Jurassic-Cretaceous Biochronology and Paleogeography of North America,
edited by G.E.G. Westermann,
Geological Association of Canada Special Paper 27, 1984

JURASSIC AMMONITE SUCCESSIONS IN NORTH AMERICA AND BIOGEOGRAPHIC IMPLICATIONS

R.W. Imlay
United States Geological Survey, E-501, United States National Museum, Washington, D.C. 20560

ABSTRACT

During the Early Jurassic, marine waters covered areas now represented by southern Mexico, Sonora, Nevada, Idaho, British Columbia, southern Alaska, northern Alaska, northernmost Canada, and East Greenland. The ammonites that lived in those waters are very similar to those of the same ages in western Europe and, likewise, during late Pliensbachian time, changed southward from a faunule dominated by Amaltheus *to a faunule dominated by Hildoceratid genera.*

During the Middle Jurassic, marine waters covered most of the same areas as during the Early Jurassic as well as a large area in the Western Interior Region. The ammonite succession, as in Europe, changed southward from being mostly boreal in Alaska to being mostly Tethyan in Mexico but from Oregon southward it included some genera that are indigenous to the eastern part of the Pacific Ocean.

During the Late Jurassic, marine waters covered most of the same areas during the Middle Jurassic. They differed by withdrawing from most of the Western Interior region of the United States by the end of the middle Oxfordian and by extending over a large area in the Gulf of Mexico region during and after the late middle Oxfordian.

During the entire Jurassic those marine waters received a variety of sediments of which most have been fairly accurately dated by ammonites. Such dating has made possible reasonable interpretations of the major events in the Jurassic history of the North American continent.

RÉSUMÉ

Pendant le Jurassique Inférieur, des eaux marines ont recouverte des régions qui sont présentement repésentées par: le Mexique méridional, le Sonora, le Névada, l'Idaho, la Colombie-Britanique, l'Alaska méridionale et septentrionale, les régions les plus au nord du Canada et l'est du Groendland. Les ammonites qui ont vécu dans ces eaux sont très similaires à celles du même âge, en Europe de l'ouest, et en outre, pendant la fin du Pliensbachien, varient méridionalement d'un faunule dominé par Amaltheus *à un faunule dominé par* Hildoceratid *genra.*

Pendant le Jurassique Moyen, des eaux marines recouvraient encore la plupart de ces mêmes régions de la période Jurassique Inférieure ainsi qu'une grande partie de la région de l'ouest intérieure. La sucession des ammonites, comme en Europe, varie méridionalement d'un assemblage principalement boréal en Alaska, à un assemblage Tethyen au Mexique. Cependant à partir de l'Oregon et plus au sud, la succession ammonitique inclus quelques genres qui sont indigènes à l'est de l'Océan Pacifique.

Pendant le Jurassique Supérieur, des eaux marines occupaient toujours la plupart des mêmes régions que précédemment. Elles diffèrent cependant à causedu recul des eaux de la région interne de l'Ouest des Etats-Unis, à la fin de l'Oxfordien moyen, et à cause du recouvrement d'une grande partie de la région du Golfe du Mexique durant et après la fin de l'Oxfordien moyen.

Durant la totalité du Jurassique, ces eaux marines ont reçu une variété de sédiments pour la plupart datés assez précisément par les ammonites. Ces dates ont permis une interprétation raisonnable des évènements majeurs survenus pendant le Jurassique sur le continent Nord-Américain.

INTRODUCTION

The interpretation and ideas presented herein are based mainly on data concerning the Jurassic ammonite successions and geographic occurrences in conterminous United States as presented by the writer in 1976 and published in 1980 in U.S. Geological Survey Professional Paper 1062. Since 1976, however, much additional data have been presented by the writer in

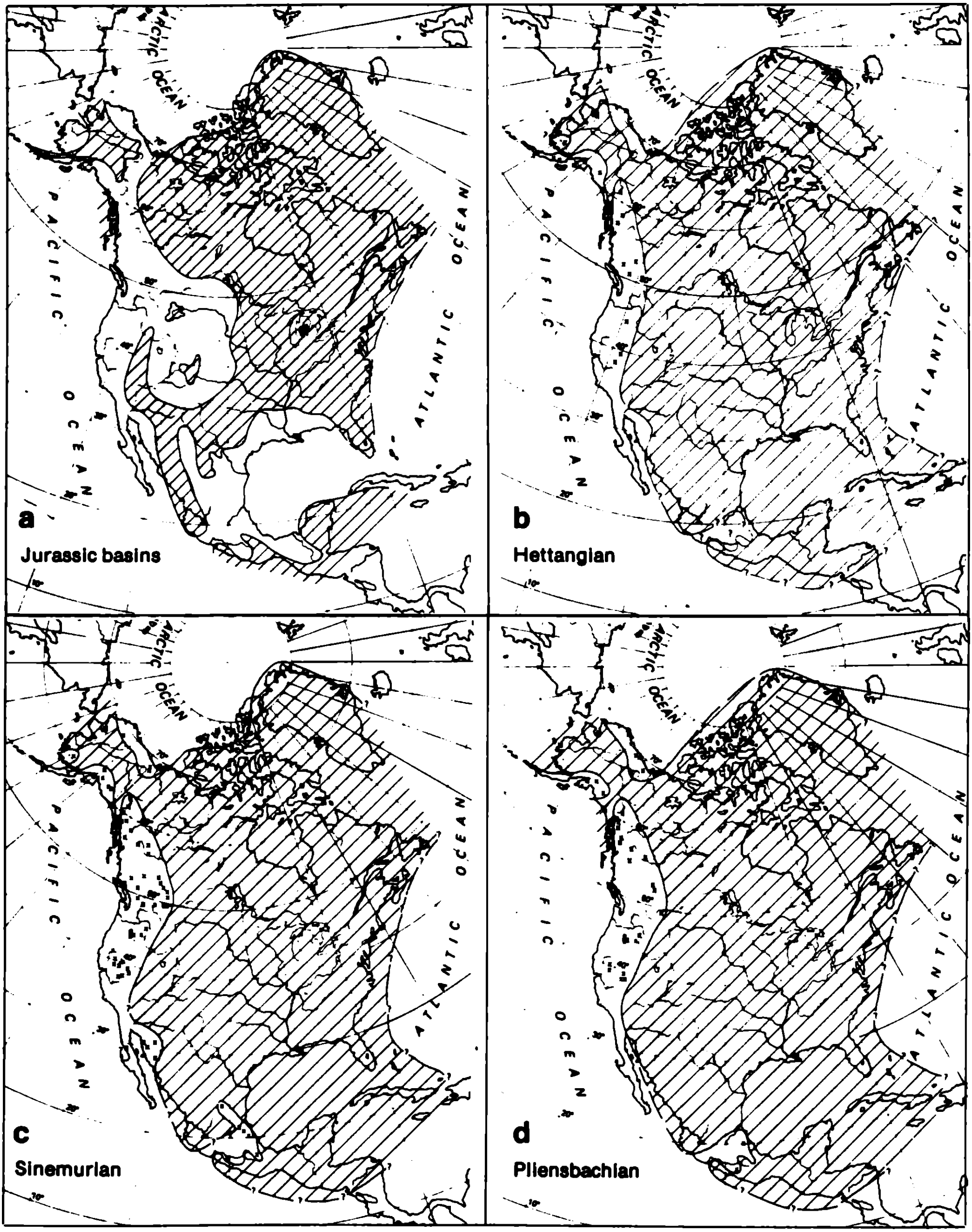

Figure 1. Paleogeologic maps for the Jurassic of North America. a) Jurassic basins of depositions (maximal extent); b-d) Hettangian to Pliensbachian seas and ammonite distributions.

seven additional Professional Papers. Of these papers, five deal with ammonites of Early to Late Jurassic ages obtained from various parts of Alaska, one with ammonites of Bathonian and Callovian ages from eastern Oregon and westernmost Idaho, and one with ammonites of late Callovian to middle Oxfordian ages from the Western Interior Region. Those Professional Papers that have been published are listed in the References.

