Jurassic Paleobiogeography of Alaska

GEOLOGICAL SURVEY PROFESSIONAL PAPER 801

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By RALPH W. IMLAY *and* ROBERT L. DETTERMAN

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Changes in the paleogeography of Alaska during Jurassic time are revealed by the distribution, succession, and differentiation of molluscan faunas and by the characteristics of the associated sedimentary rocks

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JURASSIC PALEOBIOGEOGRAPHY OF ALASKA

By Ralph W. Imlay and Robert L. Detterman

ABSTRACT

Jurassic marginal seas occupied considerable areas in southern and northern Alaska and in the western part of the Kuskokwim region of southwestern Alaska. They appear to have been absent during late Callovian time, much restricted during Hettangian, Bathonian, early Oxfordian and late Tithonian time, and most extensive during Sinemurian, Bajocian, and late Oxfordian to middle Tithonian time. A large area in central Alaska was probably never covered. A southwestern prolongation of that area from the Talkeetna Mountains westward to the western end of the Alaska Peninsula was the site of granitic intrusions during late Early Jurassic time and of extensive erosion during Middle and Late Jurassic time. Variations in the rate of uplift of the area of these granitic intrusive rocks may explain why marine transgressions and regressions were at different times in southern than in northern Alaska during the Bajocian and Bathonian. Connection of the northern and southern marginal seas occurred through Yukon Territory and easternmost Alaska.

The Jurassic ammonite succession in Alaska is similar to that in central and northern Europe and northern Asia. In Lower Jurassic beds, it is essentially identical. In Bajocian and in Oxfordian to lower Kimmeridgian beds, the ammonite succession in Alaska differs from that in the other areas mainly by the presence of some genera found only in areas bordering the Pacific Ocean and by the absence of a few genera common in central and northern Europe. In contrast, the Bathonian rocks of Alaska contain ammonites, such as *Arcticoceras*, *Arctocephalites*, and *Cranocephalites*, that are widespread in the Arctic region but are unknown in central Europe. Comparisons with the Tithonian of Europe are not possible because ammonites of that age, other than *Lytoceras* and *Phylloceras*, are not yet known from Alaska. The Alaskan Jurassic ammonites of late Pliensbachian Age and of Bathonian to early Kimmeridgian Age belong mostly to the Boreal realm and have very little in common with Tethyan realm ammonites such as those found in areas bordering the Mediterranean Sea.

INTRODUCTION

This report deals in a broad way with changes in geography, stratigraphy, and ammonite assemblages in Alaska during Jurassic time. It is based on data of which at least half has been obtained during the last 25 years; it presents maps depicting the approximate positions and distribution of megafossil occurrences of the various stages; and it describes those fossil occurrences or refers to publications in which they have been described. In addition, the report summarizes existing knowledge concerning gross stratigraphic and lithologic features, position and duration of unconformities, extent and changes in marginal Jurassic seas, succession and differentiation of ammonite faunas, comparisons with ammonite successions elsewhere, and possible relationship of ammonite differentiation to major events in the Gulf of Mexico and in the Atlantic Ocean.

The paleogeographic maps presented herein for the stages of the Jurassic are intended primarily to show the main areas of marine deposition and the provenance of the sediments; at the same time it is recognized that the areas probably are not in their true palinspastic position. Considerable evidence has been collected in recent years for large-scale transcurrent fault movements of regional proportions. Many of the Jurassic localities in southern Alaska certainly were involved in major dislocations bordering the rim of the north Pacific Ocean (Brew and others, 1966; Grantz, 1966; Richter and Jones, 1970; and St. Amand, 1957). Some dislocation of Jurassic strata occurred also in northern Alaska (Brosgé and Tailleur, 1970; Tailleur and Brosgé, 1970), but the dislocations were not as severe as in southern Alaska. The authors hope that locality and stratigraphic data published herein will stimulate field geologists to obtain more data on individual basins so that more accurate paleogeographic maps can be drawn.

Most of the geographic features, areas, and towns mentioned herein are shown on a physiographic map of Alaska prepared by Wahrhaftig (1965, pl. 1). Many of the creeks mentioned under locality descriptions dealing with northern Alaska are shown on an index map prepared by Imlay (1955, p. 79). Other streams mentioned under locality descriptions are shown on maps published by the authors listed in the locality descriptions at the end of this report.

ACKNOWLEDGMENTS

For the data published herein, the writers are greatly indebted to many geologists of the major oil companies and the U.S. Geological Survey and to a few individuals such as prospectors and mountain climbers. Especial thanks for their aid in reading the manuscript, in checking or rewriting the fossil locality data, or for contributing valuable collections are given to consulting geologist M. D. Mangus, to George Gryc, Arthur Grantz, J. M. Hoare, D. L. Jones, A. S. Keller, E. M. MacKevett, G. W. Moore, W. W. Patton, Jr., H. N. Reiser, Donald Richter, and E. G. Sable of the Geological Survey, and N. J. Silberling of Stanford University, The major oil companies whose geologists in recent years have furnished valuable fossil collections and locality data include the BP Alaska Inc., the Standard Oil Company of California, and the Atlantic Richfield Oil Company.

DISTRIBUTION OF JURASSIC ROCKS

Marine Jurassic fossils have been found in Alaska mostly in its northern, southern, and southwestern parts (fig. 1). The overall distribution of the fossils by stages is shown in figures 2–9. Most of the localities indicated therein represent single fossil collections, but some represent two or more collections from a sequence of beds in a small area, or many collections from an area of appreciable size, such as the Iniskin Peninsula or the Talkeetna Mountains (fig. 10; also see Wahrhaftig, 1965, pl. 1).

Marine Jurassic fossils have not been found in a large area in central Alaska, nor in a southwestern prolongation (fig. 1) that trends southwest near and parallel to the Alaska Range. Most of the boundaries of this area are approximations that probably will be altered by future geologic mapping. The southern boundary, however, from the Talkeetna Mountains westward and southwestward to the Alaska Peninsula is well defined by intermittent occurrences of granitic rocks that were intruded during Early Jurassic time and that shed much coarse debris southward during Middle and Late Jurassic time (Grantz and others, 1963; Detterman and others, 1965; Detterman and Hartsock, 1966, p. 64, 70, 71; Burk, 1965, p. 73, 75–77).

The apparent absence of any marine Jurassic throughout the southern part of central Alaska north of Cook Inlet may be ascribed to erosion during Middle and Late Jurassic time. The lack of Jurassic fossils throughout the rest of central Alaska may have a similar explanation, but may be due to nondeposition. Their absence cannot be explained by post-Jurassic erosion, because at many places, marine Triassic rocks are overlain directly by lowermost Cretaceous marine rocks. Overall, the evidence favors the presence of a landmass in central Alaska during Jurassic time.

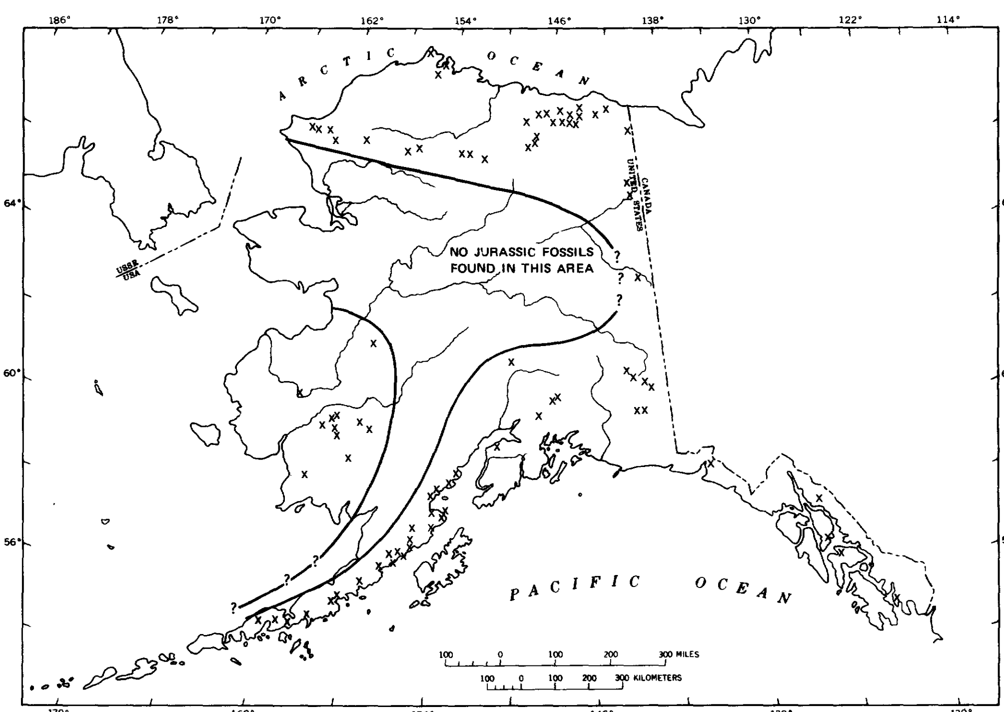


FIGURE 1.—Distribution of Jurassic fossils of all stages in Alaska.

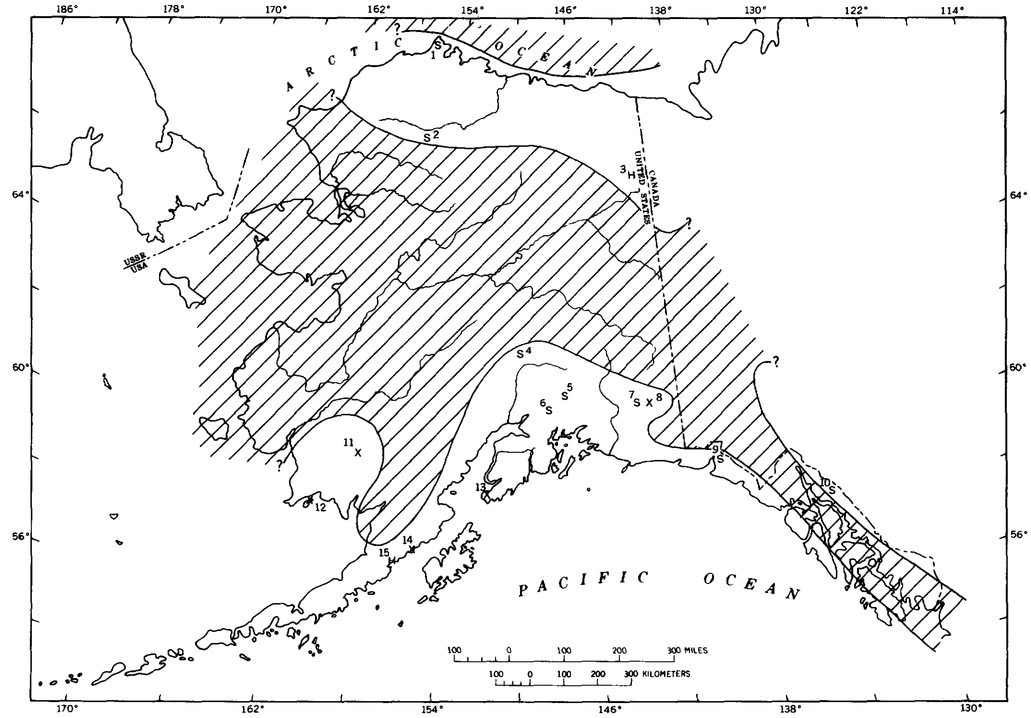


FIGURE 2.—Distribution of Hettangian and Sinemurian fossils and inferred seas in Alaska. Land areas ruled. X, Hettangian and Sinemurian; H, Hettangian only; S, Sinemurian only. Numbers keyed to descriptions of Hettangian and Sinemurian fossil occurrences.

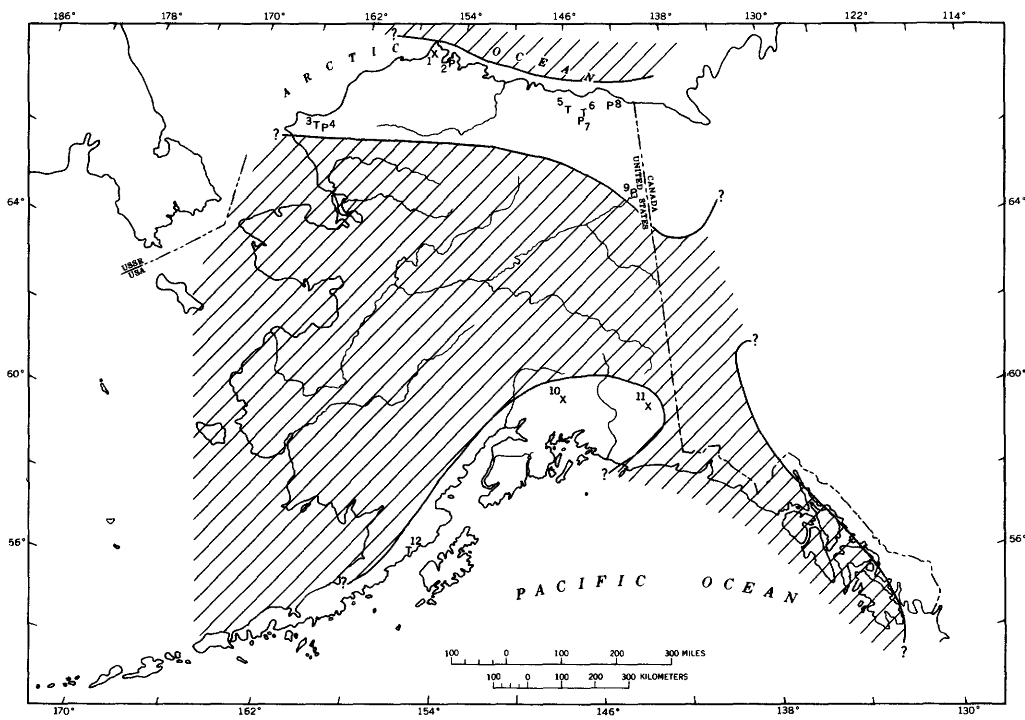


FIGURE 3.—Distribution of Pliensbachian and Toarcian fossils and inferred seas in Alaska. Land areas ruled. X, Pliensbachian and Toarcian; P, Pliensbachian only; T, Toarcian only. Numbers keyed to descriptions of Pliensbachian and Toarcian fossil occurrences.

