplerites* with forms that are closely similar. Faunas A5 and A7 are correlated with the Boreal Cranocephaloides Zone because of the characteristic small, fine-ribbed *Keplerites* they contain. In East Greenland *Keplerites* first appears suddenly and in quantity in this Zone. Hence, if the correlation is correct, it must occur in North America already somewhat earlier. Assuming that the time-interval between A4 and A5 is short, this correlation leaves a considerable gap between A4 or B6 and B4, filled in the north by faunas C5 - C8 whose close correlation with the standard Boreal succession is in no doubt. The Cranocephaloides Zone has been taken arbitrarily to mark the base of the Boreal Upper Bathonian, but that does not imply that it also correlates with the base of the European Upper Bathonian. The *Procerites* of faunas A4 - A7 still resemble rather more those of the European Middle Bathonian, although the genus does range up into the lowest, Hodsoni Zone of the Upper Bathonian there (cf. Torrens in Cope, 1980).

Faunas A8 and B7 are correlated with the Peramplius Subzone of the Calyx Zone of the Boreal succession, again on the strength of the *Keplerites* they contain, particularly the microconchs (*K. knecheli*, *alaskanus*). The single *Keplerites* of A10 resembles those of the upper Calyx Zone. Nothing can be said about the precise relative age of fauna A9, and hence it has been omitted.

Looking at Figure 3 as a whole, probably the most striking feature of the correlations proposed is the inclusion of all of the long and well-known "Callovian" faunas A3 to A8 of the Western Interior still in the Bathonian. In fact, with the exception of the single fauna A11 from Montana at the very top, the Callovian appears not to be represented by ammonites in the Western Interior at all. It may seem ironic that this marks a return to the interpretation that Imlay would clearly have

preferred originally on the strength of the mollusca other than the ammonites (Imlay, 1956). These include *Gryphaea*, and the ranges of the important species are also indicated in Figure 3 (cf. Hallam and Gould, 1975).

Callovian (Figure 4)

Standard Boreal and European zonal scales are indicated on the right and left. The richness of the faunas from southern Alaska distorts the table and weighs it heavily in favour of its lower part.

The position of the Bathonian - Callovian boundary is based on the correlation via East Greenland of *Keplerites loganiamus* with *K. kepleri*, and hence with the stratotype of the base of the Callovian in England. The Macrocephalus Zone is thus as defined stratigraphically (Callomon, 1964) and not by the supposed first appearance of *Macrocephalites* in Europe (Thierry, 1978). Most of the faunas fall into the equivalents of this Zone and probably its lowest Subzone at that, and they reveal the fact that the thick volcanoclastic turbiditic sequences of southern Alaska were deposited in short bursts of rapid sedimentation separated by major non-sequences that are inconspicuous.

Oxfordian - Volgian (Figure 5)

This figure calls for few comments. The standard Boreal Oxfordian ammonite zonation shown at the left applies to the whole of North America north of the 37th parallel, with the exception of the small corner in south-western Oregon, probably displaced tectonically from the south, that bears Tithonian faunas. Assignments of individual faunas, and their uncertainties, are discussed in the text.

CONCLUSIONS

This review has attempted to re-examine the Middle and Upper Jurassic ammonite faunas of North America in the light of what has become known in the last 25 years of ammonoid biostratigraphy more widely, particularly in the Arctic, and of what has been learned of the distribution, evolution, and classification of the Jurassic ammonites as a whole. The principal conclusions are as follows.

Faunal Provincialism

During the early Middle Jurassic, up to the Humphriesianum Zone of the Bajocian, the ammonites of North America divide into two broad faunal domains. Regions A and B, Western Interior and Cordillera, were inhabited mainly by pandemic Tethyan faunas with only minor locally provincial elements (e.g., *Zemistephanus*, *Parabigotites*, *Chondroceras oblatum*). Regions C and D, Arctic Canada and Alaska, belonged to a clearly differentiated Boreal Realm (*Pseudolicoeras*) and North Pacific or Bering Province (*Erycitoides*, *Arkelloeras*). The provinces overlapped strongly in southern Alaska, so that correlation presents no problems.

At the beginning of the Upper Bajocian, provincialism suddenly became acute. Regions A and B were now firmly part of a well-differentiated Pacific Realm, in which Eurycephalitinae of the Sphaeroceratidae dominated, with strong faunal affinities

between, for example, the Cordilleras of both North and South America. Region C (Arctic Canada) was part of an equally well-differentiated Boreal Realm characterized mainly by Arctocéphalitinae and Cadoceratinae of the Cardioceratidae; and region D appeared to be one of overlap between Pacific and Boreal Realms. The ammonites of Pacific, Boreal and Tethyan Realms became so mutually exclusive in the Upper Bajocian and Bathonian that correlation at zonal level is still not possible. Each realm, therefore, has to retain its own independent ammonite zonation up to about the top of the Lower Callovian.

A more restricted provincialism is also discernible in these realms during this time. The shallow epicontinental basins of region A, far distant from the Pacific Ocean, appeared to develop their own endemic faunas of Eurycephalitinae, forming a separate Middle Jurassic Western Interior or Shoshonean Province (see Taylor *et al.*, this volume). Some other genera, e.g., *Parareineckeia*, *Epizigzagiceras* and *Iniskinites*, extending over all of region B, mark a North Cordilleran, or Athabaskan Province (Taylor *et al.*, this volume). A Sub-Boreal Province is characterized by *Keplerites* of the Kosmoceratidae. It overlaps with the North Cordilleran and Western Interior Provinces of North America, the Boreal Province of North America and East Greenland, and thence the Submediterranean Province of Europe, thereby providing one of the few links that make even rough interprovincial correlations possible at the Bathonian - Callovian boundary.

In the Upper Jurassic, the ammonite faunas of the whole of regions A to D, mainly Cardioceratidae, become homogeneously representative of the Boreal Realm and Province. They stand in sharp contrast to the Submediterranean and Tethyan faunas of Mexico. The boundary between the realms probably oscillated somewhat with time and lay mainly in southern California, but its positions are rarely known more closely. lost or heavily obscured by subsequent tectonic deformations.