Detailed data showing the probable distribution of Jurassic seas and the Jurassic ammonite succession in North America have been presented previously (Imlay, 1980a, Figs. 1-15) and are readily accessible to readers. The locations of the Jurassic basins of deposition in North America are shown on Figure 1a.

EARLY JURASSIC AMMONITE SUCCESSIONS AND BIOGEOGRAPHIC IMPLICATIONS

Hettangian ammonites have been found in western Nevada, eastern Oregon, southern Yukon, and in southern and northern Alaska (Fig. 1b). The ammonite succession in those areas appears to be essentially the same as in western Europe (Fig. 2). The earliest Hettangian is represented by a fairly smooth species of *Psiloceras* and by the ribbed subgenus *P.* (*Franziceras*); the middle Hettangian by *Waehneroceras* and *Discamphiceras*; and the upper Hettangian by *Schlotheimia.*

Sinemurian ammonites occur in the same area as Hettangian ammonites as well as in east-central, southern, and northwestern Mexico (Fig. 1c). Their succession is, likewise, similar to that in western Europe (standard zones in parentheses) except possibly during the middle Sinemurian, which is not represented in most areas in North America. Thus the basal European Sinemurian zone of *Arietites bucklandi* (Bucklandi Zone) is well represented by *Coroniceras* and in some areas by *Arietites, Charmasseiceras,* and *Paracaloceras.* The next higher zone of *Arnioceras semicostatum* (Semicostatum Zone) is represented in most areas by *Arnicoeras* and *Coroniceras* (*Paracoroniceras*). The next younger zone of *Caenisites turneri* (Turneri Zone) has not been identified in North America. The succeeding zone of *Asteroce-*

Stages		E. Ctr. Oregon (Imlay 1968)	Canadian Rocky Mountains (Frebold 1969; Frebold & Tipper 1970)	S. British Columbia (Frebold 1964a; Frebold & Tipper 1970)	S. Yukon & N. British Columbia (Frebold & Tipper 1970)	S. Alaska (Imlay 1968, 1981a; Imlay & Detterman 1973)	N. Alaska (Imlay 1955; Imlay & Detterman 1973)
Toarcian	U.	*Catulloceras* *Dumortieria?*	*Phylseogrammoceras* *Grammoceras*	*Phylseogrammoceras* *Grammoceras*	*Catulloceras* *Grammoceras*		
						Grammoceras	*Pseudolioceras*
		Haugia *Polyplectus*	*Phymatoceras* *Peronoceras*		*Phymatoceras* *Peronoceras*	*Haugia* *Phymatoceras*	
	L.					*Dactylioceras* cf. *commune*	*Dactylioceras* cf. *commune*
			Harpoceras cf. *exaratum* *Dactylioceras*	*Harpoceras* cf. *exaratum* *Dactylioceras*			*D.* cf. *semicelatum*
		?				?	
Pliensbachian	U.	*Arieticeras, Reynesoceras, Paltarpites* *Prodactylioceras* *Leptaleoceras*	*Pleuroceras* *Dactylioceras*		*Pleuroceras, Amaltheus, Paltarpites, Arieticeras* *Leptaleoceras*	*Pleuroceras, Amaltheus, Paltarpites*	*Pseudoamaltheus*
			Amaltheus				*Amaltheus margaritatus*
		?					*A. stokesi*
	L.			?	*Prodactylioceras davoei, Becheiceras*		
			?	*Fanninoceras*	?		
		?	*Phricodoceras*	*Acanthopleuroceras* *Uptonia, Tropidoceras* ?	*Platypleuroceras?*	*Uptonia, Apoderoceras* *Acanthopleuroceras*	
Sinemurian	U.	*Eoderoceras* *Crucilobiceras* ?	*Eoderoceras* *Gleviceras*	*Echioceras*		*Crucilobiceras*	*Crucilobiceras*
				Asteroceras			
	L.	?				*Microderoceras* ?	
		Arnioceras ?	*Arietites* *Arnioceras*	*Coroniceras* *bisulcatum* *Arnioceras*	*Paracoroniceras* *Arniotites*	*Arnioceras* ?	*Arnioceras*
						Coroniceras	*Coroniceras*
Hettangian		*Schlotheimia* *Alsatites* ?	(? absent)	*Psiloceras canadense* *Paracaloceras* *Charmasseiceras*	*Psiloceras canadense*		?
		Waehneroceras *Psiloceras*		*Psiloceras* aff. *planorbis*	*Psiloceras erugatum*	*Waehneroceras* *Psiloceras*	*Psiloceras*

Figure 2. Succession and correlation of Early Jurassic ammonite faunas in North America.

ras obtusum (Obtusum Zone) may be represented by reported occurrences of *Asteroceras* in southern British Columbia (Frebold and Tipper, 1970) and in Shasta County, California (Sanborn, 1960, p. 11-14). The succeeding zone of *Oxynoticeras oxynotum* (Oxynotum Zone) is represented by occurrences of *Oxynoticeras* in Mexico (Erben, 1956, Pl. 37, Fig. 1; Hallam, 1965) western Nevada (Hallam, 1965) northwestern Canada (Frebold, 1964b), Table 1) and the Canadian Arctic islands. The highest Sinemurian zone of *Echioceras raricostatum* (Raricostatum Zone) is characterized by *Echioceras* and by the lowest occurences of *Crucilobiceras* at many places from southern Mexico to northern Alaska and to northeastern Canada (Imlay, 1980a, Fig. 13).