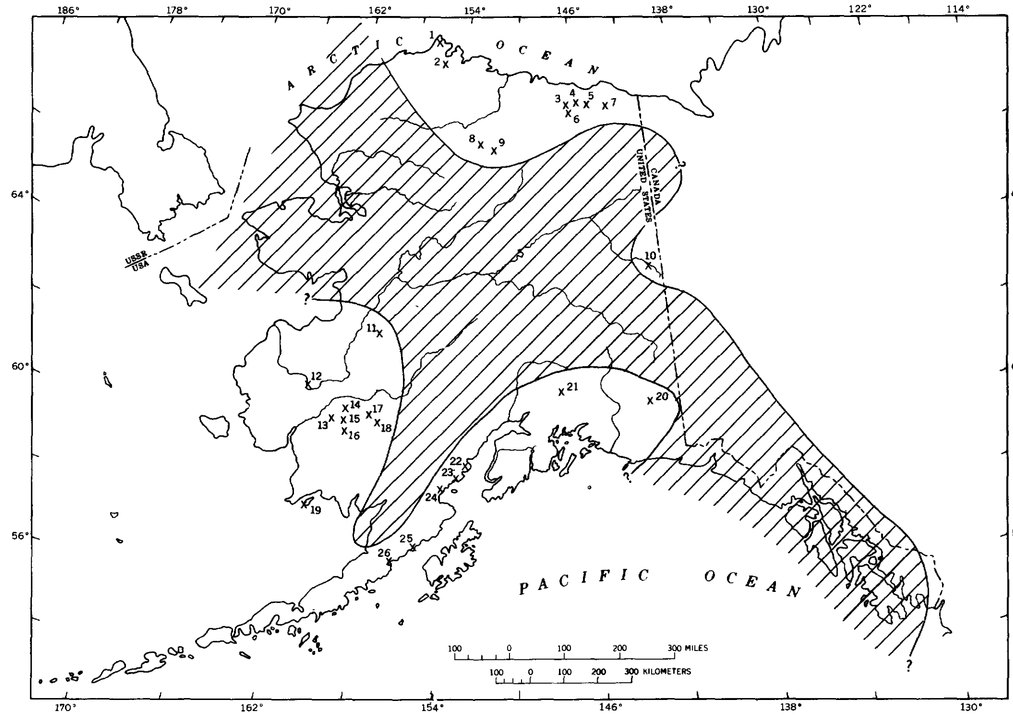


FIGURE 4.—Distribution of Bajocian fossils and inferred seas in Alaska. Land areas ruled. Numbers keyed to description of Bajocian fossil occurrences.

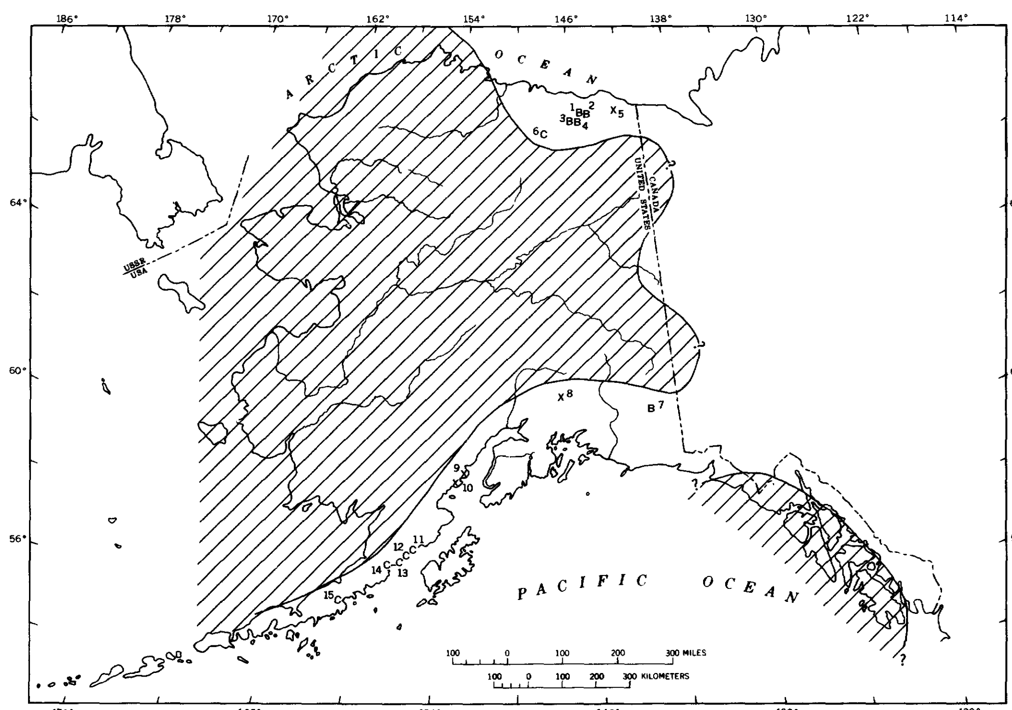


FIGURE 5.—Distribution of Bathonian and Callovian fossils and inferred seas in Alaska. Land areas ruled. X, Bathonian and Callovian; B, Bathonian only; C, Callovian only. Numbers keyed to descriptions of Bathonian and Callovian fossil occurrences.

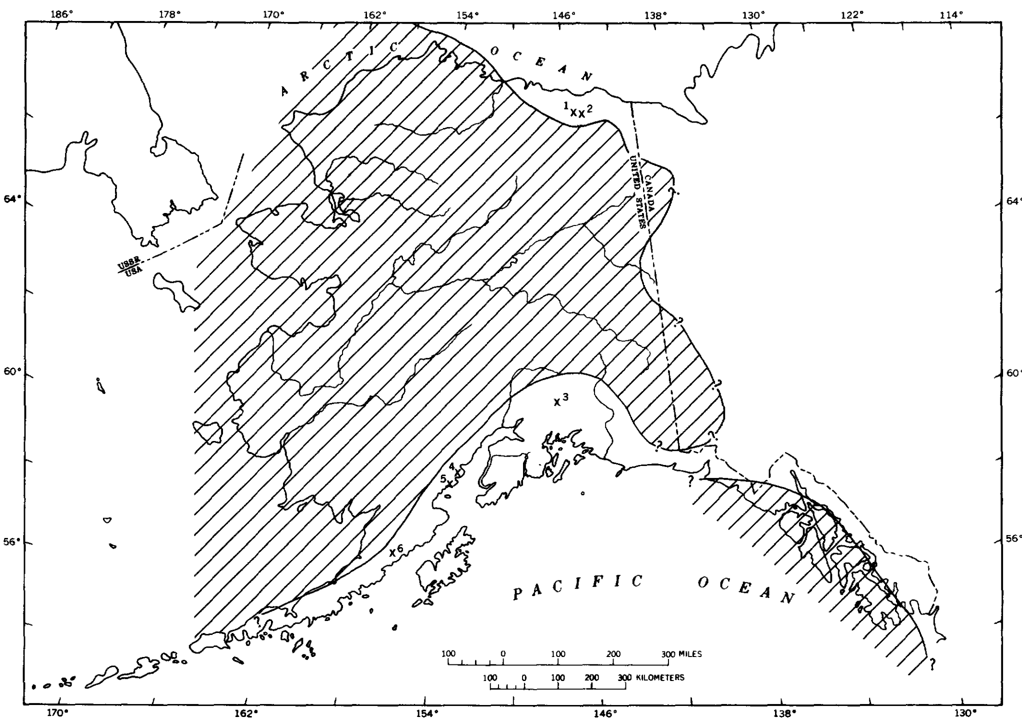


FIGURE 6.—Distribution of early Oxfordian fossils and inferred seas in Alaska. Land areas ruled. Numbers keyed to descriptions of early Oxfordian fossil occurrences.

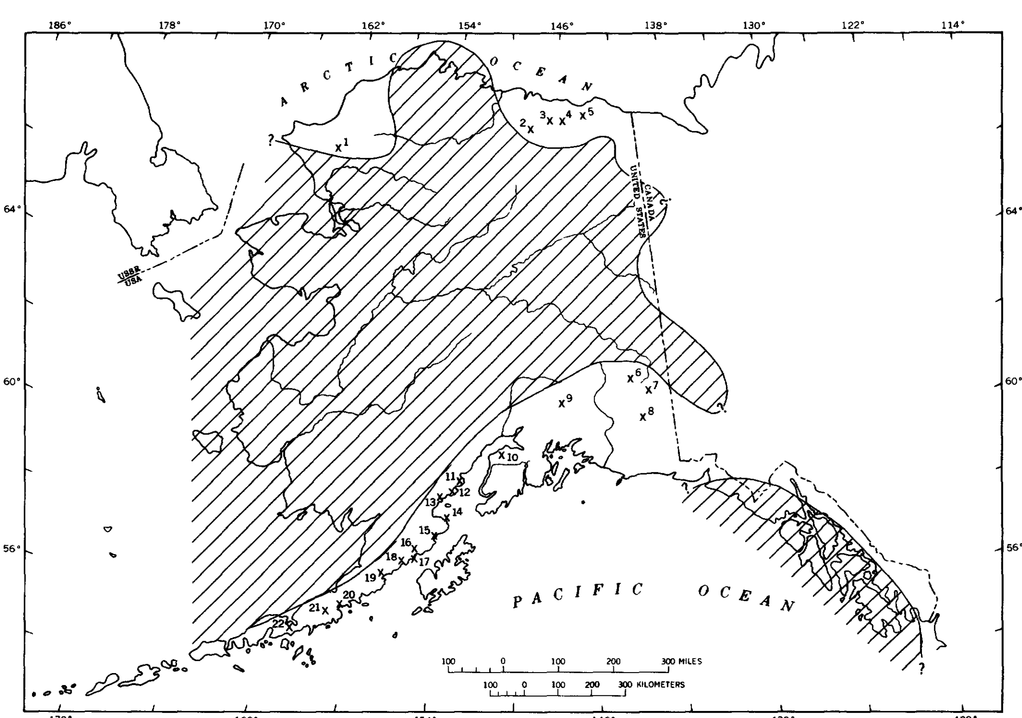


FIGURE 7.—Distribution of late Oxfordian to early Kimmeridgian fossils and seas in Alaska. Land areas ruled. Numbers keyed to descriptions of late Oxfordian to early Kimmeridgian fossil occurrences.

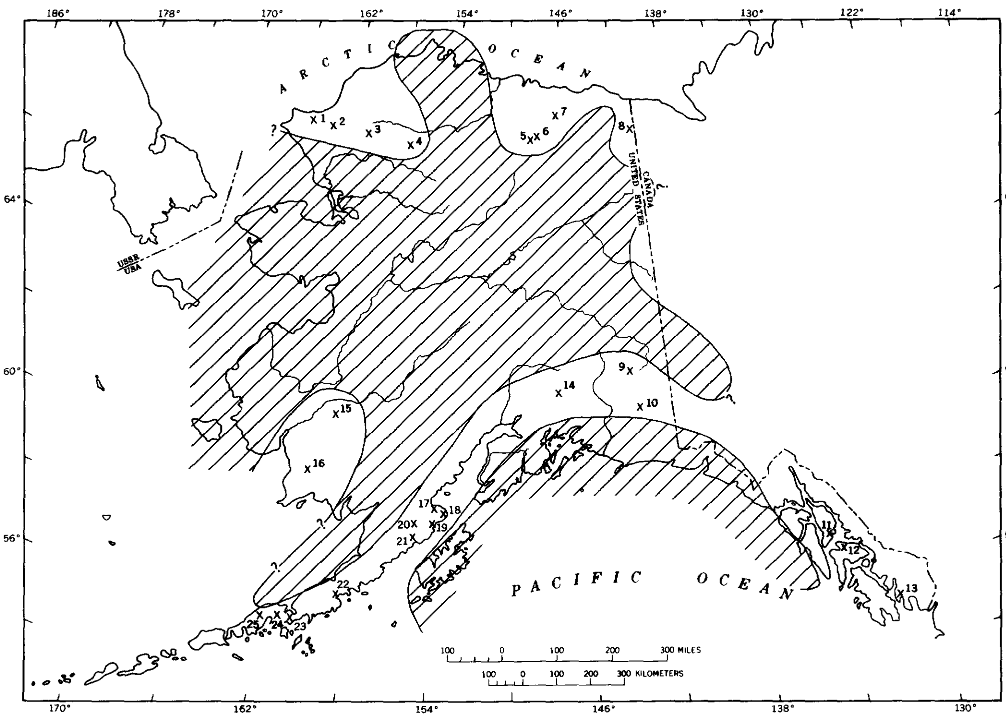


FIGURE 8.—Distribution of late Kimmeridgian to early middle Tithonian fossils and inferred seas in Alaska. Land areas ruled. Numbers keyed to descriptions of late Kimmeridgian to early middle Tithonian fossil occurrences.

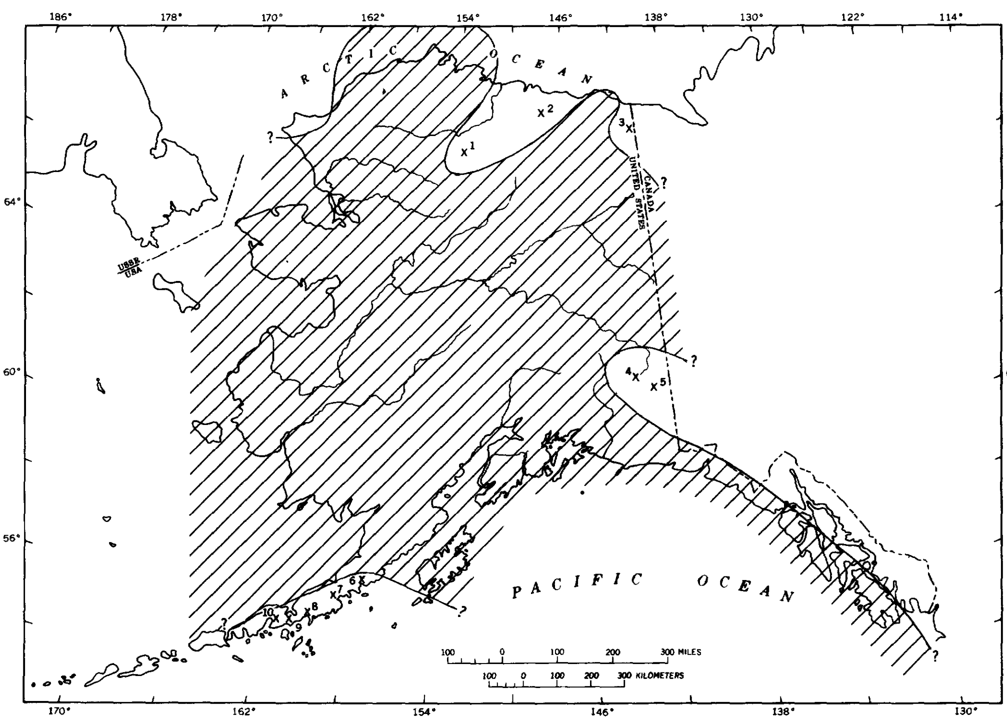


FIGURE 9.—Distribution of late middle to late Tithonian fossils and inferred seas in Alaska. Land areas ruled. Numbers keyed to descriptions of late middle to late Tithonian fossil occurrences.