Regional Allochthony and Tectonic Displacements

Current discussions of the growth of western North America by the accretion of terranes pose three questions on which the present review may have a bearing. They are: what light, if any, can the distribution of ammonites as found today throw on: 1) possible movements since the Middle Jurassic of terranes within the Cordilleran domain, region B, relative to each other? 2) movements between terranes in the Cordillera, B, and the cratonic domains of the Western Interior, A, and Arctic Canada, C? and 3) movements of the Alaskan Brooks Range and North Slope, D, relative to the craton, C?

An upper limit to movements within the Cordillera can be put forward from a comparison of the faunas of the Alaska Peninsula with those of British Columbia and Oregon. There are striking similarities that have been pointed out above, but there are also differences. The most significant lies in the distribution of *Cadoceras*. This Boreal Lower Callovian genus dominated in Alaska and at other localities as far south as Vancouver Island and southern British Columbia, but not further south. This southern limit appears to have been the Boreal provincial boundary, which suggests that had the Alaskan Peninsular terrane moved north, it could probably not have come from much further south than about the 49th parallel, putting an

upper limit on the displacement of perhaps 2000 km (1300 miles). On the other hand, the evidence is equally consistent with a movement of zero.

Evidence for or against lateral displacement between Cordilleran terranes and the cratonic Western Interior is tenuous. The Sub-Boreal *Keplerites* found in the northern parts of the Western Interior have rough equivalents in east-central Oregon and southern British Columbia, and in one case as far south as north-central California. Similarly, the Boreal Cardioceratidae of the Western Interior go right across at the same latitude into Oregon. Conversely, with the exception of the Tithonian faunas found in northern California and southwestern Oregon (and, in the Neocomian, as far north as Vancouver Island), Tethyan ammonites are not found north of California. This strongly suggests that the Boreal - Tethyan faunal boundary lay at about the same latitude in the Cordillera as it did in the Western Interior, i.e., that with the exceptions mentioned above, right lateral movements cannot have exceeded a few hundred kilometres. They could again equally well have been zero. The presence of strongly Boreal faunas (B16) as far south as Mariposa County in central California could even be construed as evidence in favour of a left-lateral (southward) displacement, although associated sub-Mediterranean forms would favour provincial overlap as a preferred explanation. Similarly, the proximity of purely Boreal Callovian and Tethyan Neocomian faunas on the west coast of Vancouver Island (Jeletzky, 1964) would seem to cancel each other out as possible indicators of serious left- and right-lateral movements respectively. In summary, Middle and Upper Jurassic ammonites as found today are consistent with lateral Cordilleran tectonic displacements of from zero to perhaps some hundreds of kilometres, with 2000 km for the Alaskan Peninsula as absolute maximum.

With regard to the North Slope terrane, D, its Jurassic ammonites are typical of the Boreal Province throughout and its affinities close with those of the adjacent region C. Comparing columns C and D in Figures 3 to 5, the number of mismatches greatly exceeds the coincidences, which could be thought to suggest that the two regions may have been much further apart during the Jurassic than they are now. However, the differences could be attributed equally satisfactorily to a combination of facies-differences and collection-failure. The Jurassic sediments of region C yielding abundant ammonites are predominantly of near-shore shallow-water facies, whereas those of D (sparsely fossiliferous Kingak Shale) are of more distal basinal type; and the distances between them today are consistent with the facies-gradients that are observed in region C. The presence of a strong residual Pacific influence (*Arkeloceras*, and "*Cranocéphalites ignenkensis* of fauna D4) points, moreover, to a former position not much further from the Pacific than what it is at present. The evidence as a whole cannot rule out relative displacements of up to at most a few hundred kilometres, but is also again consistent with displacements of zero.

The catalogue of faunas put together in this review leaves many smaller assemblages from widely scattered localities unassigned for lack of evidence. The positions of some of those that have been assigned are open to question and will doubtlessly have to be revised. Yet others will come to be discovered

and will have to be slotted into the gaps. Whatever the permanence of the present scheme may turn out to be, it will have fulfilled its purpose if, by pointing to the many gaps and uncertainties, it stimulates further efforts to make the state of our knowledge more complete.