Pliensbachian ammonites have been found in North America in the same general areas as the Sinemurian ammonites, but at fewer localities in Mexico, Alaska (Imlay, 1981a) northwestern Canada and Arctic Canada (Fig. 1d). The basal Pliensbachian zone of *Uptonia jamesoni* (Jamesoni Zone) is possibly represented in southern Mexico and in western Nevada by ammonites that are assigned questionably to *Uptonia* (Hallam, 1965). It is probably represented by *Uptonia* in southern British Columbia (Frebold and Tipper, 1970), in the Wrangell Mountains in southern Alaska (Imlay, 1981a, Pl. 9, Figs. 1-4, 8, 12-16), and on Lisburne Ridge between the Ipnavik and Anaktuvik Rivers in north-central Alaska (Imlay, 1981a, Pl. Fig. 17). This zone is also represented in the Talkeetna Mountains in south-central Alaska by one occurrence of *Apoderoceras* (Imlay, 1981a, Pl. 8, Figs. 14, 18-23). The zone of *Tragophylloceras ibex* (Ibex Zone) is represented by the Wrangell Mountains at U.S. Mesozoic Locality 28534 by *Tropidoceras actaeon* (d'Orbigny) (Imlay, 1981a, Pl. 8, Figs. 1-9) in association with *Crucilobiceras* (Imlay, 1981a, Pl. 8, Figs. 10-12, 15-17). The succeeding zone of *Prodactylioceras davoei* (Davoei Zone) is possibly represented in the southern Yukon and in northern British Columbia by *Prodactylioceras* (Frebold, 1964b, Pl. 3, Fig. 2) in association with *Becheiceras* (Frebold, 1964b, Pl. 3, Fig. 1; Pl. 4, Fig. 1; Pl. 5, Fig. 1). It is possibly represented, also, in the Wrangell Mountains by *Prodactylioceras* at the top of its range above *Tropidoceras*.

The highest European Pliensbachian zones have been dated, by the ammonite *Arieticeras* in areas between southern Mexico (Erben, 1957; Hallam, 1965; Cameron and Tipper, 1981) and southern Alaska (Imlay, 1981a). That genus in eastern Orgeon, western and northern British Columbia, southern Yukon and southern Alaska is associated with specimens of *Protogrammoceras, Fontanelliceras* and *Leptaleoceras* that are identical, or nearly identical with species in the Mediterranean region. Those genera are likewise associated rarely with *Amaltheus* in the Talkeetna Mountains of southern Alaska (Imlay and Detterman, 1973) but are fairly common in the Tulsequah area of northwestern British Columbia and in the Whitehorse area of southernmost Yukon territory (Frebold and Tipper, 1970).

A very different ammonite faunule occurs in beds of late Pliensbachian age in northern and east-central Alaska, northwestern Canada, and the Canadian Arctic islands (Tipper, 1981; Imlay, 1981a). That faunule is dominated by the genus *Amaltheus*, which is represented by the same species in the same succession as in northwestern Europe and is not associated with the Hildoceratid genera *Arieticeras, Protogrammoceras, Fontanelliceras,* or *Leptaloceras*. These faunal differences between northern and southern Alaska are identical with those between northwestern Canada and areas to the south in the southern Yukon and northern British Columbia. They are, likewise, essentially identical with southward changes in ammonite assemblages between northwestern Europe and the Mediterranean Region (Donovan, 1957; Hallam, 1969). Evidently the southern boundary of abundant Amaltheidae in Europe is hundreds of kilometers farther south than the southern boundary in Alaska and the southern Yukon. This difference could be explained: 1) by faulting in which major blocks containing Hildoceratid ammonites were moved far north of their original positions (Jones, *et al.*, 1977, Fig. 1; Coney *et al.*, 1980, Fig. 1; Tipper, 1981), 2) by present latitudes being somewhat different from those of Jurassic time, or 3) by variations in the latitudinal position of faunal provinces due to changes in ocean currents.

Toarcian ammonites have been found in westernmost North America north of Mexico in the same areas as the Pliensbachian ammonites (Fig. 3a). The succession of Toarcian ammonites is similar to that in western Europe. In western Nevada the sequence from the base upward includes: 1) *Nodicoeloceras* of early Toarcian age, 2) *Catacoeloceras* of early to late Toarcian age, and 3) *Grammoceras* and *Pseudolioceras* of latest Toarcian age. In eastern Oregon the late Toarcian is represented (1) by *Haugia* and *Polyplectus* that correlate with the European zone of *Haugia variabilis*, and (2) by *Catulloceras* of latest Toarcian age. In the Talkeeta Mountains of southern Alaska the lowest lower Toarcian is represented by *Dactylioceras* and *D.* (*Orthodactylites*) *kanense;* the upper lower Toarcian by *Harpoceras* cf. *H. exaratum* and *Eleganticeras;* the lower upper Toarcian by *Haugia, Brodeia* and *Pseudolioceras;* and the uppermost Toarcian by *Grammoceras* and *Pseudolioceras* (Imlay, 1981a). In the DeLong Mountains of northwestern Alaska the lower part of the lower Toarcian is represented by *Dactylioceras* (*orthodactylites*) and the upper part of the lower Toarcian by *Harpoceras* and *Eleganticeras*.

These ammonite occurrences show that during Early Jurassic time marine waters from the Pacific Ocean extended as much as 800 kms east of the present western margin of the North American continent (Figs. 1a-c, 3a). In southern Mexico the sea extended northeastward from the Pacific Ocean nearly as far as the Tampico area during Sinemurian and possibly during Pliensbachian times. In extreme northwestern Mexico the sea extended eastward several hundred kilometers beyond the present western margin of Sonora. Farther north the sea extended eastward into areas that now include the western half of Nevada, westernmost Idaho and southwestern British Columbia where the sea attained its maximum spread. In southern Alaska the sea extended northward and eastward at least 320 kms.

In the Arctic region during the Early Jurassic marine waters transgressed southward nearly 300 kms into areas now represented by northern Alaska and extreme northwestern Canada. The Arctic sea also extended southward into the area of northernmost Arctic islands during Sinemurian to Toarcian times and into marginal areas in East Greenland during Pliensbachian and Toarcian times.