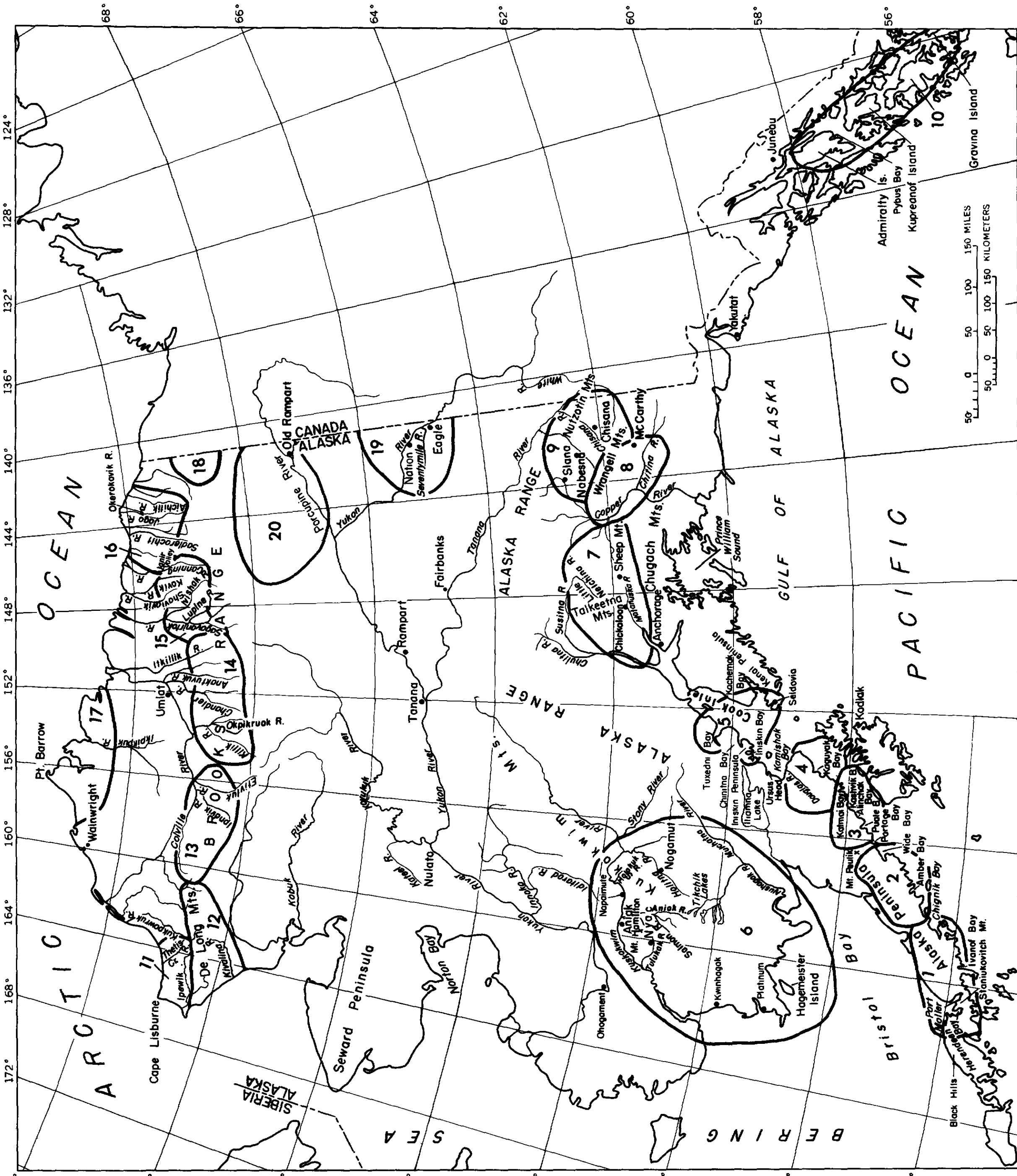


FIGURE 10.—Index map of Jurassic areas in Alaska. Numbers keyed to figure 11.

COMPARISONS OF STRATIGRAPHIC AND LITHOLOGIC FEATURES

Jurassic rocks in Alaska have been studied in greatest detail in the southern and northern parts of the State. Consequently, critical stratigraphic and fossil control is available for more areas within those parts than elsewhere, as is reflected in the correlation charts (fig. 11). Igneous rocks that are radiometrically dated (Detterman and others, 1965; Grantz and others, 1963, 1966; Reed and Lanphere, 1969; Reiser and others, 1965) are present in some of the same areas and confirm ages established by paleontology.

Stratigraphic analysis of Jurassic rocks in some areas of Alaska indicate that strata now in close proximity were originally deposited under different conditions and from different source areas. These rocks are generally near known faults of demonstrably large displacement, and the original site of deposition can be inferred with some degree of accuracy. The movement of these rocks to their present localities may result from plate tectonics initiated by continental drift, as suggested by many authors (Carey, 1958; Hamilton, 1968; Tailleur and Brosgé, 1970; Richter and Jones, 1970; Rickwood, 1970). This report is not primarily concerned with plate tectonics, but some palinspatic interpretations are pertinent to the discussion of the stratigraphy.

SOUTHERN ALASKA

In southern Alaska, Jurassic strata are exposed in a nearly continuous arcuate belt from the extreme southeastern part near Ketchikan to near the tip of the Alaska Peninsula (figs. 10 and 11*A*). Lower Jurassic rocks, however, are known only from the central part of this belt between Juneau on the east and Wide Bay on the west (Burk, 1965; Detterman and Hartsock, 1966; Detterman and Reed, 1964; Grantz, 1960a,b, 1961a,b; Imlay, 1952; Juhle, 1955; Kirschner and Minard, 1949; MacKevett, 1963, 1065a,b, 1969, 1970a,b; Martin, 1905, 1926; Martin and Katz, 1912; Moffitt, 1922a,b, 1927; Paige and Knopf, 1907; Smith, 1917, 1939; Stanton and Martin, 1905).

During Early Jurassic time, deposition occurred within a nearly continuous belt, at least part of which bordered a volcanic island-arc system. Volcanic and volcaniclastic rocks form most of the record from the Katmai area in the south (Mather, 1925; Keller and Reiser, 1959) to the Talkeetna Mountains in the north (Grantz, 1960a,b, 1961a,b), but the main eruptive centers were in the Cook Inlet area (Detterman and Hartsock, 1966). At the same time, argillite, limestone, chert, spiculite, and shale were deposited both as beds within the volcanic rocks, and at a considerable distance from the island-arc system in areas now represented by the Kuskokwim region (Cady and others, 1955; Hoare, 1961; Hoare and Coonrad, 1961a,b) and the Wrangell Mountains (MacKevett, 1963, 1965a,b, 1969, 1970a,b). Near the end of the subperiod, the rocks of southern Alaska were highly deformed and intruded by granitic batholiths in the Talkeetna Mountains (Grantz and others, 1963) and in the Cook Inlet area (Detterman and others, 1965; Reed and Lanphere, 1969). These granitic rocks are dated at 155 to 175 m.y. The oldest date probably represents the beginning of plutonism and may correspond to an unconformity dated paleontologically as late Toarcian to early Bajocian. Small mafic intrusive bodies are associated with the Lower Jurassic volcanic rocks in the Cook Inlet area and predate the granitic plutons.

Middle Jurassic rocks in southern Alaska are mainly graywacke-type sandstone, polymictic conglomerate, siltstone, and shale suggestive of rapid deposition in a subsiding epieugeosynclinal trough. Volcanic rocks are a major part of the sequence only in the Kuskokwim region (Cady and others, 1955; Hoare, 1961). In general, the characteristics of the rocks in southern Alaska indicate a considerable change in depositional environment between Early and Middle Jurassic time. This change probably reflects orogenic activity that resulted in plutonism near the boundary of the subperiods. Similar orogenic activity continued throughout Middle Jurassic time, as indicated by the shifting positions of the seas and the uplift and erosion of the bordering uplands to the west and northwest. The many polymictic conglomerates in the Middle Jurassic sequence that contain clasts of both the granitic plutons and the Lower Jurassic volcanic rocks, which were mainly of marine origin, are evidence of these events. However, the presence of laumontite in the rocks of the Cook Inlet area suggests derivation from active volcanoes in the Kuskokwim region and indicates, therefore, that the relative geographic position of the two regions has not greatly changed since Middle Jurassic time.

During most of Late Jurassic time, marine deposition in southern Alaska took place in two or more basins that fragmented from an earlier larger Jurassic basin after a period of general emergence at about the transition from Callovian to Oxfordian time. One basin occupied the site of the Alaska Peninsula-Cook Inlet region and continued as far east as the Wrangell Mountains; it was filled mainly with arkosic sediments derived from nearby granitic batholiths to the west and north (Atwood, 1911; Burk, 1965; Capps, 1923, 1934; Detterman and Hartsock, 1966; Grantz and others, 1966; Keller and Reiser, 1959; Kellum, 1945; Kirschner and Minard, 1949; Kirschner and Lyon, 1973; MacKevett, 1963, 1965a,b, 1969, 1970a,b, 1971; Martin, 1905, 1921, 1925, 1926; Martin and Katz, 1912; Mather, 1925; Miller and others, 1959; Moffit, 1922a,b, 1927, 1938a, 1943, 1954; Paige, 1906; Smith, 1925; Smith and Baker, 1924; Spurr, 1900; Stanton and Martin, 1905; Stone, 1905). Some silt and clay were deposited as beds within the arkosic sediments throughout most of the basin and locally formed a considerable part of the section. Deposition was continuous to the end of the Jurassic only at the extreme southern end of the Alaska Peninsula; elsewhere, the uppermost Jurassic beds were removed or deposition did not occur.

Another basin, or basins, existed in easternmost Alaska and probably extended into adjoining British Columbia, as shown by the presence of thousands of feet of Upper Jurassic graywacke, mudstone, conglomerate, argillite, and slate now exposed in southeastern Alaska (Brew and others, 1966; Lathram and others, 1960; Loney, 1964; Martin, 1926) and in the eastern Alaska Range (Richter, 1971). The characteristics of these rocks contrast so much with those of the arkosic rocks deposited at the same time in the Cook Inlet region that the provenance of deposition and the lithology of the source areas must have been quite different. The differences could be explained by extensive crustal movements, as postulated by Richter and Jones (1970). These crustal movements have apparently foreshortened the distance between the basins by many tens of miles along major faults in southeastern Alaska.

NORTHERN ALASKA

Jurassic rocks in northern Alaska have been studied in detail only in the eastern part (figs. 10 and 11*B*). Characteristics of the strata indicate that the provenance of deposition and lithology of the source areas were considerably different than in southern Alaska during most of the Jurassic (Brosgé and Tailleur, 1970; Detterman, 1973; Gryc and Lathram, 1954; Gryc and Mangus, 1954; Keller and others, 1961; Leffingwell, 1919; Reed, 1968; Reiser and Tailleur, 1969; Reiser and others, 1970; Sable, 1965; Smith and Mertie, 1930). However, marine connections with southern Alaska probably existed via Yukon Territory and east-central Alaska (Frebold and others, 1967; Jeletzky, 1962). The stratigraphic sequence in the western part of northern Alaska is complicated by thrust faulting, which has juxtaposed two dissimilar Jurassic sections; one is typical of northern Alaska sedimentary rocks, and the other is more closely related to Jurassic volcanic rocks south of the Brooks Range (Brosgé and Tailleur, 1970; Detterman, 1972; Gates and Gryc, 1963; Jones and Grantz, 1964; Lathram, 1965; Patton and Grantz, 1962; Tailleur, 1969).

Lower Jurassic rocks in northern Alaska are mainly fissile clay shale and claystone that commonly contain limestone concretions. Siltstone and silty shale are abundant locally. Chert, tuff, graywacke, and oil shale are present at a few localities in the western part (Brosgé and Tailleur, 1970; Detterman, 1973; Imlay, 1955, 1967; Mangus and others, 1954; Tailleur, 1964; Tailleur and Kent, 1954; Tailleur and others, 1966). A glauconitic sandstone is present in the subsurface along the north coast (Bergquist, 1966; Collins, 1958, 1961; Detterman, 1973; Gates and others, 1968; Imlay, 1955; Loeblich, 1954; Payne, 1955; Payne and others, 1951; Robinson, 1959), and a massive sandstone of earliest Jurassic or latest Triassic age is present along the north flank of the Brooks Range in northeastern Alaska (Detterman, 1973); Sable, 1965). The sandstones would indicate that sediment sources were both north and south. The Lower Jurassic section is not complete at any locality and is only sparsely fossiliferous; consequently, regional unconformities are impossible to determine. There are probably many local unconformities, and paleontologic evidence suggests that parts of the Hettangian, Sinemurian, and Pliensbachian are missing.

Siltstone, silty shale, and pyritic clay shale are the main rock types present in the Middle Jurassic of northern Alaska. Orange-weathering clay ironstone concretions and beds are also common. Graywacke and tuff are present locally in the central part (Chapman and others, 1964; Jones and Grantz, 1964; Patton and Keller, 1954; Patton and Tailleur, 1954, 1964). The only good exposures for this part of the Jurassic are in northeastern Alaska (Brosgé and Tailleur, 1970; Detterman, 1973; Gryc, 1951; Gryc and Mangus, 1954; Keller and others, 1961; Leffingwell, 1919; Reiser and Tailleur, 1969; Reiser and others, 1970; Sable, 1965; Whittington and Sable, 1954), where a major middle Bajocian to early Bathonian unconformity can be detected both lithologically and paleontologically (Imlay, 1955, 1970). Elsewhere in northern Alaska, the rocks are too poorly exposed to determine the presence of unconformities.