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REFERENCES

- Arkell, W.J., 1939, The Ammonite Succession at the Woodham Brick Company's Pit, Akeman Street Station, Buckinghamshire, and Its Bearing on the Classification of the Oxford Clay. Quarterly Journal of the Geological Society, London, v.95, p.135-222.
- , 1941, 1946, A Monograph of the Ammonites of the English Corallian Beds: Monograph of the Palaeontographical Society, London, Pt.vii, 217-238, Pt.xi, p.297-332.
- , 1952, 1954, Monograph of the English Bathonian Ammonites: Monograph of the Palaeontographical Society, London, Pt.iii, p.73-102; pt.iv, p.103-128.
- , 1956, Jurassic Geology of the World: Oliver and Boyd, Edinburgh and London, 806 p.
- , 1957, in Moore, R.C., ed., Treatise on Invertebrate Paleontology, pt.L, Mollusca 4: Kansas, University of Kansas Press, 490 p.
- Besnosov, N.V., 1982, On the systematics of the Perisphinctidae (Ammonoidea): Paleontologicheskii Zhurnal, 1982, p.54-64 (in Russian).
- Bidzhiyev, R.A., 1965, Zonal Analysis of the Jurassic Deposits of the Northern Pre-Verkhnoyan Regional Depression: Geologiya i Geofizika, v.4, p.49-57, in Russian.
- Birkelund, T., Hakansson, E., and Surlyk, F., 1971, New Finds of Bathonian, Callovian and Oxfordian Ammonites in Northern Jameson Land, East Greenland: Geological Society of Denmark Bulletin 20, p.240-259.
- Blake, J.F., 1905, A Monograph of the Fauna of the Cornbrash: Monograph of the Palaeontographical Society, London, Pt.i, p.1-100.
- Bodylevsky, V.I., 1960: Callovian ammonites from northern Siberia: Zapiski Leningradskogo ... gornogo Institut, v.37, vyp.2, p.49-82, in Russian.
- Buckman, S.S., 1881, A Descriptive Catalogue of Some of the Species of Ammonites from the Inferior Oolite of Dorset: Quarterly Journal of the Geological Society, v.37, p.588-608.
- , 1918-1927, Yorkshire Type Ammonites, v.2, and Type Ammonites, v.3-7, Plates 68-790: London, published by the author and Wheldon and Wesley; reprinted 1972-1976 as Historia Naturalis Classica, v.93, J. Cramer Verlag, Lehre, and Wheldon and Wesley, Codicote, Herts., U.K.
- , 1929, Jurassic Ammonoidea: National Museum Canada Bulletin 58, p.1-27.
- Burckhardt, C., 1903, Beiträge zur Kenntniss der Jura- und der Kreide-Formation der Cordillere: Palaeontographica, v.50, Pt.i, p.1-72.
- , 1927, Cefalopodes del Jurásico Medio de Oaxaca y Guerrero: Instituto Geológico de Mexico, Bol.47, 108p.
- Callomon, J.H., 1959, The Ammonite Zones of the Middle Jurassic Beds of East Greenland: Geological Magazine, v.96, p.505-513.
- , 1964, Notes on the Callovian and Oxfordian Stages: Institut Grand-Ducal Luxembourg, Sect. Sciences Naturelles, Physiques et Mathématiques, Comptes Rendues et Mémoires du Colloque Jurassique, Luxembourg, 1962, p.269-291.
- , 1972, An Annotated Map of the Permian and Mesozoic Formations of East Greenland: Jurassic System: Meddelelser om Grønland, v.168, no.3, p.15-20.
- , 1981a, Classification of the Jurassic Ammonitina: in House, M.R., and Senior, J.R., eds., The Ammonoidea: Systematics Association Special Publication 18, Academic Press, London and New York, p.101-155.
- , 1981b, Dimorphism in Ammonoids: in House, M.R., and Senior, J.R., eds., The Ammonoidea: Systematics Association Special Publication 18, London and New York, Academic Press, p.257-273.
- Callomon, J.H. and Birkelund, T., 1980, The Jurassic Transgression and the Mid-Late Jurassic Succession in Milne Land, Central East Greenland: Geological Magazine, v.117, p.211-226.
- , 1983, The ammonite zones of the Boreal Volgian (Upper Jurassic) in East Greenland: in Embry, A.F., and Baikwill, H.R., eds., Arctic Geology and Geophysics: Canadian Society of Petroleum Geologists, Memoir 8, p.349-369.
- Clark, R.D., 1982, Type, Figured and Cited Jurassic Cephalopoda in the Collection of the Institute of Geological Sciences: Institute of Geological Sciences, London, Report 82/9, 104p.
- Cope, J.C.W., ed., 1980, A Correlation of Jurassic Rocks in the British Isles: Pt.II: Middle and Upper Jurassic: Geological Society of London, Special Report 15, 109p.
- Crickmay, C.H., 1930, Fossils from Harrison Lake Area, British Columbia: National Museum Canada, Bull.63, Geol. Ser. No.51, p.33-66.
- , 1933, Mount Jura Investigation: Geological Society of America Bulletin 44, p.895-926.
- Dietl, G., 1980, Die Ammoniten-Gattung *Leptosphinctes* aus dem südwestdeutschen Subfuranen-Oolith (Bajocium, Mittl. Jura): Stuttgarter Beiträge Naturkunde, v.66B, 49p.
- , 1981, Über *Macrocephalites* (Ammonoidea) aus dem Aspidoites-Oolith und die Bathonium/Callovium-Grenzschiechten der Zollernalb (SW-Deutschland): Stuttgarter Beiträge Naturkunde v.68B, 15p.
- Donovan, D.T., 1953, The Jurassic and Cretaceous Stratigraphy and Palaeontology of Traill 0, East Greenland: Meddelelser om Grønland, v.111, no.4, 150p.
- Douglas, J.A., and Arkell, W.J., 1928, The Stratigraphic Distribution of the Cornbrash 1, The Southwestern Area: Quarterly Journal of the Geological Society, London, v.84, p.117-178.
- Efimova, A.F., Kinasov, V.P., Paraketsov, K.V., Polubotko, I.V., Repin, Y.S., and Dagus, A.S., 1968, Field Atlas of the Jurassic Faunas and Floras of Northeastern U.S.S.R.: Magadan, Ministry of Geology of the R.S.F.S.R., 382p.
- Enay, R., 1959, Note sur quelques Tullidites (Ammonitina) du Bathonien: Bulletin de la Société Géologique de France, 7^e série, v.1, p.252-289.
- Ersnova, E.S., and Melcedina, S.V., 1968, Late Bathonian Oplididae of Northern Siberia: in Saks, V.N., ed., Mesozoic Marine Faunas of the Northern and Far-eastern U.S.S.R. and Their Stratigra-