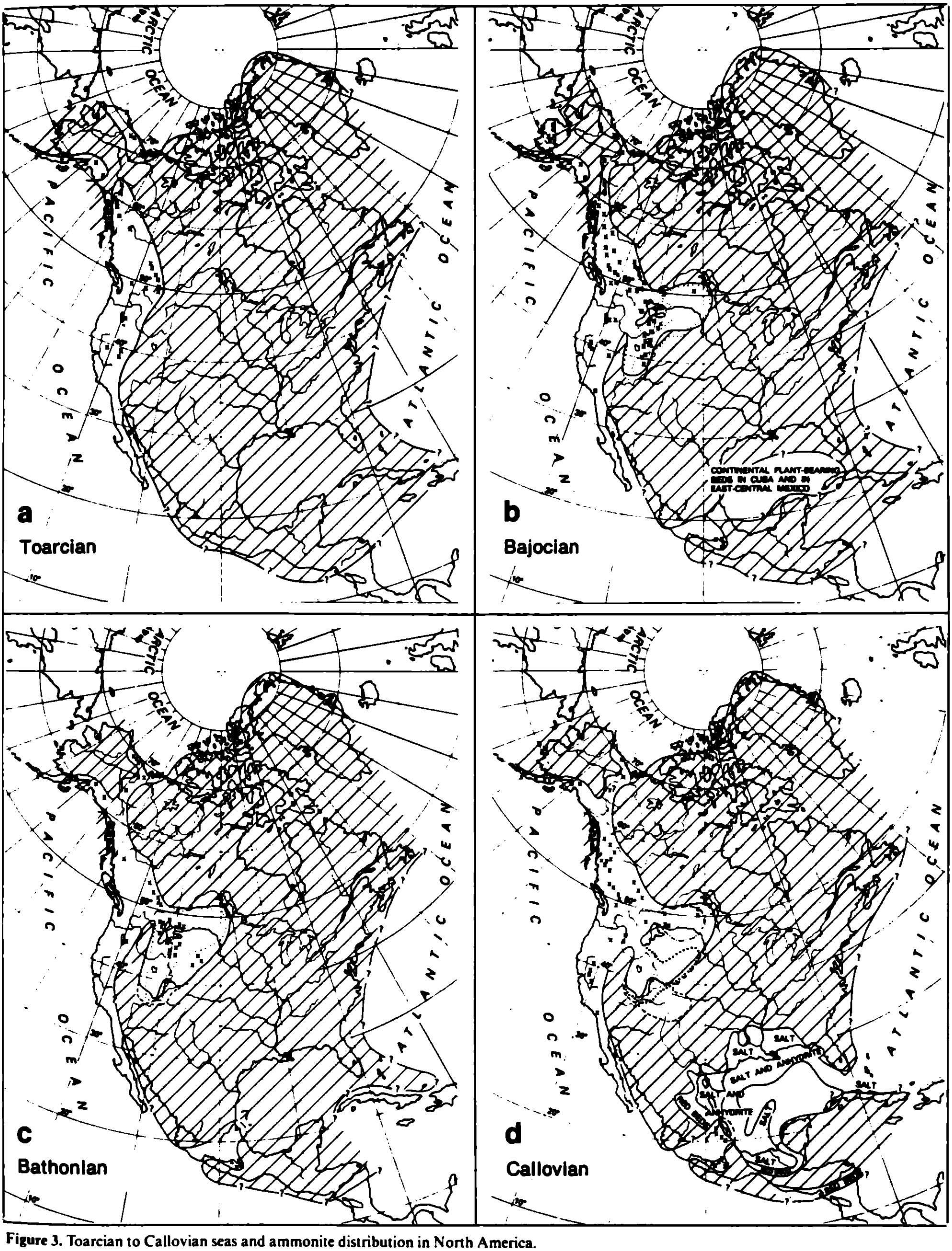

Figure 3. Toarcian to Callovian seas and ammonite distribution in North America.

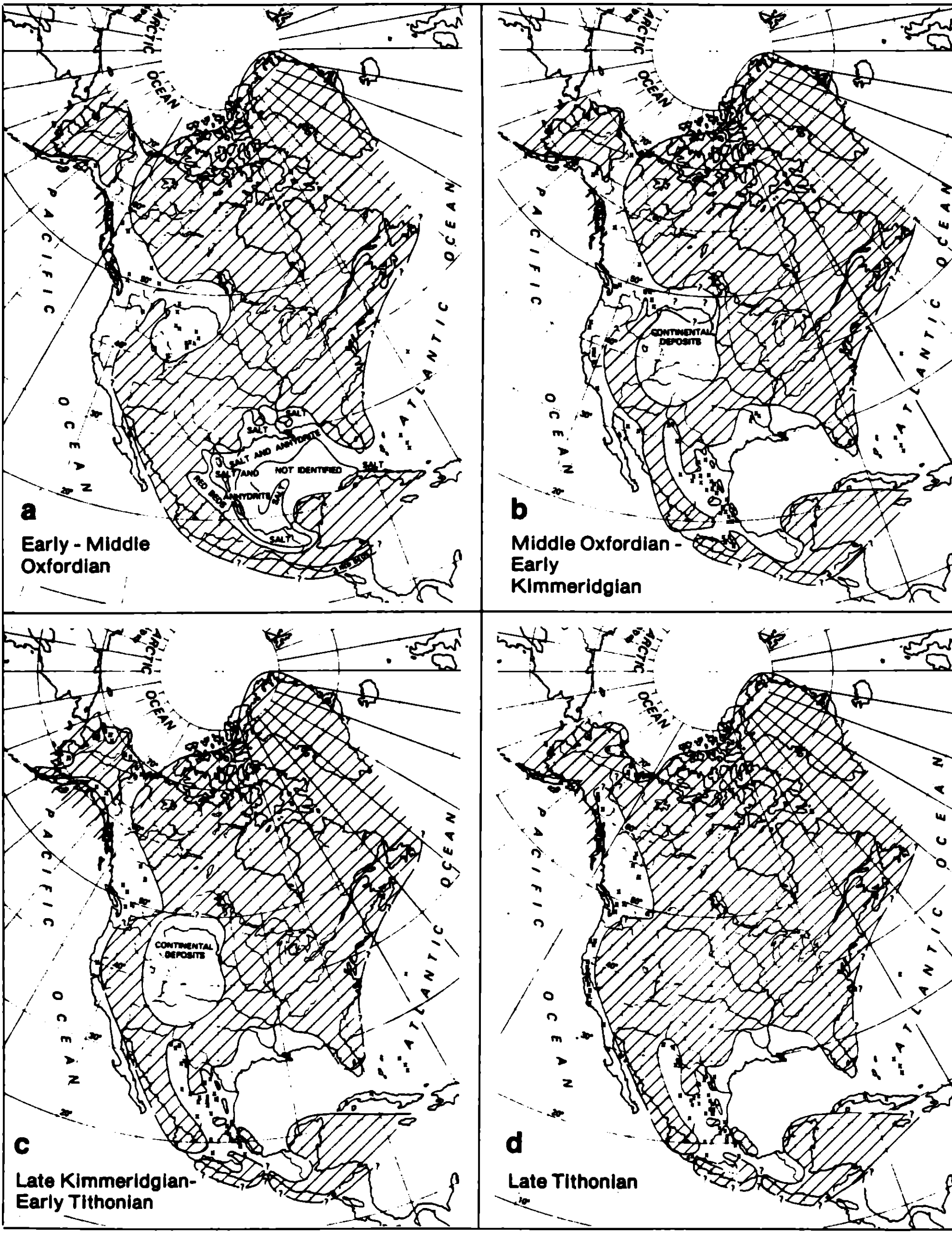

Figure 5. Late Jurassic basins of depositions and ammonite distributions in North America.

the Gulf of Mexico. Ammonites of that age, however, are common in the highest marine Jurassic beds in the Western Interior region, are fairly common from southern British Columbia northward and have not been found south of an occurrence of *Cardioceras (Scarburgiceras)* on the east side of the Snake River in westernmost Idaho about 6.4 kms south of the northeast corner of Oregon (Imlay, 1964a).

In contrast, during late middle to late Oxfordian time (Fig. 5b), ammonites became common: 1) in the Pacific Coast Region; 2) in areas now represented by southern, central, northcentral and northeastern Mexico; 3) in an area bordering the Gulf of Mexico on the west and north; and 4) in western Cuba. Ammonites of that age have never been found in the Western Interior Region of the United States where continental beds were deposited nearly as far north as the Canadian border. They do occur, however, in Canada a little northwest of Glacier Park near the boundary between Alberta and British Columbia.