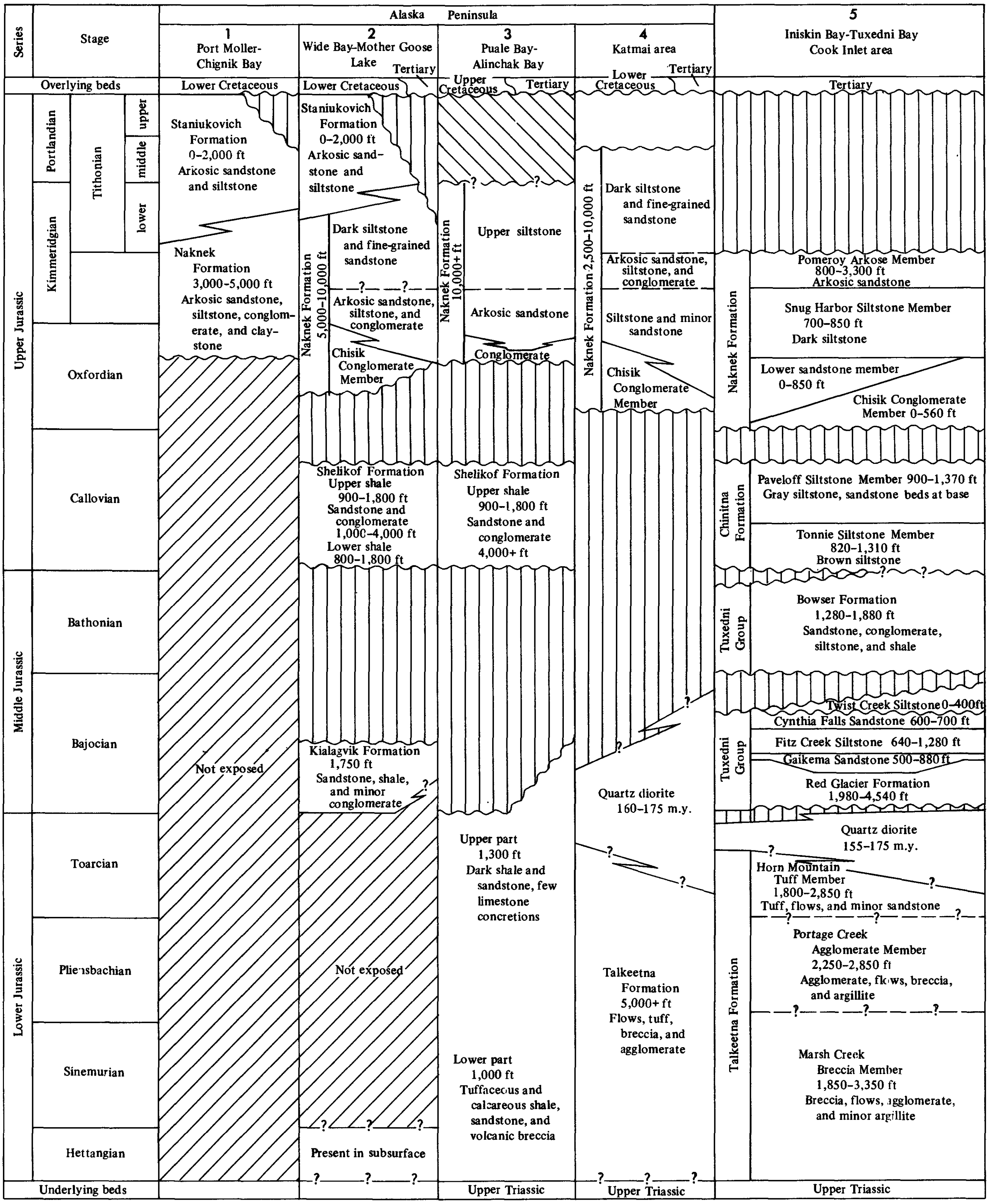
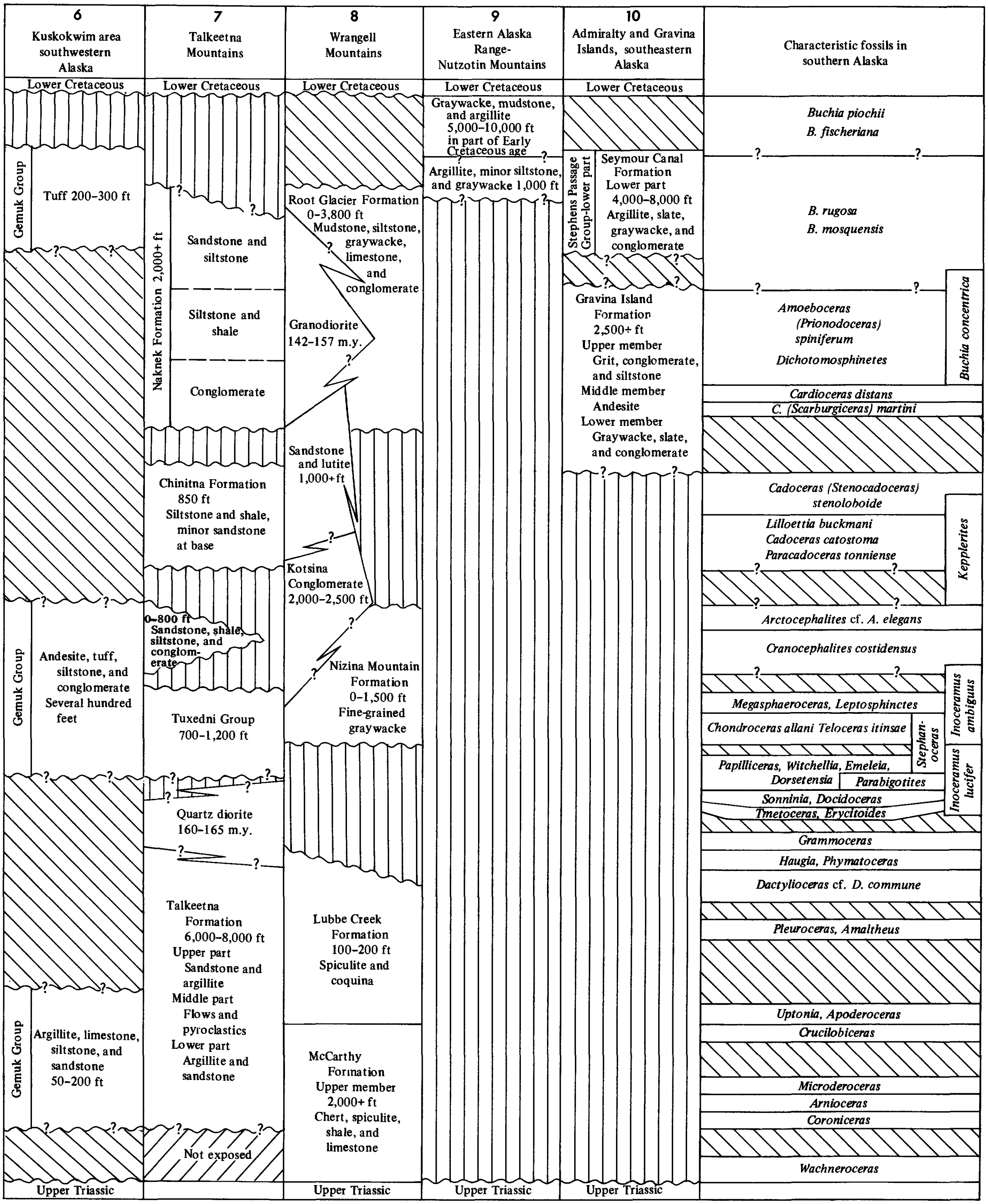


FIGURE 11.—*A*, Correlation of Jurassic rocks in southern Alaska. Vertical lines indicate strata missing; right diagonal lines ity; jagged lines indicate gradational or indefinite contact. Numbered columns keyed



indicate beds not exposed; left diagonal lines indicate lack of fossil data; wavy lines indicate unconformity or disconform-
to figure 10. Compiled October 1971. (Figure 11 continued on following pages.)

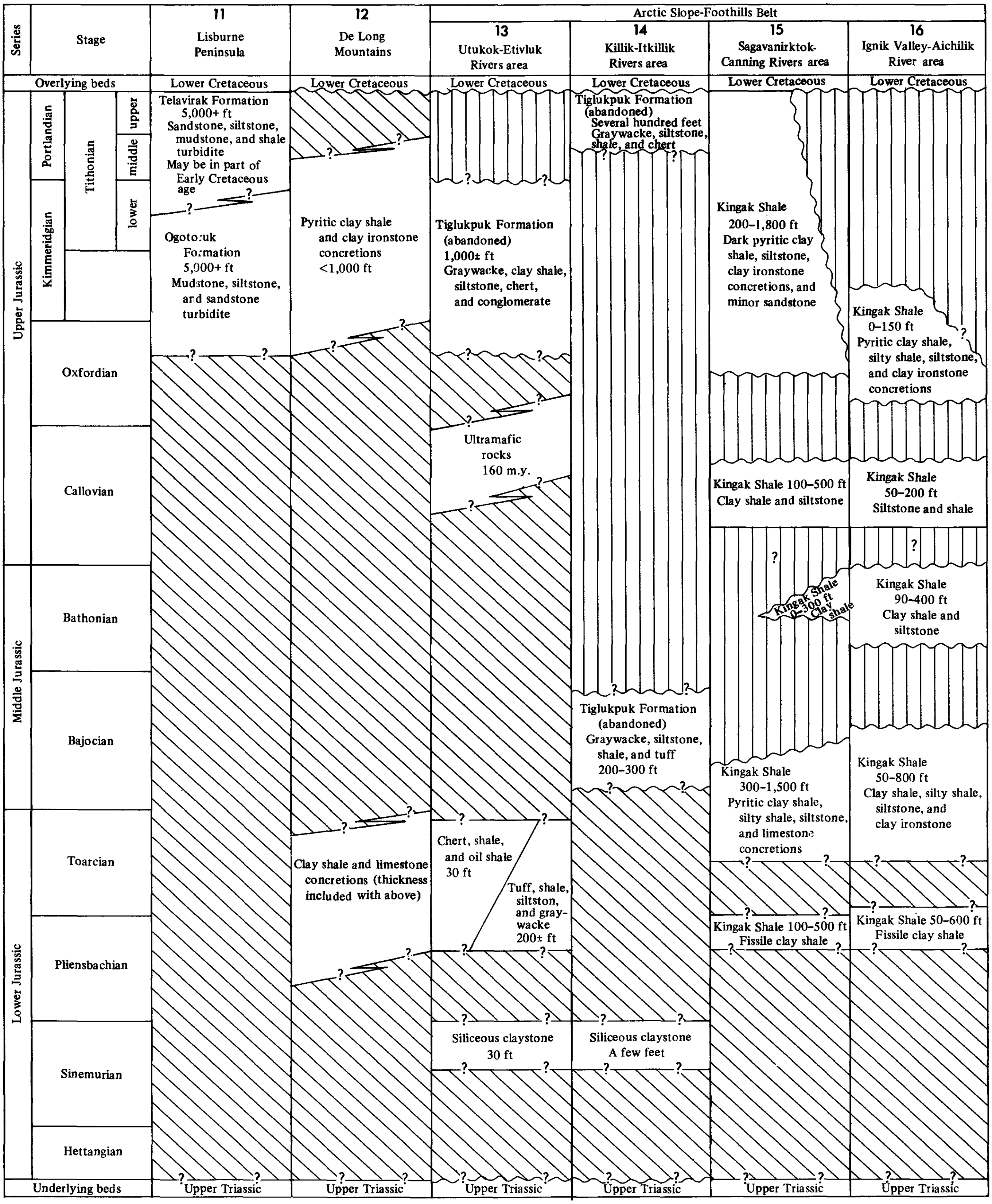
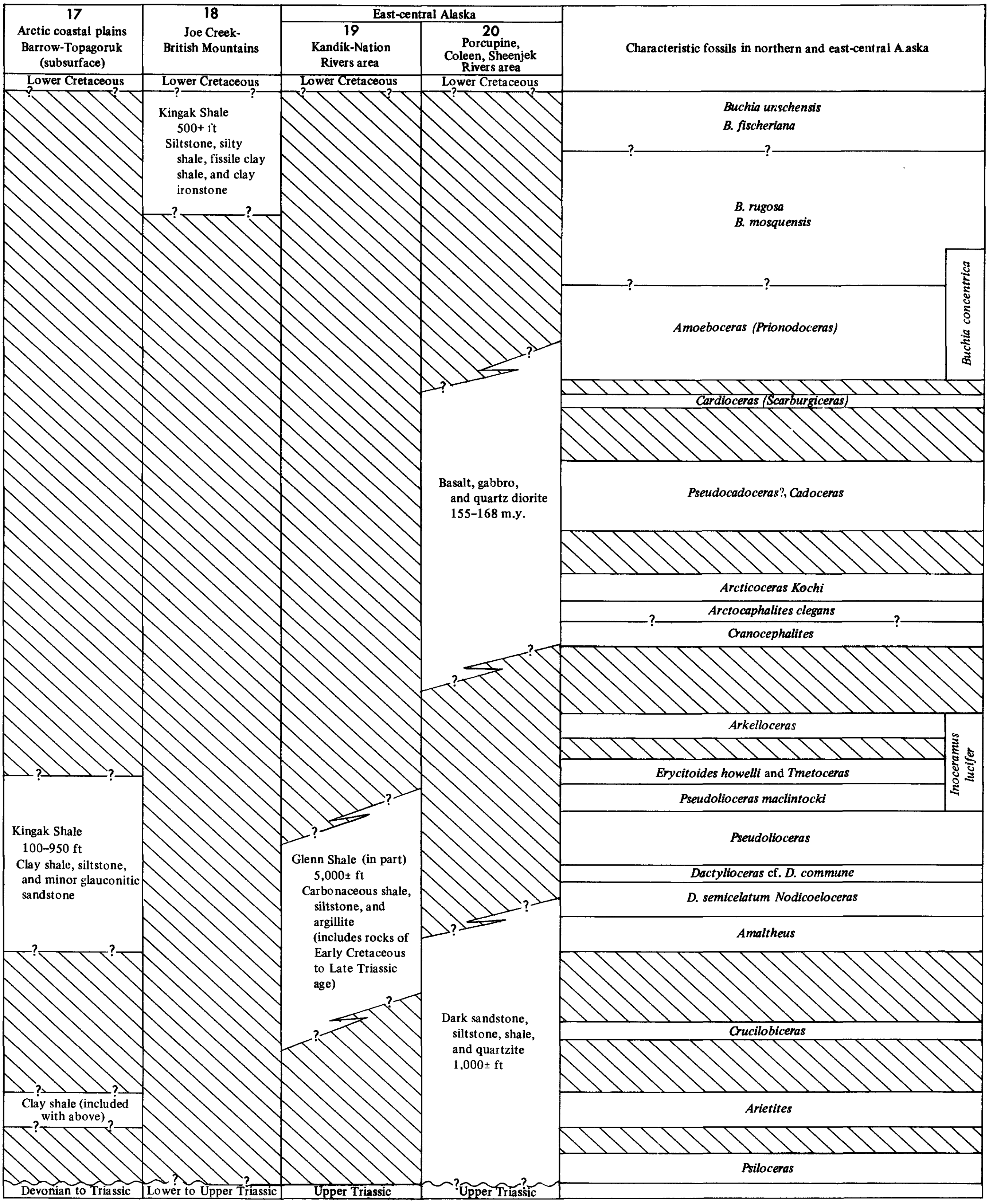


FIGURE 11.—Continued. *B*, Correlation of Jurassic rocks in northern and east-central Alaska. Vertical lines indicate strata unconformity or disconformity; jagged lines indicate gradational or



missing; right diagonal lines indicate beds not exposed; left diagonal lines indicate lack of fossil data; wavy lines indicate indefinite contact. Numbered columns keyed to figure 10. Compiled October 1971.

Upper Jurassic rocks in northern Alaska consist mainly of siltstone and shale similar to those of the Middle Jurassic. The principal exceptions are a thick sequence of sandstone, siltstone, and mudstone turbidites exposed in the far western part of northern Alaska near Cape Lisburne (Campbell, 1967; Chapman and Sable, 1960; Detterman, 1972; Knowlton, 1914; Sable and Mangus, 1954; Tailleur, 1969) and a thin sequence of tuffaceous graywacke, conglomerate, and chert exposed in the central part of northern Alaska (Brosgé and Tailleur, 1970; Chapman and others, 1964; Patton, 1956; Patton and Tailleur, 1964). These rocks that are exceptions may have been faulted into their present positions from somewhere south of the modern Brooks Range (Brosgé and Tailleur, 1970; Tailleur, 1969).

Most of northern Alaska was apparently emergent during late Callovian and early Oxfordian time and again during the late Tithonian. These periods of emergence are marked by major unconformities and by a change in the faunal assemblages. No ammonites have been found in rocks of Tithonian Age, but the pelecypod *Buchia* is present in many areas (Brosgé and Tailleur, 1970; Detterman, 1973; Imlay, 1959; Patton, 1956).

A sequence of graywacke, siltstone, shale, chert, and conglomerate in the central part of northern Alaska was formerly mapped as the Tiglukpuk Formation of Late Jurassic age (Patton, 1956). The type locality on Tiglukpuk Creek is now known to be a faulted section consisting of Middle Jurassic and Lower Cretaceous rocks (Jones and Grantz, 1964); consequently, the formation name is herein abandoned.

Jurassic strata are present in east-central Alaska (figs. 10 and 11*B*) but have not been studied in detail. The rocks are poorly exposed, and the stratigraphic succession has not been completely determined. Two facies are present, one of shale, siltstone, and argillite in the Kandik and Nation Rivers area (Brabb, 1969, 1970; Brabb and Churkin, 1969), and the other of sandstone, quartzite, and shale in the Porcupine, Coleen, and Sheenjek Rivers area (Brosgé and Reiser, 1964, 1969; Maddren, 1912; Maddren and Harrington, 1914; Mertie, 1929, 1930). Sandstone and quartzite of the Porcupine River area contain a Hettangian fauna and probably represent the initial sediments in a southward-expanding northern Alaska-Yukon Territory sea (Jeletzky, 1962). The sea continued to expand and is believed to have connected northern and southern Alaska through Middle and early Late Jurassic time (figs. 2–9). Volcanic rocks dated at 155 to 165 m.y. (Reiser and others, 1965) are present in the Christian area northwest of Porcupine and may indicate tectonic activity associated with uplift and subsequent subaerial erosion during the later part of Late Jurassic time.