- phic significance: Trudy, Instituta Geologii i Geofiziki Akad. Nauk S.S.S.R., Sibirskoe otdelenie, v.48, p.42-50, in Russian.
- Flower, R.H., 1942. Antarctic Cephalopod Faunule from the Cynthia of Kentucky: *Bulletins of American Paleontology*, v.27, p.5-41.
- Frebold, H., 1957. The Jurassic Fernie Group in the Canadian Rocky Mountains and Foothills: *Geological Survey of Canada Memoir* 287, 197 p.
- _____, 1958. Fauna, Age and Correlation of the Jurassic Rocks of Prince Patrick Island: *Geological Survey of Canada Bulletin* 41, 69 p.
- _____, 1959. Systematic Description of Fossils: in Frebold, H., Mountjoy, E., and Reed, R. The Oxfordian Beds of the Jurassic Fernie Group, Alberta and British Columbia: *Geological Survey of Canada Bulletin* 53, p.20-29.
- _____, 1960. The Jurassic Faunas of the Canadian Arctic - Lower Jurassic and Lowermost Middle Jurassic Ammonites: *Geological Survey of Canada Bulletin* 59, 33 p.
- _____, 1961. The Jurassic Faunas of the Canadian Arctic - Middle and Upper Jurassic Ammonites: *Geological Survey of Canada Bulletin* 74, 43 p.
- _____, 1963. Ammonite Faunas of the Upper Middle Jurassic Beds of the Fernie Group in Western Canada: *Geological Survey of Canada Bulletin* 93, 33 p.
- _____, 1964a. The Jurassic Faunas of the Canadian Arctic - Cadoceratinae: *Geological Survey of Canada Bulletin* 119, 27 p.
- _____, 1964b. Illustrations of Canadian fossils - Jurassic of Western and Arctic Canada: *Geological Survey of Canada Paper* 64-3, 106 p.
- _____, 1967. Systematic Descriptions: in Frebold, H., and Tipper, H.W., Middle Callovian Sedimentary Rocks and Guide Ammonites from Southwestern British Columbia: *Geological Survey of Canada Paper* 67-21, p.9-16.
- _____, 1975. The Jurassic Faunas of the Canadian Arctic - Lower Jurassic Ammonites, Biostratigraphy and Correlations: *Geological Survey of Canada Bulletin* 243, 24 p.
- _____, 1978. Ammonites from the late Bathonian "Iniskinites fauna" of central British Columbia: *Geological Survey of Canada Bulletin* 307, 26 p.
- _____, 1979. Occurrence of the Upper Bathonian Ammonite Genus *Iniskinites* in the Queen Charlotte Islands, British Columbia: *Geological Survey of Canada, Current Research C, Paper* 79-1C, p.63-66.
- Frebold, H., Mountjoy, E., and Reed, R., 1959. The Oxfordian Beds of the Jurassic Fernie Group, Alberta and British Columbia: *Geological Survey of Canada Bulletin* 53, 47 p.
- Frebold, H., Mountjoy, E.W., and Templeman-Kluit, D.J., 1967. New Occurrences of Jurassic Rocks and Fossils in Central and Northern Yukon: *Geological Survey of Canada, Paper* 67-12, 35 p.
- Frebold, H., and Tipper, H.W., 1967. Middle Callovian Sedimentary Rocks and Guide Ammonites from Southwestern British Columbia: *Geological Survey of Canada Paper* 67-21, 29 p.
- _____, 1970. Status of the Jurassic in the Canadian Cordillera of British Columbia, Alberta and Southern Yukon: *Canadian Journal of Earth Sciences*, v.7, p.1-21.
- _____, 1973. Upper Bajocian - Lower Bathonian Ammonite Faunas and Stratigraphy of Smithers Area, British Columbia: *Canadian Journal of Earth Sciences*, v.10, p.1109-1131.
- _____, 1975. Upper Callovian and Lower Oxfordian Ammonites from Southeastern Bowser Basin, British Columbia: *Canadian Journal of Earth Sciences*, v.12, p.145-157.
- Gibson, D.W., 1979. The Morrisey and Mist Mountain Formations - Newly Defined Lithostratigraphic Units of the Jura-Cretaceous Kootenay Group, Alberta and British Columbia: *Bulletin of Canadian Petroleum Geology*, v.27, p.183-208.
- Grewingk, C., 1850. Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der Nord-West-Küste Amerikas mit den anliegenden Inseln: *Verhandlungen der Russisch-kaiserlichen mineralogischen Gesellschaft zu St. Petersburg*, Jahrgang 1848 and 1849, p.76-424.
- Gygi, R.A., and Marchand, D., 1982. Les Faunes de Cardioceratinae (Ammonoidea) du Callovien Terminal et de l'Oxfordien Inférieur et Moyen (Jurassique) de la Suisse Septentrionale: *Stratigraphie, Paléobiologie, Taxonomie Préliminaire: Géobios*, v.15, p.517-571.
- Hall, R.L., and Stronach, N.J., 1981. First Record of Late Bajocian (Jurassic) Ammonites in the Fernie Formation, Alberta: *Canadian Journal of Earth Sciences*, v.18, p.919-925.
- Hall, R.L., and Westermann, G.E.G., 1980. Lower Bajocian (Jurassic) Cephalopod Faunas from Western Canada and Proposed Assemblage Zones from the Lower Bajocian of North America: *Palaentographica Americana*, v.9, no.52, 93 p.
- Hallam, A., and Gould, S.J., 1975. The Evolution of British and American Middle and Upper Jurassic *Gryphaea*: a Biometric Study: *Proceedings of the Royal Society of London, B*, v.189, p.511-542.
- Hambin, A.P., 1978. Sedimentology of a Prograding Shallow Marine Slope and Shelf Sequence, Upper Jurassic Fernie-Kootenay Transition, Southern Front Ranges: M.Sc. Thesis, McMaster University, Hamilton, 196 p.
- Hambin, A.P., and Walker, R.G., 1979. Storm-Dominated Shallow Marine Deposits: the Fernie-Kootenay (Jurassic) Transition, Southern Rocky Mountains: *Canadian Journal of Earth Sciences*, v.16, p.1673-1690.
- Houghton, S., 1858. Geological Notes and Illustrations in M'Clintock's Reminiscences of Arctic Ice Travel: *Journal of the Royal Dublin Society*, v.1, p.183-250.
- Hillebrandt, A. von, 1970. Zur Biostratigraphie und Ammoniten-Fauna des südamerikanischen Jura (insbes. Chile): *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, v.136, p.166-211.
- _____, 1977. Ammoniten aus dem Bajocien (Jura) von Chile (Südamerika): *Mitteilungen aus der Bayerischen Staatssammlung für Paläontologie und historischen Geologie*, v.17, p.35-69.
- Hyatt, A., 1913. Trias and Jura in the Western States: *Geological Society of America Bulletin* 5, p.395-434.
- Imlay, R.W., 1948. Characteristic Marine Jurassic Fossils from the Western Interior of the United States: *United States Geological Survey Professional Paper* 214B, p.13-33.
- _____, 1953a. Callovian (Jurassic) Ammonites from the United States and Alaska, Part I: Western Interior United States: *United States Geological Survey Professional Paper* 249-A, 39 p.
- _____, 1953b. Callovian (Jurassic) Ammonites from the United States and Alaska, Part II: Alaska Peninsula and Cook Inlet: *United States Geological Survey Professional Paper* 249-B, p.41-108.
- _____, 1955. Characteristic Jurassic Molluscs from Northern Alaska: *United States Geological Survey Professional Paper* 274-D, p.69-96.
- _____, 1956. Review of Arkell, W.J., 1956, Jurassic Geology of the World: *Journal of Paleontology*, v.30, p.1376-1377.
- _____, 1961a. New Genera and Subgenera of Jurassic (Bajocian) Ammonites from Alaska: *Journal of Paleontology*, v.35, p.467-474.
- _____, 1961b. Characteristic Lower Cretaceous Megafossils from