The Oxfordian ammonite succession in North America (Fig. 6) likewise differs markedly latitudinally. From Arctic Canada and Alaska southward as far as southeastern Washington the early to middle Oxfordian is represented mostly by the Boreal ammonite *Cardioceras (Scarburgiceras)* which is succeeded by *C. (Subvertebriceras)* or by *C. (Cardioceras)*. The next younger late middle to late Oxfordian is represented by *Amoeboceras (Prionodoceras)* in association with the Boreal bivalve *Buchia concentrica* (Sowerby) (Imlay, 1980a). In addition, in southern Alaska the Tethyan ammonite *Dichotomosphinctes* of late middle to late Oxfordian age occurs in association with *Buchia concentrica* on the Alaska Peninsula (Imlay, 1961) and in the Iniskin Bay area west of Cook Inlet (U.S. Geol. Survey Mesozoic loc. 22449) (Imlay and Detterman, 1973). Similarly in the Western Interior Region of the United States the earliest early Oxfordian is represented by *C. (Scarburgiceras), C. (Maltoniceras)* and *Quenstedtoceras (Pavloviceras)* and the latest early Oxtordian by *Cardioceras cordiforme* (Meek and Hayden). The presence of *Buchia concentrica* (Sowerby) in northwestern Montana (Imlay, 1956) on the south edge of Glacier National Park shows that beds of Middle Oxfordian to Late Kimmeridgean age occur there at least locally. Its association with *Cardioceras (Scoticardioceras)* at USGS Mesozoic locality 27641 (Imlay, 1982) at the south edge of the park is good evidence of an age not later than early Middle Oxfordian.

In contrast to this ammonite sequence that is mostly of Boreal origin, the late middle to late Oxfordian in Oregon, California, Mexico, the Gulf Region of the United States, and Cuba includes ammonites of Tethyan origin (Imlay, 1980a) such as *Discosphinctes, Dichotomosphinctes, Orthosphinctes, Ochetoceras, Euaspidoceras* and *Aspidoceras*. These genera in California, Oregon and Mexico are associated with the bivalve *Buchia concentrica* (Sowerby) of Boreal origin but not with ammonites of Boreal origin except possibly for one occurrence of *Amoeboceras* reported by Burckhardt (1930) from a locality near San Pedro del Gallo in north-central Mexico.

Kimmeridgian ammonities have been found in North America in the same areas as late Oxfordian ammonites (Fig. 5c). During late Kimmeridgian time, however, they became more restricted westward in their distribution along the Pacific Coast from northwestern Mexico to southernmost British Columbia. This change apparently coincided with an enlargement of the area undergoing continental deposition in the Western Interior Region and with a western expansion of the land area lying west of that region.

The Kimmeridgian ammonite succession in North America differs latitudinally from Boreal in the Arctic Regions to Tethyan in Mexico. From the Arctic regions southward to southern British Columbia the beds of that age are characterized by the Boreal ammonites *Amoeboceras, A. (Amoebites)*, and *A. (Prionodoceras)* along with the bivalve *Buchia concentrica* (Sowerby) at the top of its range (Imlay, 1980a). With these taxa in southern Alaska from the Talkeetna Mountains southwestward to the middle of the Alaska Peninsula occurs an abundance of *Phylloceras*, which genus is characteristic of the Tethyan and Pacific Realms. Much farther south the ammonite *Amoeboceras (Amoebites)* has been found in association with *Buchia concentrica* in east-central California near the Cosumnes River (Imlay, 1961). Still farther south in northwest Mexico, *Amoeboceras* occurs with the Tethyan ammonite *Idoceras* throughout 152 meters of beds and at the top of its range is associated with the bivalve *Aulacomyella* of middle to late Kimmeridgian age (Imlay, 1980a).

The Kimmeridgian ammonite sequence in southern, eastern and northcentral Mexico from the base upward is characterized by: 1) *Ataxioceras, Rasenia* and *Sutneria;* 2) *Idoceras;* and 3) *Glochiceras* in association with *Buchia concentrica* (Sowerby) and *B. mosquensis* (von Buch) (Cantu Chapa, 1971; Imlay, 1980a). These ammonites represent the early and most of the late Kimmeridgian. The association of *B. concentrica* with *B. mosquensis* indicates a middle Late Kimmeridgian age.

A similar ammonite sequence obtained from the subsurface and from outcrops in the southeastern and southcentral United States also includes *Haploceras, Metahaploceras, Nebrodites* and *Physodoceras* (Imlay, 1945). All of these genera plus many others occur in Kimmeridgian beds in Mexico (Burckhardt, 1930) and represent the Tethyan Realm.

Tithonian ammonites have been found in North America in the same areas as late Kimmeridgian ammonites (Fig. 5c, d). The major difference in faunal distribution occurs in the Pacific Coast Region from Baja California northward to southwestern Oregon where ammonites of early Tithonian age have not been found but where ammonites of late Tithonian age occur at many localities (Imlay and Jones, 1970).

The Tithonian ammonite succession in North America likewise differs markedly from north to south (Fig. 6). In most places in Alaska and Canada, Tithonian ammonites are rare but the bivalve Buchia is common. Consequently, the molluscan succession is characterized by species of *Buchia*, which from bottom to top, are represented by 1) *Buchia mosquensis* (von Buch) in association with *B. rugosa* (Fischer) of late Kimmeridgian to early late Tithonian age; 2) *Buchia piochii* in the Canadian Rocky Mountains occurs in beds similar to those that have yielded the ammonite "*Titanites*" of about early late Tithonian age (Frebold, 1964a) and 3) *Buchia fischeriana* and *B. unschensis* which in Arctic Canada are associated respectively with *Dorsoplanites* and *Craspedites* (Jeletzky, 1966; Frebold, 1961).

In addition, the early Tithonian on the Alaska Peninsula is represented by the ammonite *Aulacosphinctoides* in association with *Buchia mosquensis* (von Buch) and *B. rugosa* (Fischer) (U.S. Geol. Survey Mesozoic loc. 29254) and is probably represented by one ammonite that resembles *Subplanites* (U.S. Geol. Survey Mesozoic loc. 29255). The late Tithonian on the peninsula is represented by *Buchia piochi* (Gabb). *B. fischeriana* (d'Orbigny). *B. unschensis* (Pavlov). and possibly by an ammonite resembling *Phylloceras knoxvillensis* Stanton (Stanton. 1895; Imlay and Jones. 1970).

The Tithonian sequence in western California and southwestern Oregon is entirely of late Tithonian age. It is characterized basally by the ammonite *Kossmatia* in association with *Buchia piochii* (Gabb). Its upper part is characterized by *Substeueroceras. Proniceras. Spiticeras* and *Parodontoceras.* This sequence rests unconformably on beds of Kimmeridgian age (Imlay and Jones. 1970).

The early Tithonian in eastern and northern Mexico is represented basally by *Hybonoticeras* of latest Kimmeridgian and earliest Tithonian age. Above follows a much thicker sequence of late early Tithonian age that is characterized by such ammonites as *Virgatosphinctes. Aulacosphinctoides. Subplanites* and *Mazapilites.* Above follow beds containing the same ammonites as occur in late Tithonian beds in California plus many other genera (Imlay. 1980a).