OCCURRENCES OF JURASSIC UNCONFORMITIES

SOUTHERN ALASKA

The presence of unconformities in southern Alaska has been fairly well established (fig. 12). The lowest known unconformity is at the top of Lower Jurassic volcanic rocks north of Cook Inlet (Detterman and Hartsock, 1966, p. 69, 71; Grantz and others, 1963, p. B58); it represents a time of pronounced folding, and, on the basis of ammonites from the Talkeetna Mountains, must have formed during the latest Toarcian and the earliest Bajocian time (*Leioceras opalinum* zone). In the Wrangell Mountains, an unconformity possibly formed at the same time occurs between the Nizina Mountain and Lubbe Creek Formations (MacKevett, 1969, p. A41, A44).

The next higher well-recognized unconformity in southern Alaska formed during the later part of late Bajocian time. It is most clearly shown on the Iniskin Peninsula (Detterman and Hartsock, 1966, p. 35, 40) where the Bowser Formation of Bathonian Age cuts across 420 feet of the Twist Creek Siltstone of early late Bajocian Age onto beds of late middle Bajocian Age. The same unconformity is probably represented also on the Alaskan Peninsula in the lower part of a hiatus of middle Bajocian to late Bathonian Age. The fact that the youngest Bajocian beds exposed at Wide Bay are as old as early middle Bajocian (*Otoites sauzei* zone) is probably a result of differential erosion such as occurred on the Iniskin Peninsula. Such a possibility is supported by the presence on Alinchak Bay of *Inoceramus ambiguus* Eichwald (Mesozoic loc. 12390), which in Alaska is not known in beds older than the late middle Bajocian (*Stephanoceras humphriesianum* zone).

A third unconformity above the base of the Jurassic in the Cook Inlet region formed late in the Bathonian. It is marked between Chinitna Bay and Tuxedni Bay by northward truncation of the uppermost part of the Bowser Formation. It is marked in the Talkeetna Mountains by erosion that locally removed all beds equivalent to the Bowser Formation. It may be represented in the Wrangell Mountains in the basal part of a hiatus of probable late Bathonian to early Oxfordian Age. It is probably represented in the Alaska Peninsula in the upper part of a hitaus between beds of early middle Bajocian and early Callovian Age. On Wide Bay and Puale Bay, lower Bathonian sediments were either never deposited or were eroded away during late Bathonian time. If the latter possibility is true, then some Bathonian beds may still be present in the subsurface of the Alaska Peninsula.

A fourth unconformity in southern Alaska formed during the late Callovian and in some areas persisted into the early Oxfordian. It represents this entire time span throughout most of the Alaska Peninsula except near Mount Peulik (Mesozoic loc. 10798) west of Puale Bay. It represents only the late Callovian in the Cook Inlet region where middle Callovian beds in the upper part of the Chinitna Formation are overlain unconformably by the Naknek Formation that basally contains the early Oxfordian ammonite *Cardioceras* (Detterman and Hartsock, 1966, p. 47–49). Farther east in the Wrangell Mountains, the unconformity represents the upper part of a hiatus that apparently extends from late Bathonian to early Oxfordian time.

Another unconformity of latest Jurassic age may extend across most of southern Alaska east of Wide Bay as indicated by an absence of such late Tithonian mollusks as *Buchia piochii* (Gabb) or *B. fischeriana* (d'Orbigny) and by the presence locally of beds of Valanginian to Hauterivian Age resting on beds of late Kimmeridgian to middle Tithonian Age. For example, in the Talkeetna Mountains, the uppermost Jurassic beds containing *B. rugosa*

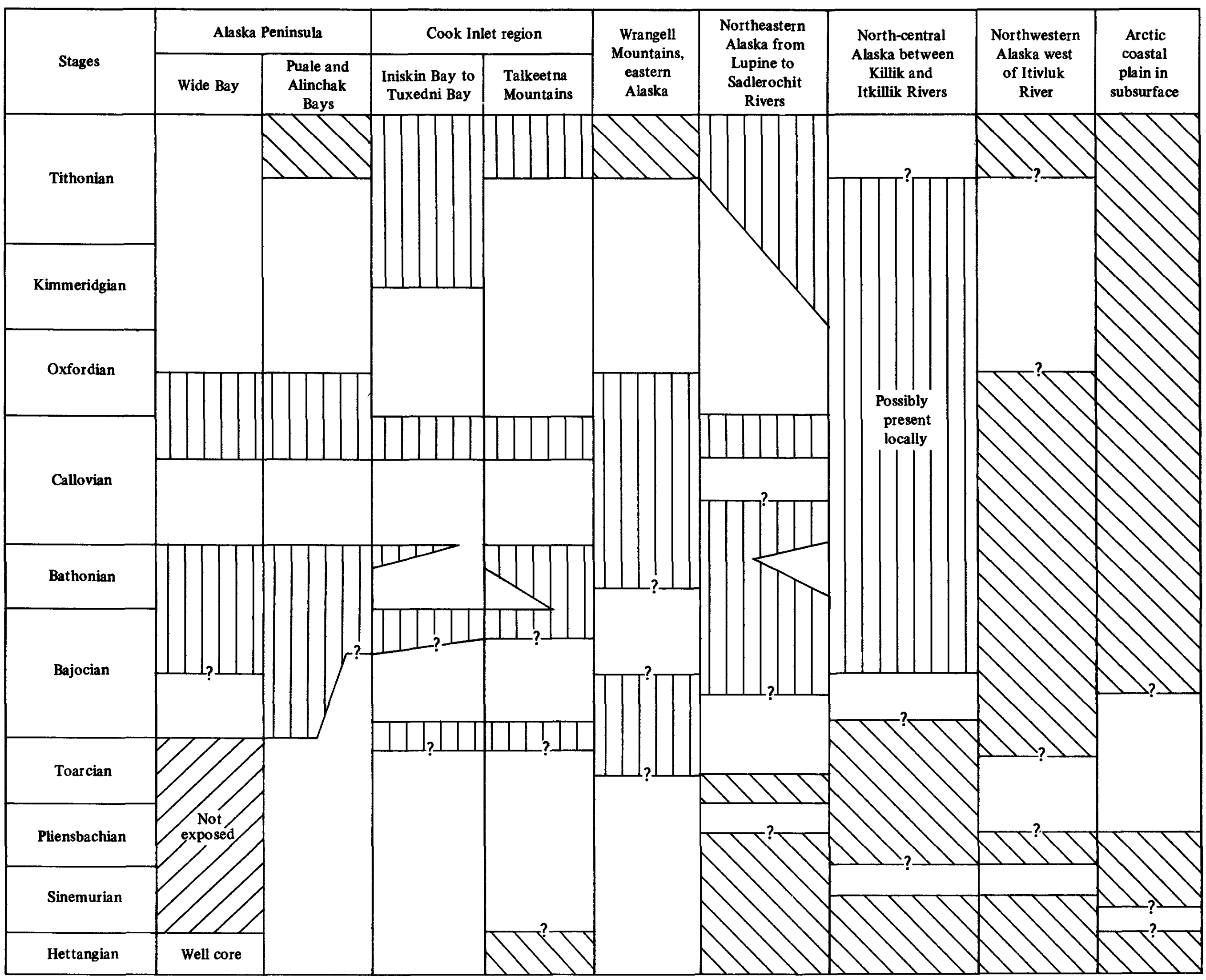


FIGURE 12.—Occurrences of unconformities in the Jurassic of Alaska. Blank spaces indicate strata of known ages; vertical lines indicate strata missing; right diagonal lines indicate beds not exposed; left diagonal lines indicate lack of fossil data.

(Fischer) and *B. mosquensis* (von Buch) are overlain by conglomerates and sandstones containing Buchias of early to middle Valanginian Age (Imlay and Reeside, 1954, p. 233; Grantz and others, 1966, p. C46). Evidently the unconformity below the Valanginian beds could have formed during the late Tithonian, or the Berriasian, or the entire time interval.

NORTHERN ALASKA

In northern Alaska, only the area east of the Lupine River has been studied in sufficient detail for the presence and positions of unconformities to be fairly well documented. In that area, one unconformity has been dated as late middle Bajocian to possibly early Bathonian because the youngest known Bajocian beds contain *Arkelloceras,* and the oldest Bathonian beds contain *Cranocephalites.* A slightly higher unconformity may exist at the Bathonian-Callovian boundary (see columns 15 and 16, fig. 11B), although the westward pinchout of the Bathonian beds between the Canning and Sagavanirktok Rivers could be depositional against a landmass in the area of the Killik and Itkillik Rivers. The next higher unconformity has been dated as late Callovian because the underlying beds contain *Cadoceras* and *Pseudocadoceras*?, and the overlying beds contain *Cardioceras.*

The absence of any ammonites of late Callovian Age deserves special mention because beds of that age are also absent in Canada (Frebold, 1961, table 1 opposite p. 26; 1964a, p. 4; Frebold and Tipper, 1967, p. 18) and have been found in North America only in east-central California (Imlay, 1961b, p. D6, D27) and in the states of Oaxaca and Guerrero in southern Mexico (Burckhardt, 1927; 1930, p. 26, 32–36, 43; Imlay, 1961b, p. D12). Evidently marine waters covered very little of North America during late Callovian time.

The existence of other unconformities in northern Alaska has not as yet been proven. The fact that the latest Tithonian has been identified at only two places (Mesozoic locs. 26390, M2531) suggests however, that marine deposition was not widespread at that time. Also, nondeposition of Upper Jurassic beds throughout a large area in north-central Alaska is indicated by the fact that to date only Early Cretaceous species of *Buchia* have been collected in the foothills of the Brooks Range between the Killik and Itkillik Rivers (Jones and Grantz, 1964), and those species were obtained near beds of Late Triassic age. Similarly, the reported Late Jurassic age of certain beds in the subsurface of north-central Alaska is questioned because their age determination was based on species of Foraminifera that were originally obtained from the beds just mentioned (Tappan, 1955, p. 25).

The sequence of events in northern Alaska during the Jurassic both resembled and differed from that in southern Alaska. Resemblances include moderately widespread seas from Sinemurian to early middle Bajocian time and from Oxfordian to middle Tithonian time. Resemblances also include formation of unconformities in late Callovian and late Tithonian time. Differences from southern Alaska include the absence of an unconformity in northern Alaska at the end of Toarcian time and the formation of an unconformity at a different time during Bajocian and Bathonian time. For example, in northern Alaska no ammonites have been found that represent the late middle Bajocian (*Stephanoceras humphriesianum* zone), the late Bajocian, and the early Bathonian. In southern Alaska, by contrast, that time is well represented, except for the latest late Bajocian. If failure to find ammonites of certain ages in northern Alaska is not due to inadequate collecting, then the advances and retreats of the seas in general occurred at different times in northern than in southern Alaska and reflect local diastrophic movements. These differences are probably related to times of intrusion and uplift of granitic rocks of the Aleutian Range batholith in southern Alaska (Detterman and Hartsock, 1966, p. 63, 64, 69–71).

EXTENT OF JURASSIC SEAS

In the Early Jurassic, the fossil record indicates that marine waters spread most widely across southern Alaska during Sinemurian time and most widely across northern Alaska during Pliensbachian and Toarcian time (figs. 2, 3, and 13). The Sinemurian in northern Alaska may be coextensive, however, with the geographic range of *Otapiria tailleuri* Imlay (1967, p. B3–B7, pl. 1, figs. 1–23, pl. 2, fig. 32), which species occurs in a distinctive, rather thin organic shale and has been found over a distance of at least 200 miles north of the Brooks Range between the Etivluk and Itkillik Rivers. Evidence for such an extension of the Sinemurian consists (1) of a large well-preserved float specimen of *Crucilobiceras* (Mesozoic loc. 29774 from the same place as localities M 2451 and 29280 in Imlay, 1967, p. B7); (2) four small ammonite molds identical with the inner whorls of *Crucilobiceras* (Mesozoic loc. 29775 from the same place as locality 24060 in Imlay, 1967, p. B7); (3) similar small ammonite molds (Mesozoic locs. 29281 and 29282) that previously were compared with *Tmetoceras* and other genera

(Imlay, 1967, p. B6, B7) ; and (4) the association of the ammonites with *Otapiria tailleuri* Imlay at USGS Mesozoic localities 29282 and 29775. The inferences from this data are that the Sinemurian sea was probably nearly as extensive in northern Alaska as the Pliensbachian and Toarcian seas, and in Alaska as a whole the Sinemurian sea was nearly as extensive as the Bajocian sea.

During Bajocian time, marine waters transgressed widely in southern, southwestern, north-central and northeastern Alaska and were connected eastward with seas in Canada. Near Wide Bay on the Alaska Peninsula, deposition continued at least until the early middle Bajocian (*Parabigotites crassicostatus* beds), in the Cook Inlet region until the early late Bajocian (*Megasphaeroceras rotundum* beds), and in northeastern Alaska until the early middle Bajocian (*Arkelloceras* beds) (fig. 14). The duration of the sea in the Kuskokwim region of southwestern Alaska is not known because the fossil evidence consists almost entirely of *Inoceramus ambiguus* Eichwald, which in the Cook Inlet regions range from late middle Bajocian (*Teloceras itinsae* beds) through the Bathonian and occurs rarely in beds of early Callovian Age. Southeastern Alaska was probably also covered by a sea during at least middle Bajocian time, as indicated by occurrences of fossils of that age in nearby northwestern British Columbia (Frebold and Tipper, 1970, fig. 6 on p. 10). Whether the Bajocian sea ever extended across northwestern Alaska west of the Okpikruak River must await more fieldwork.