- Southern Alaska: United States Geological Survey Professional Paper 335, 74 p.
- _____. 1961c, Late Jurassic Ammonites from the Western Sierra Nevada, California: United States Geological Survey Professional Paper 374-D, 30 p.
- _____. 1962a, Jurassic (Bathonian or Early Callovian) Ammonites from Alaska and Montana: United States Geological Survey Professional Paper 374-C, 32 p.
- _____. 1962b, Late Bajocian Ammonites from the Cook Inlet Region, Alaska: United States Geological Survey Professional Paper 418-A, 15 p.
- _____. 1964a, Middle Bajocian Ammonites from the Cook Inlet Region, Alaska: United States Geological Survey Professional Paper 418-B, 54 p.
- _____. 1964b, Upper Jurassic Molluscs from Eastern Oregon and Western Idaho: United States Geological Survey Professional Paper 483-D, 24 p.
- _____. 1965, Jurassic marine faunal differentiation in North America: *Journal of Paleontology*, v.39, p. 1023-1038.
- _____. 1967, Twin Creek Limestone (Jurassic) in the Western Interior of the United States: United States Geological Survey Professional Paper 540, 105 p.
- _____. 1973, Middle Jurassic (Bajocian) Ammonites from Eastern Oregon: United States Geological Survey Professional Paper 756, 100 p.
- _____. 1975, Stratigraphic Distribution and Zonation of Jurassic (Callovian) Ammonites in Southern Alaska: United States Geological Survey Professional Paper 836, 28 p.
- _____. 1976, Middle Jurassic (Bajocian and Bathonian) Ammonites from North Alaska: United States Geological Survey Professional Paper 854, 22 p.
- _____. 1980a, Jurassic Paleobiogeography of the Conterminous United States in its Continental Setting: United States Geological Survey Professional Paper 1062, 134 p.
- _____. 1980b, Middle Jurassic (Bathonian) Ammonites from Southern Alaska: United States Geological Survey Professional Paper 1091, 42 p.
- _____. 1981a, Jurassic (Bathonian and Callovian) Ammonites in Eastern Oregon and Western Idaho: United States Geological Survey Professional Paper 1142, 25 p.
- _____. 1981b, Late Jurassic Ammonites from Alaska: United States Geological Survey Professional Paper 1190, 40 p.
- _____. 1982a, Late Bajocian Ammonites from Southern Alaska: United States Geological Survey Professional Paper 1189, 19 p.
- _____. 1982b, Jurassic (Oxfordian and Late Callovian) Ammonites from the Western Interior Region of the United States: United States Geological Survey Professional Paper 1232, 44 p.
- Imlay, R.W., and Jones, D.L., 1970, Ammonites from the *Buchia* Zone in Northwestern California and Southwestern Oregon: United States Geological Survey Professional Paper 647-B, 59 p.
- Jeletzky, J.A., 1964, Illustrations of Canadian Fossils - Early Lower Cretaceous (Berriasian and Valanginian) of the Canadian Western Cordillera, British Columbia: Geological Survey of Canada Paper 64-6, 18 p.
- _____. 1966, Upper Volgian (latest Jurassic) Ammonites and *Buchias* of Arctic Canada: Geological Survey of Canada Bulletin 128, 52 p.
- _____. 1973, Biochronology of the marine Boreal latest Jurassic, Berriasian and Valanginian of Canada: in Casey, R., and Rawson, P.F. eds., *The Boreal Lower Cretaceous*: Liverpool, Geological Journal Special Issue No. 5, p.41-80.
- Keyserling, A. von, 1846, Wissenschaftliche Beobachtungen auf einer Reise in das Petschoraland im Jahre 1843: St. Petersburg, Carl Kray, 465 p.
- Kilian, W., and Reboul, P., 1909, Les Céphalopodes Néocrétacés des Îles Seymour et Snow Hill: Wissenschaftliche Ergebnisse der Schwedischen Südpolar-Expedition, 1901-1903, v.1, Lief.6, 75 p.
- Leckenby, J., 1859, On the Kelloway Rock of the Yorkshire Coast: *Quarterly Journal of the Geological Society*, London, v.15, p.4-15.
- Madsen, V., 1904, On Jurassic Fossils from East-Greenland: *Meddelelse om Grønland*, v.29, p.157-211.
- Maire, V., 1938, Contribution à la Connaissance des Cardioceratidés: *Mémoires de la Société Géologique de France, Nouvelle Série*, Méin. 34, 132 p.
- McLearn, F.H., 1927, Some Canadian Jurassic Faunas: *Transactions of the Royal Society of Canada, Sect. IV, Ser.3*, v.21, p.61-73.
- _____. 1928, New Jurassic Ammonoidea from the Fernie Formation, Alberta: *Geological Survey of Canada Bulletin 49*, Geological Series No. 48, p.19-22.
- McLearn, F.H., 1929, Contributions to the Stratigraphy and Palaeontology of Skidegate Inlet, Queen Charlotte Islands, B.C.: *National Museum of Canada Bulletin 58*, p.1-27.
- Meeck, F.B., 1859, Remarks on the Cretaceous fossils collected by Professor Henry Y. Hind, on the Assiniboine and Saskatchewan Exploring Expedition, with Description of Some New Species, Northwest Territory: in Hind, H.Y., *Reports of Progress, Together with a Preliminary and General Report on the Assiniboine and Saskatchewan Exploring Expedition*: Toronto.
- Meeck, F.B., and Hayden, F.V., 1859, Description of New Organic Remains Collected in Nebraska Territory in the Year 1857, by Dr F.V. Hayden, Geologist to the Exploring Expedition under the Command of Lieut. G.K. Warren, Top. Engr. U.S. Army, Together with Some Remarks on the Geology of the Black Hills and Portions of the Surrounding Country: *Academy of Natural Sciences, Philadelphia, Proceedings for 1858*, p.41-59.
- _____. 1865, Palaeontology of the upper Missouri: a Report upon Collections Made Principally by the Expedition under the Command of Lieut. G.K. Warren, U.S. Top. Engineers, in 1855 and 1856. *Invertebrates*: *Smithsonian Contributions to Knowledge*, v.14, art.5, 135 p.
- Meléndez, S.V., 1967, A New Genus of Middle Jurassic Arctic Ammonites: in Saks, V.N., ed., *Problems of Paleontological Substantiation of Detailed Mesozoic Stratigraphy of Siberia and the Far East of the U.S.S.R.*: Leningrad, Academy of Sciences of the U.S.S.R., Siberian Branch, Institute of Geology and Geophysics, p.103-109 (in Russian).
- _____. 1968, Middle Jurassic Boreal ammonites of Siberia and their stratigraphical significance: *Doklady Akademii Nauk S.S.S.R.*, v. 183, p. 416-419; and *Doklady Earth Science Sections*, American Geological Institute, v.183, p.54-57.
- _____. 1973, The Ammonoid Zonal Stratigraphy of the Bajocian - Bathonian of Siberia: *Trudy, Institut Geologii i Geofiziki, Akad. Nauk S.S.S.R., Sibirskoje otdel.*, v. 153, 152 p. (in Russian).
- _____. 1977, The ammonites and Zonal Stratigraphy of the Callovian of Siberia: *Trudy, Institut Geologii i Geofiziki, Akad. Nauk S.S.S.R., Sibirskoje otdel.*, v. 356, 290 p. (in Russian).
- Meszhnikov, M.S., 1967, A New Ammonite Zone of the Upper Oxfordian and the Position of the Oxfordian-Kimmeridgian Boundary in Northern Siberia: in Saks, V.N., ed., *Problems of Paleontological Substantiation of Detailed Mesozoic Stratigraphy of Siberia and the Far East of the U.S.S.R.*: Leningrad, Academy of Sciences of the U.S.S.R., Siberian Branch, Institute of Geology and Geophysics, p.110-113, in Russian.
- Newmarch, C.B., 1953, Geology of the Crownstee Coal Basin with Special Reference to the Fernie Area: *British Columbia Department of Mines Bulletin* 53, 107 p.
- Newton, E.T., and Teall, J.H.H., 1897, Notes on a Collection of