The Tithonian ammonite sequence in the Gulf Region of the United States appears to be nearly identical with that in Mexico. The early Tithonian is probably represented by a single specimen of *Virgatosphinctes;* the late Tithonian by *Parodontoceras, Hildoglochiceras.* and *Micracanthoceras:* the early late Tithonian by *Durangites;* and the late late Tithonian by *Substeueroceras, Proniceras* and *Aulacosphinctes.*

EXTENT OF LATE JURASSIC SEAS IN NORTH AMERICA

The occurrences of these ammonites of Late Jurassic age show that marine waters covered nearly the same areas in Canada. Greenland. and Alaska as during the Middle Jurassic (Fig. 3, 5). Farther south. however. several major changes occurred in the extent of the seas. First. in the Western Interior

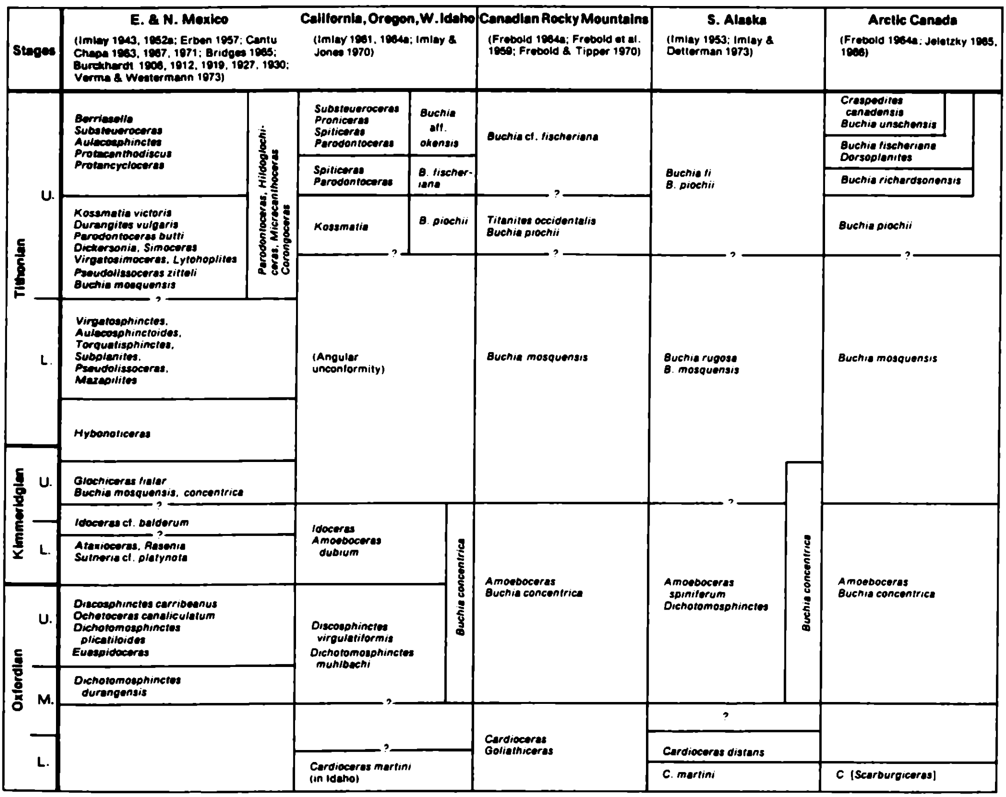

Figure 6. Succession and correlation of Late Jurassic ammonite faunas in North America.

region, the inland sea extended a little farther eastward during early Oxfordian time than it had previously, but then withdrew into the Montana area during middle Oxfordian time and as far west as westernmost Alberta during middle late Oxfordian time. Its withdrawal was followed by deposition of continental sediments (Morrison Formation), whose basal beds range in age from late middle to middle late Oxfordian and whose deposition continued during most, or perhaps all of the remainder of the Jurassic.

Second, along the Pacific Coast Region of the United States and northwestern Mexico the Late Jurassic sea did not extend as far inland as the Middle Jurassic sea and apparently withdrew west of the present land area from latest Kimmeridgian to earliest Tithonian time.

Third, in the Gulf of Mexico region occurred deposition of thick masses of salt, anhydrite and some red beds that are probably of late Callovian and early Oxfordian ages (Imlay, 1943, 1980a; Viniegra, 1971). The marine waters that furnished the salt could have come from the west through southern Mexico, or from the east in the area between Florida and Cuba, or from both directions.

Fourth, the Gulf of Mexico was formed during late middle Oxfordian to late Tithonian times as shown by the presence of thick marine sediments of those ages throughout much of southern, central and northern Mexico and much of the southern United States from Texas to Florida.

REFERENCES

Arkell, W.J., 1956, Jurassic Geology of the World: London, Oliver and Boyd, 806 p.

Bartlett, B.A., and Smith, Leigh, 1971, Mesozoic and Cenozoic history of the Grand Banks of Newfoundland: Canadian Journal of Earth Sciences, v. 8, p. 65-84.

Bridges, L.W. 2d, 1965, Estudios Geólogicos en el Estado de Chihuahua Pt. 1, Geologia del area de Plomosas, Chihuahua: México Univ. Nac. Antónoma Instituto Geologia Boletin 74, p. 1-134.

Burckhardt, Carlos, 1906, La Faune Jurassique de Mazapil avec un Appendice sur les Fossiles du Cretacique Inferieur: Instituto de Geologia de México, Boletin 23, 216 p.

———, 1912, Faunas Jurassiques et Cretaciques de San Pedro del Gallo: Instituto de Geologia de México Boletin 29, 264 p.

———, 1919, 1921, Faunas Jurasicas de Symon (Zacatecas): Instituto de Geologia de México Boletin 33, 135 p.

———, 1927, Cefalopodos del Jurasico Medio de Oaxaca y Guerrero: Instituto de Geologia de México Boletin 47, 108 p.

———, 1930-31, Etude Synthetique sur le Mesozoique Mexicain: Mémoires Societé Paléontologique Suisse, v. 49, p. 1-23 (1930); v. 50, p. 123-280 (1931).

Callomon, J.W., 1959, The Ammonite Zones of the Middle Jurassic Beds of East Greenland: Geological Magazine, v. 96, no. 6, p. 505-513.

Cameron, B.E.B., and Tipper, H.W., 1981, Jurassic Biostratigraphy, Stratigraphy and Related Hydrocarbon Occurrences of Queen Charlotte Islands, British Columbia: *in* Current Research, Part A, Geological Survey of Canada Paper 81-1A, p. 209-212.

Cantu Chapa, Abelardo, 1963, Etude Biostratigraphique des Ammonites du Superieur et Cretace: Societé Géologique de France Mémoire 99, Nouvelle Serie, Tome 42, pt. 4, 102 p.

———, 1967, El Limite Jurasico-Cretacico en Mazatepec, Puebla (Mexico): Instituto Mexicano del Petróleo Techologia de la Exploration Seccion Geologia, Monografia No. 1, p. 3-24.

———, La Serie Huasteca (Jurásico Medio-Superior) del Centro Este de México: Instituto Mexicano del Petroleo Revista, v. 3, no. 2, p. 17-40.

Coney, P.J., Jones, D.L., and Monger, J.W.H., 1980, Cordilleran Suspect Terranes: Nature, v. 288, no. 5789, p. 329-333.

Donovan, D.T., 1957, The Jurassic and Cretaceous Systems in East Greenland: Meddelelser om Gronland, v. 155, no. 4, 214 p.

Erben, H.K., 1956, El Jurasico Inferior de México y sus Amonitas: México, D.F., Congreso Geologico International, 20th, 1956, 393 p.