During Bathonian time, marginal seas definitely occurred in northeastern Alaska east of the Sagavanirktok River and in southern Alaska between the Iniskin Peninsula and the Wrangell Mountains (fig. 5). These clearly were westward extensions of seas of that age in central and northern Yukon Terri-

Stages	Western Nevada (Muller and Ferguson, 1939; Hallam, 1965)	Southern and eastern Mexico (Erben, 1956, 1957)	East-central Oregon (Imlay, 1968)	Southern Alaska (Imlay, 1968)	Northern Alaska (Imlay, 1955)
Toarcian	*Grammoceras* and *Pseudolioceras*	Lower part of coal- and plant-bearing beds	*Catulloceras* and *Dumortieria*		*Pseudolioceras*
				Grammoceras	
	Catacoeloceras and *Dactylioceras* ?		*Haugia* and *Polyplectes* ?	*Haugia* and *Phymatoceras* ?	
	Nodicoeloceras			*Dactylioceras* cf. *D. commune* ?	*Dactylioceras* cf. *D. commune*
					Dactylioceras cf. *D. semicelatum* and *Nodicoeloceras*
Pliensbachian	*Arieticeras*	*Arieticeras* ?	*Arieticeras, Reynesoceras, Paltarpites, Prodactylioceras,* and *Leptaleoceras* ?	*Pleuroceras, Amaltheus,* and *Paltarpites*	*Amaltheus* ?
	?	?		?	
	Uptonia?	*Uptonia*	?	*Uptonia, Apoderoceras,* and *Acanthopleuroceras* ?	?
Sinemurian	*Eoderoceras* and *Crucilobiceras*	*Microderoceras* and *Echioceras*	*Crucilobiceras* ?	*Crucilobiceras* ?	*Crucilobiceras* ?
	Oxynoticeras ?	*Pleurechioceras* ?			
		Vermiceras ?			
		Oxynoticeras ?		*Microderoceras* ?	
	?	*Euagassiceras* ?	?		?
	Arnioceras, Arietites, Coroniceras, and *Megarietites*	*Arnioceras* ?	*Arnioceras* ?	*Arnioceras* ?	*Arietites*
		Coroniceras		*Coroniceras*	
Hettangian	*Schlotheimia* and *Alsatites*	Not exposed	*Schlotheimia* and *Alsatites* ?	?	?
	Waehneroceras and *Psiloceras*		*Waehneroceras* and *Psiloceras*	*Waehneroceras*	*Psiloceras*

FIGURE 13.—Correlation of Hettangian to Toarcian ammonite faunas in Alaska.

tory, Canada (Frebold and others, 1967, p. 11, 12, 23). The fossil record (fig. 14) indicates that the sea in southern Alaska existed during the entire Bathonian, and the sea in northeastern Alaska existed only during the middle to late Bathonian. Marine waters probably did not extend as far southwest as Puale Bay and Wide Bay in the Alaska Peninsula, because beds of early Callovian Age rest directly on beds of middle Bajocian Age in both places. Whether or not the Bathonian sea ever extended westward across north-central and northwestern Alaska must await detailed mapping and fossil collecting comparable with that now nearing completion in northeastern Alaska. Failure to find any Bathonian fossils in southeastern Alaska coincides with an absence of such fossils in western British Columbia (Frebold and Tipper, 1967, p. 4; 1970, p. 12, 16, 17). The Bathonian may be represented in the Kuskokwim region by some occurrences of *Inoceramus ambiguus* Eichwald.

The seas of Callovian time in Alaska were continuations and extensions of the Bathonian seas (fig. 5). They extended at least as far southwest as Wide Bay on the Alaska Peninsula, whch is 200 miles beyond the southernmost Bathonian occurrence in the Cook Inlet region. Failure to find any megafossils of Callovian Age in north-central and northwestern Alaska may have some significance paleogeographically but could be due to inadequate collecting. Failure to find any Callovian megafos-

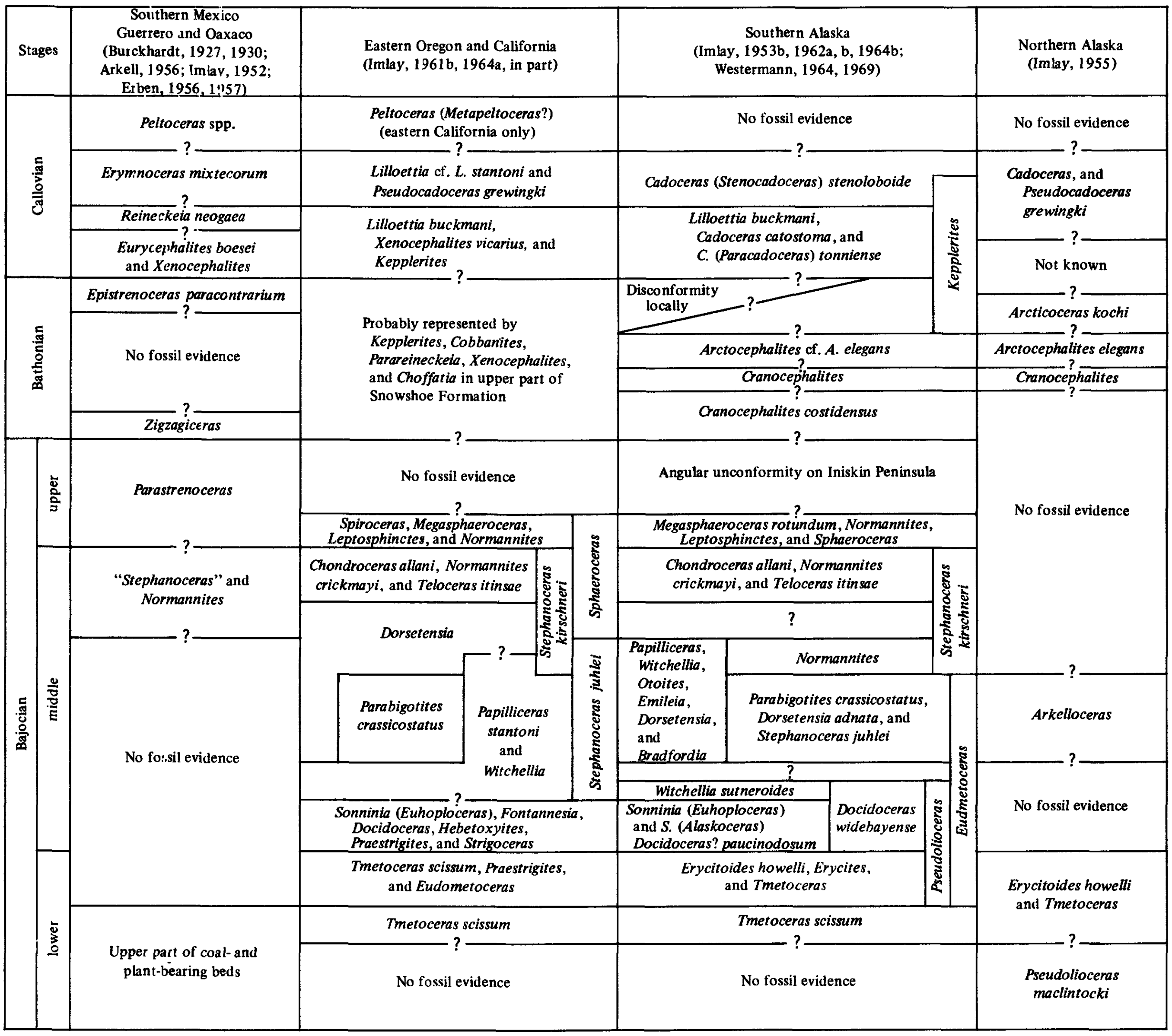


FIGURE 14.—Correlation of Bajocian to Callovian ammonite faunas in Alaska.

sils in the Wrangell Mountains is probably related to a disconformity of pre-late Oxfordian Age at the base of the Root Glacier Formation (MacKevett, 1969, p. A46). The fossil record (fig. 14) indicates that the sea withdrew entirely from Alaska at the end of the middle Callovian.

Early in the Oxfordian, marine waters covered the same areas in Alaska as during the Callovian (compare figs. 5 and 6), but later in the epoch and during the early Kimmeridgian they spread widely across both northern and southern Alaska (fig. 7). Evidently in southern Alaska the sea spread over an uneven terrain south of mountains that shed much conglomerate and sandstone into the sea (Detterman and Hartsock, 1966, p. 49, 71). The uneven character of the terrain is shown by the fact that the basal beds of the Oxfordian sequence contain the early Oxfordian ammonite *Cardioceras* in four areas, whereas in the Wrangell Mountains and at most places on the Alaska Peninsula the basal beds contain the younger ammonite *Amoeboceras* and its associate *Buchia concentrica* (Sowerby) (figs. 11*A* and 15). Failure to find any Oxfordian or early Kimmeridgian fossils in the Kuskokwim region or in southeastern Alaska suggests that rocks of that age are missing in those areas, but more verification is needed before paleogeographical conclusions can be drawn.

Stages		Eastern and northern Mexico (Imlay, 1943, 1952; Erben, 1957)		California, Oregon, and western Idaho (Imlay, 1953a; 1961b; Imlay and Jones, 1970)		Southern Alaska (Imlay, 1953b, 1961a)		Northern Alaska (Imlay, 1955)	
Tithonian	upper	*Substeuroceras* and *Proniceras* ? *Kossmatia*, *Durangites*, and *Corongoceras*	*Micracanthoceras*, *Paradontoceras*, and *Hildoglochiceras*	*Substeueroceras* and *Spiticeras* *Parodontoceras* ? *Kossmatia*	*Buchia* aff. *B. okensis* ? *Buchia piochii*	*Buchia piochii* and *B. fischeri*		*Buchia* cf. *B. fischeriana*	
	middle	? *Pseudolissoceras* and *Subplanites*	*Virgatosphinctes* and *Aulacosphinctoides*	? Not identified		? *B. rugosa* and *B. mosquensis*		? *B. rugosa* and *B. mosquensis*	
	lower	*Mazapilites*							
Kimmeridgian	upper	*Hybonoticeras* cf. *H. beckeri* *Idoceras durangense* and *Glochiceras fialar*					*Buchia concentrica*		*Buchia concentrica*
	lower	*Idoceras balderum* *Sutneria* cf. *S. platynota*		? *Amoeboceras (Amoebites)* and *Idoceras*	*Buchia concentrica*	? *Amoeboceras (Prionodoceras) spiniferum* and *Dichotomosphinctes*		? *Amoeboceras (Prionodoceras)*	
Oxfordian	upper	*Discosphinctes caribbeanus* and *Ochetoceras canaliculatum* *Dichotomosphinctes durangensis*		*Discosphinctes virgulatus* and *Dichosphinctes mulbachi*					
	lower	Not identified *Creniceras* and *Parapaltoceras* locally		*Cardioceras martini* (Idaho only)		*Cardioceras distans* *C. (Scarburgiceras) martini* Not identified		*Cardioceras (Scarburgiceras)* Not identified	

FIGURE 15.—Correlation of Oxfordian to Tithonian molluscan faunas in Alaska.

From late Kimmeridgian until middle Tithonian time (fig. 8) marine waters spread even more widely over Alaska. They covered large parts of the Kuskokwim region and of southeastern Alaska, and, to judge by the fossil record, covered more of Alaska than at any other time during the Jurassic. The absence of Jurassic sediments younger than early Kimmeridgian in the area between Iniskin Bay and Tuxedni Bay on Cook Inlet is probably due to Late or post-Jurassic uplift and erosion (Detterman and Hartsock, 1966, p. 71) rather than to nondeposition.

During late Tithonian time, the marginal seas in Alaska became much reduced, compared with those of the immediately preceding time (compare figs. 8 and 9). One sea covered most of the present site of the Alaska Peninsula southwest of Wide Bay. Another sea existed in an area now occupied by the eastern part of the Alaska Range and apparently extended eastward into the Yukon Territory (Frebold and Tipper, 1970, p. 15; Frebold and others, 1967, p. 10). Failure to find any marine fossils of that age elsewhere in southern Alaska could be explained by erosion or by nondeposition, or both. In southeastern Alaska the sequence exposed on Admiralty Island (Loney, 1964, p. 59, 92, 97) apparently represents continuous deposition from Kimmeridgian until Valanginian time. In northern Alaska, the geographic position of a single specimen of *Buchia* cf. *B. fischeri* (d'Orbigny) indicates the presence of a fairly widespread sea that presumably extended eastward into the northern Yukon (Jeletzky, 1958, p. 5, 1960, p. 4; 1966, p. 25, 30; 1967, p. VI; Frebold and others, 1967, p. 10).

In summation, Jurassic marginal seas occupied considerable areas in northern, southern, and southwestern Alaska, but probably never covered a huge area in central Alaska or a southwestern prolongation of that area. From the presently known fossil occurrences (figs. 2–9), it is inferred that marine waters were absent during late Callovian time, much restricted during Hettangian, Bathonian, early Oxfordian and late Tithonian time, somewhat less restricted during Pliensbachian, Toarcian, and Callovian time, fairly widespread during Sinemurian, Bajocian, and late Oxfordian to early Kimmeridgian time, and most widespread in late Kimmeridgian to middle Tithonian time.

SUCCESSION AND DIFFERENTIATION OF AMMONITES

Most of the Early Jurassic ammonites of Alaska are identical with and occur in essentially the same succession as ammonites of that age in central and northern Europe and in Canada (fig. 13). In fact, the Alaskan ammonites of late Pliensbachian Age have more in common with the ammonites of those areas than with late Pliensbachian ammonites of eastern Oregon, which have Mediterranean affinities (Imlay, 1968, p. C21). Such close resemblances eastward across Canada show that the seaways between Alaska and northwest Europe were open during Early Jurassic time. They suggest that continental drift either did not occur during that time or had no influence on the distribution of ammonites between those areas.

The succession of ammonites in Alaska during Bajocian time (fig. 14), as previously discussed (Imlay, 1965, p. 1030), was similar to that in Europe and in the Tethyan region except for the presence in Alaska of a few genera that have been found only in areas near the Pacific Ocean and the absence in Alaska of a few genera that are fairly common in Europe. These differences were slight during the early Bajocian but became more pronounced by late Bajocian. In southern Alaska, the succession ended early in late Bajocian time. In northern Alaska the succession ended in early middle Bajocian time.

The succession of ammonites in Alaska during Bathonian time (fig. 14) was essentially identical with that in northern Canada (Frebold, 1964b), in East Greenland (Callomon, 1959), and in other lands bordering the Arctic Ocean. It was dominated by the genera *Cranocephalites*, *Artocephalites*, and *Arcticoceras*. It had almost nothing in common generically with the Bathonian ammonite assemblages of central Europe and the Tethyan region (Imlay, 1965, p. 1024, 1030, 1031). In southern Alaska, however, the Bathonian ammonite succession includes genera, such as *Parareineckeia* and *Xenocephalites*, that are known only from the Western Hemisphere. Evidently the Bathonian ammonites of the Boreal region were almost completely separated from Bathonian ammonites farther south by barriers of some kind, except along the Pacific Coast south of Alaska. As a consequence, the ammonite faunas of the world became differentiated into distinct Boreal and Tethyan realms and a somewhat less distinct Pacific realm.

A Callovian ammonite succession has been established in Alaska only in the southern part between the Talkeetna Mountains and Wide Bay on the Alaska Peninsula (fig. 14). This succession is essentially the same as along the Pacific Coast in British Columbia (Frebold and Tipper, 1967, p. 5), Oregon (Imlay, 1964a, p. D7–D10), and California (Imlay, 1961b, p. D5). It is characterized by such taxa as

Cadoceras, *C.* (*Paracadoceras*), *C.* (*Stenocadoceras*), *Pseudocadoceras*, *Kepplerites*, *Lilloettia*, and *Xenocephalites*; the first five are of Boreal origin, and the last two originated in seas of the Western Hemisphere. Except for *Lilloettia* and *Xenocephalites*, the succession has very little in common generically with ammonites of that age in Mexico and even less in common with ammonites of the Mediterranean region, as discussed elsewhere (Imlay, 1953b, p. 56; 1965, p. 1023–1033). It bears no resemblances on the specific levels to ammonites in the western interior of the continent and in northern Canada (Imlay, 1953a; Frebold, 1961, p. 17–22; 1964a, p. 4, 1964b. The succession differs even more with ammonites of the same age in Greenland and northern Eurasia (see comparisons in Frebold, 1961). Overall, the Callovian ammonites of southern Alaska are dominantly of Boreal origin but are in part of local origin and in part of Pacific origin.