- Rocks and Fossils from Franz Josef Land, Made by the Jackson-Harmsworth Expedition During 1894-1896. Quarterly Journal of the Geological Society, London, v.53, p.477-519.
- Nikitin, S.N., 1881, Der Jura der Umgegend von Elatma: Mémoires de la Société Impériale des Naturalistes de Moscou, Nouvelle Série, v.14, p.85-133.
- Oppel, A., 1862, Über jurassische Cephalopoden: Palaeontologische Mittheilungen des Museum des königlichen Bayerischen Staates, v.3, p.127-162.
- Parsons, C.F., 1976, A Stratigraphic Revision of the *Humphriesianum*/Subfucatum Zone Rocks (Bajocian Stage, Middle Jurassic) of Southern England: Newsletter of Stratigraphy, v.5, p.114-142.
- Pavia, G., 1973, Ammoniti del Baiociano Superiore di Digne (Francia SE, Dip. Basses-Alpes): Società Paleontologica Italiana, Boll. 10, p.75-142.
- Pompeckj, J.F., 1900a, The Jurassic Fauna of Cape Flora, Franz Josef Land: in Nansen, F., ed., The Norwegian North Polar Expedition 1893-1896: Scientific Results, v.1, pt.ii, p.33-148.
- _____, 1900b, Jura-Fossilien aus Alaska: Verhandlungen der kaiserlichen Russischen Mineralogischen Gesellschaft St. Petersburg, Ser.2, v.38, p.239-281.
- Poulton, T.P., 1978a, Internal Correlations and Thickness Trends, Jurassic Bug Creek Formation, Northeastern Yukon and Adjacent Northwest Territories: Geological Survey of Canada Paper 78-1B, p.27-30.
- _____, 1978b, Pre-Late Oxfordian Jurassic Biostratigraphy of Northern Yukon and Adjacent Northwest Territories: in Stelek, C.R., and Chatterton, B.D.E., eds., Western and Arctic Canadian Biostratigraphy: Geological Association of Canada Special Paper 18, p.445-471.
- _____, 1982, Palaeogeographic and Tectonic Implications of the Lower and Middle Jurassic Facies Patterns in Northern Yukon Territory and Adjacent Northwest Territories: Embry, A.F., and Balkwill, H.R., eds., Arctic Geology and Geophysics: Canadian Society of Petroleum Geologists, Memoir 8, p.13-27.
- _____, 1983, Boreal Bathonian and Lower Callovian Ammonites, Zonation and Correlation, Salmon Cache Canyon, Northern Yukon: Geological Survey of Canada Bulletin, in press.
- Poulton, T.P., and Callomon, J.H., 1976, Major Features of the Lower and Middle Jurassic Stratigraphy of Northern Richardson Mountains, Northeastern Yukon Territory and Northwestern District of Mackenzie: Geological Survey of Canada Paper 76-1B, p.345-52.
- Poulton, T.P., Ileskiw, K., and Audreusch, A., 1982, Stratigraphy and Microfossils of the Jurassic Bug Creek Group of Northern Richardson Mountains, Northern Yukon and Adjacent Northwest Territories: Geological Survey of Canada Bulletin 325, 137 p.
- Poulton, T.P., and Templeman-Kluit, D.J., 1982, Recent Discoveries of Jurassic Fossils in the Lower Schist Division of Central Yukon: Geological Survey of Canada Paper 82-1C, p.91-94.
- Quenstedt, F.A., 1886-7, Die Ammoniten des schwäbischen Jura, 2. Band: Der Braune Jura, mit Atlas: Stuttgart, Schwäbischerbart, p.441-815; reprinted 1973.
- Quilty, P.G., 1970, Jurassic Ammonites from Ellsworth Land, Antarctica: Journal of Paleontology, v.44, p.110-116.
- Rawson, P.F., 1982, New Arctocephalitinae (Ammonoidea) from the Middle Jurassic of Kong Karls Land, Svalbard: Geological Magazine, v.119, p.95-100.
- Reeside, J.B., 1919, Some American Jurassic Ammonites of the Genera *Quenstedticeras*, *Cardioceras*, and *Amoeboceras*, Family Cardiocerataceae: United States Geological Survey Professional Paper 118, 38 p.