———, 1957, New Biostratrigraphic Correlations in the Jurassic of Eastern and South-Central Mexico: *in* El Mesozoico del Hemisferio Occidental y Sus Correlations Mundiales: International Geological Congress 20th, Mexico, D.F., 1956, sec. 2, p. 43-52.

Frebold, Hans, 1961, The Jurassic Faunas of the Canadian Arctic - Middle and Upper Jurassic Ammonites: Geological Survey of Canada Bulletin 74, 43 p.

———, 1964a, Illustrations of Canadian Fossils - Jurassic of Western and Arctic Canada: Geological Survey of Canada Paper 63-4, 106 p.

———, 1964b, Lower Jurassic and Bajocian Ammonoid Faunas of Northwestern British Columbia and Southern Yukon: Geological Survey of Canada Bulletin 116, 31 p.

———, 1969, Subdivision and Facies of Lower Jurassic Rocks in the Southern Rocky Mountains and Foothills: Geological Association of Canada Proceedings, v. 20, p. 76-87.

Frebold, Hans, Mountjoy, E.W., and Reed, R.A., 1959, The Oxfordian Beds of the Jurassic Fernie Group, Alberta and British Columbia: Geological Survey of Canada Bulletin 53, 47 p.

Frebold, Hans and Tipper, H.W., 1970, Status of the Jurassic in the Canadian Cordillera of British Columbia, Alberta, and southern Yukon: Canadian Journal Earth Sciences, v. 7, p. 1-21.

———, 1975, Upper Callovian and Lower Oxfordian Ammonites from Southeastern Bowser Basin, British Columbia: Canadian Journal of Earth Sciences, v. 12, p. 145-157.

Hall, R.L., and Stronach, N.J., 1981, First Record of Late Bajocian (Jurassic) Ammonites in the Fernie Formation, Alberta: Canadian Journal Earth Sciences, v. 18, p. 919-925.

Hall, R.L. and Westermann, G.E.G., 1980, Lower Bajocian (Jurassic) Cephalopod Faunas of Western Canada and North American Assemblage Zones: Palaeontographical Americana, v. 9, no. 52, p. 1-93.

Hallam, Anthony, 1965, Observations on Marine Lower Jurassic Stratigraphy of North America, with Special Reference to United States: American Association of Petroleum Geologists Bulletin, v. 49, p. 1485-1501.

———, 1969, Faunal Realms and Facies in the Jurassic: Palaeontology, v. 12, pt. 1, pl. 18.

Imlay, R.W., 1943, Jurassic Formations of Gulf Region: American Association of Petroleum Geologists Bulletin, v. 27, no. 11, p. 1407-1533.

———, 1945, Jurassic Fossils from the Southern States, No. 2: Journal of Paleontology, v. 19, no. 3, p. 253-276.

———, 1952a, Correlation of the Jurassic Formations of North America Exclusive of Canada: Geological Society of America Bulletin, v. 63, no. 9, p. 953-992.

———, 1952b, Marine Origin of Preuss Sandstone of Idaho, Wyoming, and Utah: American Association of Petroleum Geologists Bulletin, v. 36, no. 9, p. 1735-1753.

———, 1952c, Summary of Jurassic History in the Western Interior of the United States: Billings Geological Society, Guidebook, 3d Annual Field Conference, Sept. 1952, p. 79-85.

———, 1953, Callovian (Jurassic) Ammonites from the United States and Alaska, Part 2, Alaska Peninsula and Cook Inlet Regions: United States Geological Survey Professional Paper 249-B, p. 41-108.

———, 1955, Characteristic Jurassic Mollusks from Northern Alaska: United States Geological Survey Professional Paper 274-D, p. 69-96.

———, 1956, Marine Jurassic Exposed in the Bighorn Basin, Pryor Mountains, and Northern Big Horn Mountains, Wyoming and Montana: American Association of Petroleum Geologists Bulletin, v. 40, no. 4, p. 562-599.

———, 1961, Late Jurassic Ammonites from the Western Sierra Nevada, California: United States Geological Survey Professional Paper 374-D, 30 p.

———, 1962a, Late Bajocian Ammonites from the Cook Inlet Region, Alaska: United States Geological Survey Professional Paper 418-A, 15 p.

———, 1962b, Jurassic (Bathonian or Early Callovian) Ammonites from Alaska and Montana: United States Geological Survey Professional Paper 374-C, p. C1-C32.

———, 1964a, Upper Jurassic Mollusks from Eastern Oregon and Western Idaho: United States Geological Survey Professional Paper 483-D, p. 1-21.

———, 1964b, Middle Bajocian Ammonites from the Cook Inlet Region, Alaska: United States Geological Survey Professional Paper 418-B, 61 p.

———, 1965, Jurassic Marine Faunal Differentiation in North America: Journal of Paleontology, v. 39, no. 5, 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.

———, 1968, Lower Jurassic (Pliensbachian and Toarcian) Ammonites from Eastern Oregon and California: United States Geological Survey Professional Paper 593-C, p. C1-C51.

———, 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 Northern Alaska: United States 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, Early Jurassic Ammonites from Alaska: United States Geological Sruvey Professional Paper 1148, 49 p.

———, 1981b, Jurassic (Bathonian and Callovian) Ammonites in Eastern Oregon and Western Idaho: United States Geological Survey Professional Paper 1142, 24 p.

———, 1982, Jurassic (Oxfordian and Late Callovian) Ammonites from the Western Interior Region of the United States: United States Geological Survey Professional Paper 1232, p. 1-44.

Imlay, R. W., and Jones, D.L., 1970, Ammonites from the *Buchia* Zones in northwestern California and Southwestern Oregon: United States Geological Survey Professional Paper 647-B, 59 p.

Imlay, R.W., and Detterman, R.L., 1973, Jurassic Paleobiogeography of Alaska: United States Geological Survey Professional Paper 801, 34 p.

Jeletzky, J.A., 1965, Late Upper Jurassic and Early Lower Cretaceous Fossil Zones of the Canadian Western Cordillera, British Columbia: Geological Survey of Canada Bulletin 103, 70 p.

———, 1966, Upper Volgian (Latest Jurassic) Ammonites and Buchias of Arctic Canada: Geological Survey of Canada Bulletin 128, 51 p.

Jones, D.L. Silberling, N.J., and Hillhouse, J., 1977, Wrangellia - A Displaced Terrane in Northwestern North America: Canadian Journal of Earth Sciences, v. 14, p. 265-2577.

McIver, N.L., 1972, Cenozoic and Mesozoic Stratigraphy of the Nova Scotia Shelf: Canadian Journal of Earth Sciences, v. 9, p. 54-70.

Mouterde, R., Enay, R., Carieu, E., Contini, D., Elmi, S., Gabilly, J., Mangold, Ch., Mattei, J., Rioult, M., Thierry, J., and Tintont, H., 1971, Les Zones du Jurassque en France: Société Géologique de France., C.R. No. 2, p. 76-102.

Parsons, C.F., 1974, The Suazei and "So-Called" Sowerby Zones of the Lower Bajocian: Newsletter on Stratigraphy, v. 3, p. 153-179.