The succession in Alaska of ammonites of Oxfordian to early Kimmeridgian Age (Imlay, 1952, p. 977–978) (fig. 15) is nearly the same as that along the Pacific Coast from British Columbia to California (Frebold and Tipper, 1967, p. 5; Imlay, 1961b, p. D5, 1964a, D7–10). It is likewise identical with, or closely similar to, the succession in the western interior of the continent and in northern Canada (Frebold and others, 1959, 1967, p. 10; Frebold, 1964b, p. 481). It can be correlated with ammonite successions in East Greenland and northern Eurasia by means of *Cardioceras* and *Amoeboceras* but otherwise differs by having far fewer genera (see comparisons in Frebold, 1961, table 1). The succession has nothing in common with ammonites of that age in Mexico or in the Mediterranean region, except for the presence of *Dichotomosphinctes*.

An ammonite succession has not been established in the uppermost Jurassic beds of Alaska. A few specimens of *Lytoceras* and *Phylloceras* occur in beds of middle Kimmeridgian to middle Tithonian Age which are identified by the presence of *Buchia rugosa* (Fischer) and *B. mosquensis* (von Buch). The very latest Jurassic, characterized by *Buchia piochii* (Gabb), has not furnished any ammonites. This scarcity of ammonites in Alaska in beds younger than early Kimmeridgian is in marked contrast to a fair abundance of ammonites in equivalent beds in East Greenland and northern Eurasia. As a consequence of this scarcity, most correlations above the lower Oxfordian are made on the basis of species of *Buchia* whose succession during the Late Jurassic appears to be the same throughout the Arctic.

The succession of Jurassic ammonites in Alaska, in comparison with successions in other parts of the world, shows that differentiation into Boreal and Tethyan realms started in late Pliensbachian time, increased gradually during the Bajocian, was completed by the Bathonian, and persisted into the Early Cretaceous. Evidently faunal differentiation during Bathonian and later Jurassic time coincides very well with the deposition of Jurassic salt and some associated red beds in the Gulf of Mexico region (Imlay, 1943, p. 1438, 1508, 1509; Bishop, 1967, p. 249; Viniegra-O, 1971, p. 478–484; fig. 10 on p. 492) which apparently coincides in time with early stages of continental drift. Faunal differentiation probably resulted from a combination of events (Imlay, 1965) which may include the separation of the continents.

In summation, the ammonite succession in Alaska from Hettangian to Toarcian time is essentially the same as that in central and northern Europe. It is also similar to that in the Mediterranean region except for certain ammonites of late Pliensbachian Age. The Bajocian ammonite succession in Alaska is likewise similar to that in the above-named regions except for a few genera known only from areas bordering the Pacific Ocean. In contrast, the Bathonian succession in Alaska is dominated by the Boreal genera *Cranocephalites*, *Arctocephalites*, and *Arcticoceras*, which are unknown in central Europe or farther south. The Callovian ammonite genera of Alaska are likewise dominantly Boreal in origin, but, as in the Bajocian and Bathonian ammonites, include some genera that are known only from the Western Hemisphere. During the rest of Jurassic time, ammonites became uncommon in Alaska but include the Boreal genera *Cardioceras* of early Oxfordian Age and *Amoeboceras* of late Oxfordian to early Kimmeridgian Age.

FOSSIL OCCURRENCES BY STAGES

Locality in figure 2	Description
	Hettangian
3	USGS Mesozoic locs. 29737 and 29738. From Spike Mountain near the Porcupine River about 30 miles north of Old Rampart, Coleen quadrangle, lat 63°35.75′ N., long 141°40′ W. *Psiloceras*.
8	USGS Mesozoic locs. 29890 and 29891. About 15 miles northeast of McCarthy, northern part of sec. 26, T. 4 S., R. 16 E., near NW. cor. McCarthy B–4 quadrangle, southern Wrangell Mountains, eastern Alaska. *Waehneroceras* and *Psiloceras*.

Locality in figure 2	Description

Hettangian—Continued

11----USGS Mesozoic loc. 29874. East bank of Allen River at middle rapids, Tikchik Lakes area, lat 60°7′ N., long 158°38′ W., Taylor Mountains A-8 quadrangle. Kuskokwim region, southwest Alaska. *Weyla* and other pelecypods identical with species in basal Jurassic near Seldovia on the Kenai Peninsula (loc. 13). These could be of Hettangian or Sinemurian Age.

12----USGS Mesozoic loc. 24357. Hagermeister Island in Bristol Bay area, lat 58°43′50″ N., long 160°58′10″ W. Kuskokwim region, southwest Alaska. *Weyla* and other pelecypods identical with species near Seldovia (loc. 13). These could be Hettangian or Sinemurian Age.

13----USGS Mesozoic locs. 21242 and 22664. From 2.8 to 2.95 miles S. 67° W. of Pt. Naskowhak on south shore of Kachemak Bay, Seldovia B-5 quadrangle, Kenai Peninsula. *Waehneroceras.*

14----USGS Mesozoic locs. 3110, 12394, 19803, 25694 and 29268 on peninsula between Puale Bay and Alinchak Bay about 1 mile N. 65° W. of Cape Kekurnoi, Alaska Peninsula. *Waehneroceras.*

15----Richfield Oil Co. Wide Bay test well 1, core 5 at depth of 2,235 to 2,236 feet, on north side of Wide Bay, Alaska Peninsula. *Waehneroceras.*

Sinemurian

1----Avak test well 1 at depth of 1,836 feet on Point Barrow, northern Alaska (See Imlay, 1955, p. 82, 87). *Arietites.*

2----USGS Mesozoic loc. 29774. On Blankenship Creek in Lisburne Ridge area west of Etivluk River, lat 68°37.5′ N., long 156°42.5′ W., northwest Alaska. *Crucilobiceras.*

4----USGS Mesozoic loc. 16229. Head of small eastern tributary of Partin Creek that heads against Little Shotgun Creek north of Eldridge Glacier on west side of Chulitna Valley, eastern Alaska. *Arnioceras.*

5----USGS Mesozoic loc. 26722. Talkeetna Mountains A-2 quadrangle, coordinates 1.20, 17.23, lat 62°59′58″ N., long 147°57′48″ W. Mesozoic loc. 28661 in Talkeetna Mountains A-3 quadrangle, coordinates 15.35, 15.63, lat 62°13′29″ N., long 148°01′27″ W. Talkeetna Mountains, Cook Inlet region. *Crucilobiceras.*

6----USGS Mesozoic loc. 27586. Carbon Creek, 2.3 miles S. 7° E. of its mouth, which enters Matanuska River from south near mouth of Chickaloon River, near south boundary of sec. 12, T. 19 N., R. 5 E., Anchorage D-4 quadrangle, Cook Inlet region. *Arnioceras.*

7----USGS Mesozoic loc. 30137. Near center of north half of SW¼ sec. 8, T. 4 S., R. 11 E., in south-central part of McCarthy (C-7) quadrangle. Mesozoic locs. 30138-30140 in west half of sec. 17, T. 4 S., R. 12 E., near southeast corner of McCarthy (C-7) quadrangle. Wrangell Mountains, eastern Alaska. All localities are in upper member of McCarthy Formation. *Arnioceras* (loc. 30140), *Megarietites*?, and *Arnioceras*? (loc. 30139), and arietitid ammonites (locs. 30137 and 30138).

Locality in figure 2	Description

Sinemurian—Continued

8----Many localities in upper member of McCarthy Formation, in McCarthy C-4, C-5, and B-4, quadrangles, Wrangell Mountains, eastern Alaska (MacKevett, 1970a, b, 1971). Ammonites include *Arietites* (loc. 29870), *Arnioceras* (locs. 28535, 28536, 28538, 28688), *Crucilobiceras* (loc. 28537, 28540, 28671-73), and *Microderoceras* (loc. 14472).

9----USGS Mesozoic loc. 29773. Float, sec. 37, T. 23 S., R. 35 E., Yakutat D-4 quadrangle, southeast Alaska. *Crucilobiceras.*

10----Property of State Museum at Juneau. Ammonite found near center of face of Norris Glacier about 14 miles northeast of Juneau. Juneau B-1 quadrangle, southeast Alaska. *Xipheroceras*?

11----Described under Hettangian fossil occurrences.

12----Do.

13----USGS Mesozoic loc. 2981. Two miles west of Pt. Naskowhak on west side of Seldovia Bay. Seldovia B-5 quad., Kenai Peninsula. *Coroniceras.*

14----USGS Mesozoic locs. 3111, 12396, and 21237 on east side of Puale Bay about 8,400 feet northwest of Cape Kekurnoi, Alaska Peninsula. *Coroniceras.*

Locality in figure 3	Description

Pliensbachian

1----South Barrow test well 3 at depths of 2,069 to 2,198 feet, Point Barrow, northern Alaska (Imlay, 1955, p. 82, 87; Howarth, 1958, p. XXVI). *Amaltheus* spp.

2----Simpson test well 1 at depth of 5,680 feet, southeast of Point Barrow, northern Alaska. (Imlay, 1955, p. 82, 87). *Amaltheus* sp.

4----USGS Mesozoic loc. M2441. Ipewik River, De Long Mountains, lat 68°37′ N., long 164°11′ W. Mesozoic loc. 29164 on east bank Ipewik River, lat 68°40′ N., long 164° 13′ W., northern Alaska. *Amaltheus* sp.

7----USGS Mesozoic loc. 29165. Three miles east of Shrader Lake, lat 69°22′ N., long 144°48′ W., near head of Sadlerochit River, northern Alaska. *Amaltheus.*

8----USGS Mesozoic loc. 30074. West side of Aichilik River about 2 miles west of *VABM ATTE*, lat 69° 33′ N., long 143°05′ W., from 800-1,000 feet above base of Kingak Shale. *Amaltheus* cf. *A. stokesi* (J. Sowerby).

9----USGS Mesozoic loc. 29340. Float from bluff on the Middle Salmon Trout River near Old Rampart, Kandik area, east central Alaska. *Amaltheus.*

10----Many USGS Mesozoic localities in the Talkeetna Mountains A-3 quadrangle and the Anchorage D-1 and D-2 quadrangles, Talkeetna Mountains, Cook Inlet region. *Paltarpites, Harpoceras, Arieticeras, Leptaleoceras, Fontanelliceras, Amaltheus, Protogrammoceras, Fanninoceras,* and *Acanthopleuroceras.*

11----USGS Mesozoic loc. 28675, SW¼SW¼ sec. 23, T. 4 S., R. 16 E., McCarthy C-4 quadrangle. Less than 100 feet below Lubbe Creek Formation. *Uptonia.* Mesozoic loc. 28531 on east side of McCarthy Creek, probably a little northwest of center of sec. 25, T. 3 S., R. 14 E., McCarthy C-5, quadrangle, southern Wrangell Mountains, Lubbe Creek Formation. *Arieticeras.*

Locality in figure 3	Description
	Toarcian
1	South Barrow test well 3 at depths of 1,772 to 2,063 feet at Point Barrow, northern Alaska (Imlay, 1955, p. 82, 87–89). *Catacoeloceras* at 2,063 feet. *Dactylioceras* at 1,772 to 2,018 feet.
3	USGS Mesozoic locs. 29159-29161, 29163. North bank of Thetis Creek, lat 68°41'50" N., long 164°45'05" W., northwestern Alaska. *Harpoceras* cf. *H. exaratum* (Young and Bird) and *Dactylioceras*. Mesozoic loc. 29776 near Thetis Creek, lat 68°40.8' N., long 164°45.5' W., *Harpoceras*.
5	USGS Mesozoic loc. 23772 and 24035 (Imlay, 1955, p. 80, 89). *Pseudolioceras*.
6	USGS Mesozoic loc. 22081 (Imlay, 1955, p. 80). *Harpoceras* cf. *H. exaratum* (Young and Bird) (not *Pseudolioceras*).
10	Many USGS Mesozoic localities in the Talkeetna Mountains A–1, A–2, and A–3 quadrangles, the Anchorage D–2 and D–5 quadrangles, and the Valdez D–8 quadrangle, Talkeetna Mountains, Cook Inlet region. *Dactylioceras*, *Harpoceras*, *Grammoceras*, *Haugia*, *Phymatoceras*, and *Pseudolioceras*.
11	USGS Mesozoic locs. 28546-28548, 28678, and 28679 in southern part of McCarthy C–5 quadrangle, southern Wrangell Mountains. Upper part of Lubbe Creek Formation. *Weyla dufrenoyi* (d'Orbigny), identified by S. W. Müller.
12	USGS Mesozoic loc. 19804. East shore of Puale Bay about 9,500 feet northwest of Cape Kekurnoi, Alaska Peninsula. *Haugia*.

Locality in figure 4	Description
	Bajocian
1	South Barrow test well 2 at depth of 2,391 feet near Point Barrow, northern Alaska (Imlay; 1955, p. 82, 89). *Tmetoceras*.
2	Topogaruk test well 1 at depth of 8,113 feet about 58 miles south-southeast of Point Barrow, lat 70°37'30" N., long 155°53'36" W., northern Alaska (Imlay, 1955, p. 82, 89). *Tmetoceras*.
3	USGS Mesozoic loc. 24035. Canning River, lat 69°34' N., long 146°23' W., northern Alaska (Keller and others, 1961, p. 193). *Pseudolioceras maclintocki* (Haughton) and *Oxytoma jacksoni* (Pompeckj).
4	USGS Mesozoic locs. 29152-29156. West end of Ignek Valley, lat 69°41' N., long 145°36' W. to lat 69°33' N., long 145°43' W., northern Alaska. *Pseudolioceras maclintocki* (Haughton), *Erycitoides* cf. *E. howelli* (White), *Canaverella* cf. *C. belophora* Buckman, and *Inoceramus* cf. *I. lucifer* Eichwald.
5	USGS Mesozoic loc. 29147 at junction of Sadlerochit and Kekiktuk Rivers, lat 69°33' N., long 144°43' W.; Mesozoic loc. 29150 on Fire Creek in central part of Ignek Valley, lat 69°32' N., long 145°09' W.; Mesozoic loc. 29880 on Fire Creek, lat 69°32'22" N., long 145°12'30" W.; Mesozoic locs. 29884 to 29886 on Kaviak Creek, 0.7 miles SW. of Sadlerochit River, lat 69°29' N., long 145°03' W.; Mesozoic locs. 10307 and 10308 (Imlay, 1955, p. 81). Northeastern Alaska. *Pseudolioceras maclintocki* (Haugh-