- Riaz, A. de, 1898, Description des ammonites des couches à *Peltoceras transversarium* (Oxfordien supérieur) de Trep (Isère): Paris, Masson, 69 p.
- Rioult, M., 1964, Le stratotype du Bajocien: Colloque du Jurassique, Luxembourg, 1962: Volume des Comptes Rendus et Mémoires, Institut Grand-Ducal, Section des Sciences Naturelles, Physiques et Mathématiques, p.239-258.
- Saks, V.N., 1976, ed., Stratigraphy of the Jurassic System of the North of the U.S.S.R.: Moscow, Nauka, 436 p. (in Russian).
- Salfeld, H., and Friebold, H., 1924, Reports on the Scientific Results of the Norwegian expedition to Nowaya Zemlya, 1921; No.23, Jura und Kreidfossilien von Nowaya Zemlya: Oslo, Broeggers, 12 p.
- Sato, T., 1954, Découverte de *Tmetoceras* dans le Plateau de Kitikama au Nord du Japon: Japanese Journal of Geology and Geography, v.24, p.115-121.
- _____, 1957, Biostratigraphie de la Série de Shizukawa (Jurassique inférieur) du Japon Septentrional: Journal of the Faculty of Science, University of Tokyo, v.10, p.313-350.
- _____, 1958, Supplement à la Faune de la Série de Shizukawa (Jurassique inférieur) du Japon Septentrional: Japanese Journal of Geology and Geography, v.29, p.153-159.
- Sazonov, N.T., 1957, Jurassic deposits of the central region of the Russian Platform: Leningrad, VNIGNI, 154 p. (in Russian).
- _____, 1965, New data on Callovian, Oxfordian and Kimmeridgian ammonites: in Sazonova, N.T., and Shutskey, E.K., eds., Mesozoic and Cainozoic faunas of the European part of the U.S.S.R. and Middle Asia: Moscow, VNIGNI, p.1-99, in Russian.
- Sey, I.I., and Kalacheva, E.D., 1980, Biostratigraphy of the Lower and Middle Jurassic Deposits of the Far East: Leningrad, Trudy VNIGI, new series, v.285, 187 p., in Russian, with English summary.
- Siemiradzki, J. von, 1898-9, Monographische Beschreibung der Ammonitengattung *Perisphinctes*: Palaeontographica, v.45, p.69-352.
- Sokolov, D.N., 1912, Zur Ammonitenfauna des Petschoraschen Jura: Mémoires du Comité Géologique de St. Petersburg, Nouvelle Série, livr.76, p.1-49 (in Russian), 50-65 (in German).
- _____, 1913, Sur les Fossiles des Blocs Erratiques de Novaia Zemlia: Travaux du Musée géologique de St. Petersburg, v.7, p.59-92.
- Spath, L.F., 1924, On the Blake Collection of Ammonites from Kachh, India: Palaeontologia Indica, New Series, v.9, no.1, 39 p.
- _____, 1928, 1933, Revision of the Jurassic cephalopod fauna of Kachh (Cutch), India: Palaeontologia Indica, New Series, v.9, no.2, pt.iii, p.163-278; pt.vi, p.659-945.
- _____, 1935, The Invertebrate Faunas of the Bathonian-Callovian Deposits of Jameson Land (East Greenland): Meddelelser om Gronland, v.87, no.7, 158 p.
- _____, 1935, The Upper Jurassic Invertebrate Faunas of Cape Leslie, Milne Land, I. Oxfordian and Lower Kimmeridgian: Meddelelser om Gronland, v.99, no.2, 82 p.
- Stehn, E., 1924, Beiträge zur Kenntniss des Bathonium und Callovium in Südmertika: Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Beilage-Band 49, p.52-158.
- Sturani, C., 1967, Ammonites and Stratigraphy of the Jurassic in the Digne - Barrême Area (Southeastern France, Dépt. Basses-Alpes): Società Paleontologica Italiana, Boll. 5, 55 p.
- _____, 1971, Ammonites and Stratigraphy of the *Posidonia alpina* Beds of the Venetian Alps: Memorie degli Istituti di Geologia e Mineralogia dell' Università di Padova, v.28, 190 p.
- Sykes, R.M., and Callomon, J.H., 1979, The *Amoeboceras* Zonation of the Boreal Upper Oxfordian: Palaeontology, v.22, p.839-903.
- Thierry, J., 1976, Essai de Taxonomie et de Phylogénie de la Famille