Sanborn, A.F., 1960, Geology and Paleontology of the Southwest Quarter of the Big Bend Quadrangle, Shasta County, California: California Division of Mines Special Report 63, p. 3-26.

Stanton, T. W., 1895, Contributions to the Cretaceous Paleontology of the Pacific Coast - The Fauna of the Knoxville Beds: United States Geological Survey Bulletin 133, 132 p. (Issued Feb. 3, 1896).

Surlyk, F., Callomon, J.H., Bromley, R.G., and Birkelund, Tove, 1973, Stratigraphy of the Jurassic-Lower Cretaceous Sediments of Jameson Land and Scoresby Land, East Greenland: Greenland Geological Undersogelse Bulletin 105, p. 5-76.

Tipper, H.H., 1981, Offset of an Upper Pleisbachian Geographic Zonation in the North American Cordillera by Transcurrent Movement: Canadian Journal of Earth Sciences, v. 18, p. 1988-1992.

Tipper, H.W., and Cameron, B.E.B., 1980, Stratigraphy and Paleontology of the Upper Yakoun Formation (Jurassic) in Alliford Bay Syncline, Queen Charlotte Islands, British Columbia: *in* Current Research, Part C, Geological Survey of Canada, Paper 80-1C, p. 37-44.

Upshaw, C.G., Armstrong, W.E., Creath, W.B., Kidson, E.J., and Sanderson, G.A., 1974, Biostratigraphic Framework of Grand Banks: American Association of Petroleum Geologists Bulletin, v. 58, no. 6, pt. 2, p. 1124-1132.

Verma, H. and Westermann, G.E.G., 1973, The Tithonian (Jurassic) Ammonite Fauna and Stratigraphy of Sierra Catorce, San Luis Potosi, Mexico: Bulletins of American Paleontology, v. 63, no. 277, p. 103-320.

Viniegra, O. 1971, Age and Evolution of Salt Basins of Southeastern Mexico: American Association of Petroleum Geologists Bulletin, v. 55, no. 3, p. 478-494.

Westermann, G.E.G., 1964, The Ammonite Fauna of the Kialagvik Formation at Wide Bay, Alaska Peninsula, Part 1, Lower Bajocian (Aalenian): Bulletins American Paleontology, v. 47, p. 329-503.

———, 1969, The Ammonite Fauna of the Kialagvik Formation at Wide Bay, Alaska Peninsula, Part 2, *Sonninia sowerbyi* Zone (Bajocian): Bulletins American Paleontogy, v. 57, no. 255, 226 p.

———, 1979, Troublesome Definition of the Lower Middle Jurassic Boundary: Canadian Journal of Earth Sciences, v. 16, p. 2060-2062.

———, 1981, Ammonite Biochronology and Biogeography of the Circum-Pacific Middle Jurassic: in The *Ammonoidea:* Systematics Association, Special Volume 18, p. 459-498.

Jurassic-Cretaceous Biochronology and Paleogeography of North America,
edited by G.E.G. Westermann,
Geological Association of Canada Special Paper 27, 1984

EARLY JURASSIC STRATIGRAPHY AND MICROPALEONTOLOGY OF THE GRAND BANKS AND PORTUGAL

J. Exton
Petro-Canada Exploration Inc., P.O. Box 2844, Calgary, Alberta T2P 3E3
F.M. Gradstein
Geological Survey of Canada, Bedford Institute of Oceanography, Box 1006, Dartmouth, Nova Scotia
B2Y 4A2

ABSTRACT

The Triassic-Lower Jurassic sedimentary sequence in the Grand Banks subsurface and in outcrop sections in the Lusitanian Basin of western Portugal are closely similar. Major vertical changes of lithology in both areas, from red beds and evaporites through shallow marine dolostones and limestones to calcareous shales, are synchronous within the limits of biostratigraphic resolution. Portuguese latest Pliensbachian beds are more calcareous and less shaly than below and above and indicate a slightly regressive cycle, as in France and England. The Early Toarcian bituminous shale of northwestern Europe did not extend to Portugal and the Grand Banks.

Foraminifer and ostracode assemblages of Portugal and the Grand Banks have many taxa in common and allow for the recognition of three zones in each area; the Zone of Involutina liassica *recognized in the Grand Banks is considered equivalent to the Zone of* Frondicularia terquemi *of the Lusitanian Basin which corresponds to the ammonite standard zones of Raricostatum through Tenuicostatum (latest Sinemurian-earliest Toarcian). The Zones of* Bairdiacypris *sp. and* Lenticulina dorbignyi *are common to both basins with age ranges of Early through Middle Toarcian and Late Toarcian-Aalenian respectively. The Grand Banks and Portuguese foraminiferal assemblages form part of a cosmopolitan Early Jurassic microfauna which spread throughout the world's epicontinental seas before continental fragmentation.*

RÉSUMÉ

Il y a une ressemblance remarquable entre les séries sédimentaires triassiques et jurassiques inférieures des Grands Bancs de Terre Neuve et les affleurements du Bassin Lusitanien du Portugal. Dans les deux régions, les changements verticaux majeurs de la lithologie, des grès et argiles rouges et évaporites à travers les dolomites marins d'eau peu profonde aux argiles calcaires, sont synchrones dans les limites de la résolution biostratigraphique. Les dépots lusitaniens du Pliensbachien supérieur sont plus calcaires et moins schisteux que les dépots au dessous et au dessus et indiquent un cycle légèrement régressif tel qu'en France et en Angleterre. Les argiles bitumineux du Toarcien inférieur du nord-ouest de l'Europe ne sont pas étendus au Portugal et aux Grands Bancs.

*Les assemblages de foraminifères et d'ostracodes du Portugal et des Grands Bancs sont très comparables et permettent de reconnaitre trois zones dans les deux régions. La Zone d'*Involutina liassica *des Grands Bancs est considerée comme étant équivelante à la Zone de* Frondicularia terquemi *du Bassin Lusitanien qui correspond aux zones d'ammonites de Raricostatum jusque'au Tenuicostatum (Sinémurien supérieur au Toarcien inferieur). Les Zones de* Bairdiacypris *et de* Lenticulina dorbignyi *sont communes aux deux bassins et s'étendent respectivement du Toarcien inférieur à l'Aalenien. Les assemblages foraminifères du Portugal et des Grands Bancs sont partie d'une microfaune cosmopolitaine du Jurassique inférieur qui s'est étendue à travers les mers épicontinentales du monde avant la séparation des continents.*

INTRODUCTION

Pre-drift reconstructions of the North Atlantic continental margins indicate that before the onset of sea-floor spreading the Lusitanian Basin of central Portugal was in close proximity to the Grand Banks of Newfoundland basin(s). Just how close these two areas were is still uncertain (Fig. 1). Kristoffersen (1978) shows a gap of several hundreds of kilometres between the southern Grand Banks and Iberia, while Le Pichon *et al.* (1977) and the Groupe Galice (1979) present somewhat tighter reconstructions in which Iberia has been moved westwards along the North Pyrenean fault. Laughton (1975) and Wilson (1975) have produced the closest reassembly by arbitrarily shuffling Orphan Knoll, Galicia Bank and Flemish Cap into the gap between Porcupine Bank and the Labrador Shelf.