- des Macrocephalitidae (Ammonitina, Stephanocerataceae; Jurassique moyen): 4^e Réunion Annuelle des Sciences de la terre, Société Géologique de France, Paris, 1 p.
- _____. 1978, Le Genre Macrocephalites au Callovien Inférieur (Ammonites, Jurassique moyen): Mémoires Géologiques de l'Université de Dijon, v.4, 492 p.
- Tintant, H., 1963, Les Kosmoceratides du Callovien Inférieur et Moyen d'Europe Occidentale: Essai de Paléontologie Quantitative: Publications de l'Université de Dijon, v.29, 500 p. and Atlas.
- Tintant, H., and Mouterde, R., 1981, Classification et Phylogénie chez les Ammonites Jurassiques: Martinell, J., ed., International Symposium on Concepts and Methodology in Paleontology, Barcelona 1981, Contributed Papers, p.85-101.
- Tipper, H.W., and Richards, T.A., 1976, Jurassic Stratigraphy and History of North-Central British Columbia: Geological Survey of Canada Bulletin 270, 73 p.
- Troitskaya, E.A., 1956, The genus *Rondieros* Troitskaya gen. nov.: in Kiparisova, L.D., Markovski, B.P. and Radchenko, G.I., eds.: Contributions to Paleontology, VSEGEI, Moscow, New Series, Paleontology, v.12, p.79-80 (in Russian).
- Tuchkov, I.I., 1972, New Data on the Stratigraphy and the Upper Boundary of the Jurassic in the Boreal and Arctic regions: Izvestiya Akad. Nauk SSSR, ser. geologicheskaya, 1972, no.2, p.111-125, in Russian.
- Voronets, N.S., 1962, Stratigraphy and Cephalopodean Molluscs of the Jurassic and Lower Cretaceous Deposits of the Lena-Anabar region: Moscow, Trudy NIIGA, v.110, 237 p., in Russian.
- Westermann, G.E.G., 1956, Monographie der Bajocien-Gattungen *Sphaeroceras* and *Chondroceras* (Ammonoidea): Geologisches Jahrbuch, Hannover, Beihefte, v.24, 125 p.
- _____. 1958, Ammoniten-Fauna und Stratigraphie des Bathonien NW-Deutschlands: Geologisches Jahrbuch, Hannover, Beihefte, v.32, 103 p.
- _____. 1964a, The Ammonite Fauna of the Kialagvik Formation at Wide Bay, Alaska Peninsula, Part I: Lower Bajocian (Aalenian): Bulletins of American Paleontology, v.47, no.216, p.329-503.
- _____. 1964b, Occurrence and Significance of the Arctic *Arkelloceras* in the Middle Bajocian of the Alberta foothills (Ammonitina, Jurassic): Journal of Paleontology, v.38, p.405-409.
- _____. 1964c, Sexual-Dimorphism bei Ammonoiten und seine Bedeutung für die Taxonomie der Oitoidae (einschliesslich Sphaeroceratinae; Ammonitina, M.-Jura): Palaeontographica, v.A125, p.33-73.
- _____. 1966, The Holotype (Plastotype) of ?*Titanites occidentalis* Frebold from the Kootenay Sandstone (Upper Jurassic) of southern British Columbia: Canadian Journal of Earth Sciences, v.3, p.623-625.
- _____. 1969, The Ammonite Fauna of the Kialagvik Formation at Wide Bay, Alaska Peninsula, Part II: *Sonninia sowerby* Zone (Bajocian): Bulletins of American Paleontology, v.57, no.255, 226 p.
- _____. 1981, Ammonite Biochronology and Biogeography of the Circum-Pacific Jurassic: in House, M.R. and Senior, J.R., eds., The Ammonoidea: Systematics Association Special Publication 18, London and New York, Academic Press, p.459-498.
- Westermann, G.E.G., and Riccardi, A.C., 1976, Middle Jurassic Ammonite Distribution and the Affinities of the andean Faunas: Primer Congreso geológico Chileno, Santiago de Chile, v.1, p.C23-C39.
- _____. 1979, Middle Jurassic Ammonoid Fauna and Biochronology of the Argentine-Chilean Andes, Part II: Bajocian Stephanocerataceae: Palaeontographica, v.A164, p.85-188.
- White, C.A., 1889, Mesozoic molluscs from the Southern Coast of the Alaskan Peninsula: United States Geological Survey Bulletin 51, p.64-70.
- Whiteaves, J.F., 1900, On Some Additional or Imperfectly Understood Fossils from the Cretaceous Rocks of the Queen Charlotte Islands, With a Revised List of Species from these Rocks: Geological Survey of Canada, Mesozoic Fossils, IV, p.263-307.
- _____. 1903, Description of a Species of *Cardioceras* from the Crowsnest Coalfields: Ottawa Naturalist, v.17, p.65-67.
- Whitfield, R.P., 1880, Report on the geology and Resources of the Black Hills of Dakota: United States Geographic and Geologic Survey, Rocky Mountains Region, p.380-381.
- Wierzbowski, A., Kulicki, C., and Pugaczewska, H., 1982, Fauna and Stratigraphy of the Uppermost Triassic and the Toarcian and Aalenian Deposits in the Sassenforjeden, Spitsbergen: Acta Palaeontologica Polonica, v.26, p.195-241.
- Wright, C.W., 1981, Cretaceous Ammonoidea: in House, M.R. and Senior, J.R., eds.: The Ammonoidea, Systematics Association Special Volume No. 18: Academic Press, Ch.6, p.157-174.
- Zakharov, V.A., and Mesezhnikov, M.S., 1974, The Volgian Stage in the sub-polar Urals: Novosibirsk, Institut Geologii i Geofiziki Akad. Nauk S.S.S.R., Sibirsk otdel., Trudy, v.196, 216 p., in Russian.