Locality in figure 4	Description
	Bajocian—Continued
	ton), *Erycitoides*, *Canavarella* (loc. 29884 only), and *Inoceramus lucifer* Eichwald.
6	USGS Mesozoic loc. 29157 on Canning River near Shublik Island, lat 69°24' N., long 146°10' W., northern Alaska, Mesozoic locs. 21023 and 22595 (Imlay, 1955, p. 80). *Pseudolioceras whiteavesi* (White) (loc. 21023 only) and *P. maclintocki* (Haughton); Mesozoic locs. 29138–29142, Canning River near Shublik Island, lat 69°24' N., long 146°10' W., northeastern Alaska. *Arkelloceras;* Mesozoic locs. 21024, 22597, and 24033 on west bank of Canning River opposite mouths of Eagle and Cache Creeks, lat 69°27' N., long 146°13'30" W. (Imlay, 1955, p. 80, 91; Keller and others, 1961, p. 193). *Arkelloceras*.
7	USGS Mesozoic loc. 30135 on ridge west of Okerokvik River, 7.6 miles S. 80° W. of *VABM ATTE*, lat 69°29'45" N., long 143°26' W. *Pseudolioceras maclintocki* (Haughton).
8	USGS Mesozoic loc. 21552. Cutbank on Fortress Creek, lat 68°31' N., long 153°03' W. (Patton and Tailleur, 1964, p. 444). *Pseudolioceras*? and *Inoceramus lucifer* Eichwald.
9	USGS Mesozoic loc. 22591. Cutbank on Tiglukpuk Creek, lat 68°20' N., long 151°50' W. (Patton and Tailleur, 1964, p. 444). *Arkelloceras*? sp. juv. and *Inoceramus cf. I. lucifer* Eichwald.
10	USGS Mesozoic loc. M1717 (Imlay, 1967, p. B8), about 3 miles east-southeast of Nation. *Otapiria* sp. undet. and *Pentacrinus subangularis alaska* Springer. This variety of *Pentacrinus* has been found in the northeast Alaska near the Sadlerochit River associated with *Inoceramus* cf. *I. lucifer* Eichwald (Mesozoic loc. 29885) and directly above beds containing *Canavarella*, *Pseudolioceras* cf. *P. maclintocki* (Haughton), and *Inoceramus* cf. *I. lucifer* Eichwald (Mesozoic loc. 29884) of early Bajocian Age. As the full stratigraphic range of the crinoid subspecies has not yet been established, its presence alone is not proof of a Bajocian Age.
11	USGS Mesozoic loc. 13430. Northwest side of Innoko River, about 30 miles airline upstream from confluence of Innoko and Iditarod Rivers, Innoko District, Kuskokwim region, Alaska, *Inoceramus* cf. *I. ambiguus* Eichwald.
12	USGS Mesozoic loc. 27716. East bank of Yukon River about 7 miles N. 25° W. from village of Ohogament, coordinates 0.65, 11.35, lat 61°39' N., long 161°55.5' W., Russian Mission quadrangle, Kuskokwim region. *Stephanoceras*? sp. Probably Middle Jurassic.
13	USGS Mesozoic loc. 21481 on south side of Tuluksak River, 2.7 miles S. 55° W. of Nyac, and 1.5 miles N. 50° W. of Nyac hydroelectric power plant; Mesozoic loc. 21029 on north side of Tuluksak River about 1 mile north of loc. 21481, Bethel quadrangle, Kuskokwim region, southwest Alaska (Hoare and Coonrad, 1959a). *Inoceramus ambiguus* Eichwald.
14	USGS Mesozoic loc. 27091. Crest of low ridge 12.7 miles S. 59° W. from junction of Buckstock and

Locality in figure 4	Description
	Bajocian—Continued
	Aniak Rivers and 6.8 miles N. 55° E. of Mt. Hamilton, coordinates 20.5, 4.4. Russian Mission quadrangle, Kuskokwim region, southwest Alaska. *Inoceramus* cf. *I. ambiguus* Eichwald.
15	USGS Mesozoic loc. 21031. About 3 miles west of Salmon River, about 23.5 miles S. 36° E. of Mt. Hamilton, Kuskokwim region, southwest Alaska (Hoare and Coonrad, 1959b). *Inoceramus* cf. *I. ambiguus* Eichwald.
16	USGS Mesozoic loc. 20717. About 4½ miles S. 6° E. of confluence of Cripple Creek with Salmon River, about 23.5 miles E. 36° E. of Nyac, Bethel quadrangle, Kuskokwim region, southwest Alaska (Hoare and Coonrad, 1959b). *Inoceramus* cf. *I. ambiguus* Eichwald.
17	USGS Mesozoic loc. 19729. Cutbank southeast of Holokuk River, 27 miles S. 20° E. of Napaiment and 3.6 miles upstream (southwest) from mouth of Boss Creek, Kuskokwim region, southwest Alaska. *Inoceramus* sp.
18	USGS Mesozoic loc. 19395b. East of Holitna River, 4½ miles S. 42° E. of Nagamut, Kuskokwim region, southwest Alaska. *Inoceramus* cf. *I. ambiguus* Eichwald.
19	USGS Mesozoic loc. 29889. South-central part of Hagemeister Island, Bristol Bay, lat 58°38'25" N., long 160°58'50" W. *Inoceramus* cf. *I. ambiguus* Eichwald.
20	USGS Mesozoic loc. 28682, in part. Near center SE¼NW¼ sec. 20, T. 3 S., R. 16 E., McCarthy C-5 quadrangle, southern Wrangell Mountains, eastern Alaska (MacKevett, 1963; 1971). *Normannites* cf. *N. variabilis* Imlay and *Teloceras* cf. *T. blagdeni* (Sowerby) obtained with *Cranocephalites*, *Parareineckeia*, and *Cobbanites* as float derived from a fairly thin sequence.
21	Many USGS Mesozoic localities in Talkeetna Mountains A-1 and A-2 quadrangles and Anchorage D-2, D-3, and D-4 quadrangles, Talkeetna Mountains, Cook Inlet region (Imlay, 1962a, p. A5, A6, 1964b, p. B2, B22, B27).
22 and 23	Many USGS Mesozoic localities from area between Iniskin Bay and Tuxedni Bay, north side of Cook Inlet (Imlay, 1961a, p. A-5, 1964b, p. B22-B27).
24	USGS Mesozoic loc. 29115. Iliamna Lake region, 2.1 miles N. 30° E. of mouth of Amakdedori Sreek, lat 59°18'25" N., long 154°05'40" W., coordinates 1.25, 4.95, Iliamna B-3 quadrangle, Cook, Inlet region. *Inoceramus ambiguus* Eichwald.
25	USGS Mesozoic loc. 12390. Half a mile south of head of Alinchak Bay, Alaska Peninsula. *Inoceramus lucifer* Eichwald (5 specimens) and *I. ambiguus* Eichwald (1 specimen found loose at bottom of cliff).
26	Many localities near Wide Bay, Alaska Peninsula (Imlay, 1964b, p. B18; Westermann, 1964, 1969).

Locality in figure 5	Description
	Bathonian
1	USGS Mesozoic locs. 28817, 29143, 29144, 29435, 29855, 29875 to 29877. Central part of Ignek Valley, lat 69°33'30"-34' N., long 145°20' W., northeastern Alaska. *Arcticoceras*, *Arctocephalites* *Cranocephalites*, and *Inoceramus* cf. *I. ambiguus* Eichwald.
2	USGS Mesozoic loc. 22083. North bank of Sadlerochit River, between Gravel and Fire Creeks, lat 69°31' N., long 145°02" W., northeastern Alaska. *Arctocephalites*?.
3	USGS Mesozoic loc. 21023 (in part), Canning River at mouth of Eagle and Cache Creeks, lat 69°25' N., long 146°08' W., *Arcticoceras;* Mesozoic loc. 22596, west side of Canning River, lat 69°23'30" N., long 146°07'30" W., *Arcticoceras;* Mesozoic loc. 29146, Canning River near Shublik Island, lat 69°24' N., long 146°10' W. *Arctocephalites*.
4	USGS Mesozoic loc. 29145, west end of Ignek Valley, lat 69°33' N., long 145°50' W. *Arctocephalites*.
5	USGS Mesozoic loc. 30075. Aichilik River, lat 69°33' N., long 143°05' N., northeastern Alaska. *Arcticoceras ishmae* (Keyserling) and *Choffatia*? sp.
7	Many USGS Mesozoic localities in the Nizina Mountain Formation in southeastern part of McCarthy C-5 quadrangle, southern Wrangell Mountains (Mackevett, 1969, p. A42-A45). *Parareineckeia*, *Cobbanites*, *Cranocephalites*, and *Inoceramus* cf. *I. ambiguus* Eichwald. (Most collections are from float.)
8	Seven USGS Mesozoic localities in the Talkeetna Mountains A-2 quadrangle and one in the Anchorage D-4 quadrangle (Imlay, 1962a, p. C3-C5, C16), Talkeetna Mountains, Cook Inlet region, *Cranocephalites*, *Parareineckeia*, *Cobbanites*, *Oecotraustes*, and *Inoceramus ambiguus* Eichwald.
9	Peninsula between Tuxedni Bay and Chinitna Bay, west side of Cook Inlet. *Parareineckeia* and *Cranocephalites* in lower two-thirds of Bowser Formation (Inlay, 1962a, p. C16, 17, 20; Detterman and Hartsock, 1966, p. 38, 39) are overlain by beds containing *Arctocephalites* cf. *A. elegans* Spath (Mesozoic loc. 22699).
10	Iniskin Peninsula, west side of Cook Inlet. *Parareineckeia* and *Cranocephalites* in the lower two-thirds of the Bowser Formation are overlain by beds containing *Kepplerites*? (Mesozoic loc. 22553) (Imlay, 1962a, p. 16, 17, 20; Detterman and Hartsock, 1966, p. 38, 39).
	Callovian
5	USGS Mesozoic loc. 30136. Float from beds directly overlying the beds at Mesozoic loc. 30075. *Cadoceras* sp.
6	USGS Mesozoic loc. 22745, West Fork Ivishak River, lat 69°0' N., long 148°04'30" W. (Keller and others 1961, p. 193; Imlay, 1955, p. 80, 90). *Pseudocadoceras grewingki* (Pompeckj)?, or possibly immature *Arcticoceras*.

Locality in figure 5	Description
	Callovian—Continued
8	Many USGS Mesozoic localities in the Talkeetna Mountains A-1 and A-2 quadrangles and the Anchorage D-3 quadrangle, Talkeetna Mountains, Cook Inlet region. Ammonites include most of the same genera and species described by Imlay (1953b, p. 50).
9, 10	Many localities (see Imlay, 1953b. p. 65-69).
11	USGS Mesozoic loc. 29271, lat 57°57.3′ N., long 155°4.4′ W., Kashvik Bay, Karluk quadrangle Alaska Peninsula. *Cadoceras* (*Stenocadoceras*) *multicostatum* Imlay.
12	Many USGS Mesozoic localities in the Puale Bay area, Alaska Peninsula (Imlay, 1953b, p. 63 and table 6). Common ammonites include *Cadoceras tenuicostatum* Imlay, *C. doroschini* (Eichwald), and many species of *C.* (*Stenocadoceras*) and *Pseudocadoceras*. The abundance of *C.* (*Stenocadoceras*) and the absence of *C.* (*Paracadoceras*) show that the beds are equivalent to the upper part of the Chinitna Formation north of Cook Inlet.
13	A few USGS Mesozoic localities between Jute Bay and Portage Bay, Alaska Peninsula (Imlay, 1953b, p. 63 and table 6). *Cadoceras* (*Stenocadoceras*) *multicostatum* Imlay and *Pseudocadoceras grewingki* (Pompeckj).
14	Many localities near Wide Bay, Alaska Peninsula (Imlay, 1953b, p. 64, 70, 71, and table 6). Same ammonites present as in the Chinitna Formation north of Cook Inlet.
15	USGS Mesozoic loc. 29342. Axial region of Chignik Bay anticline near Conglomerate Creek. Approximate lat 65°26′13″ N., long 158°36′48″ W., Chignik Bay, Alaska Peninsula. *Xenocephalites vicarius* Imlay.

Locality in figure 6	Description
	Early Oxfordian
1	USGS Mesozoic loc. 29856. Ignek Mesa in Ignek Valley, 6.8 miles S. 75° E. of Katakturuk Canyon, lat 69°33′30″ N., long 145°20′ W., northeast Alaska. *Cardioceras* (*Scarburgiceras*).
2	USGS Mesozoic loc. 29137. Fire Creek in Ignek Valley, lat 69°32′ N., long 145°09′ W., northeast Alaska. *Cardioceras* (*Scarburgiceras*).
3	USGS Mesozoic locs. 24165, 24166, 24168, 24837, and 24841. Near headwaters of Little Nelchina River in central and east-central part of Talkeetna Mountains A-2 quadrangle, Talkeetna Mountains, Cook Inlet region. *Cardioceras* (*Scarburgiceras*) *martini* Reeside and *C. distans* (Whitfield).
4, 5	Many localities between Iniskin Bay and the Hickerson Lake area west of Cook Inlet (Detterman and Hartsock, 1966, p. 50, 51). *Cardioceras* (*Scarburgiceras*) *martini* Reeside, *C. distans* Whitfield, and *C.* (*Scoticardioceras*) *alaskense* Reeside.

Locality in figure 6	Description
	Early Oxfordian—Continued
6	USGS Mesozoic loc. 10798. Five miles southeast of Mount Peulik, west of Puale Bay and north of Wide Bay, Alaska Peninsula. *Cardioceras* cf. *C. canadense* Whiteaves.

Locality in figure 7	Description
	Late Oxfordian to early Kimmeridgian
1	USGS Mesozoic loc. 22126 (Imlay, 1955, p. 78, 79). Mesozoic loc. 30071 on Kukpowruk River west of Igloo Mountain, lat 68°43′ N., long 163°12′30″ W., *Buchia concentrica* (Sowerby).
2	USGS Mesozoic loc. 22759 (Imlay, 1955, p. 79, 80). *Buchia concentrica* (Sowerby).
3	USGS Mesozoic loc. 21026 (Imlay, 1955, p. 79, 80). *Buchia concentrica* (Sowerby).
4	Many USGS Mesozoic localities near the Canning River, northeast Alaska. Mesozoic locs. 24014, 21028, 25598, and 29882 (Imlay, 1955, p. 79, 80; Keller and others, 1961, p. 193) from lat 69°30′45″ N. to 69°33′ N.; long 146°18′ W. to 146°23′ W.; Mesozoic locs. 29134-29136 near Shublik Island at lat 69°24′ N., long 146°10′ W. *Amoeboceras* (*Prionodoceras*) and *Buchia concentrica* (Sowerby).
5	USGS Mesozoic loc. 29133. North side of central part of Sadlerochit Mountains, lat 69°41′ N., long 144°50′ W. *Buchia* cf. *B. concentrica* (Sowerby).
6	USGS Mesozoic locs. 5723, 16921, 16922, 18082, 18086, and 18089. Area between Slana and Nabesna in eastern part of Alaska Range (Moffit and Knopf, 1910, p. 29; Moffit, 1938b, p. 32; Moffit, 1954, p. 131). *Buchia concentrica* (Sowerby).
7	USGS Mesozoic loc. 5772. Trail along Notch Creek northwest of Chisana, eastern part of Alaska Range (Moffit and Knopf, 1910, p. 29; Moffit, 1954, p. 131). *Buchia concentrica* (Sowerby).
8	Many localities in the McCarthy C-5 quadrangle, Wrangell Mountains (MacKevett, 1969, p. A41, A45-49). *Buchia concentrica* (Sowerby) and *Amoeboceras* (*Prinodoceras*) from lower part of Root Glacier Formation.
9	Many localities in the Talkeetna Mountains A-1 quadrangle, Cook Inlet region. *Buchia concentrica* (Sowerby).
10	Richfield Oil Company—Swanson River unit 2 well, SW¼SE¼ sec. 22, T. 8 N., R. 9 W., Seward Meridian, Kenai Peninsula, Alaska. *Buchia concentrica* (Sowerby) in cores from depths of 11,794-11,804 feet. Also, a species of *Pseudolimea*, very common in the Naknek Formation, occurs in cores from depths of 11,846-11,856 feet.
11, 12	Many localities in Snug Harbor Siltstone Member of the Naknek Formation between Iniskin Bay and Tuxedni Bay, Cook Inlet region (Martin, 1926, p. 178-180; Detterman and Hartsock, 1966, p. 51). *Amoeboceras* (loc. 3046 only) and *Buchia concentrica* (Sowerby).

Locality in figure 7	Description
	Late Oxfordian to early Kimmeridgian—Continued
13	USGS Mesozoic loc. 28520, 1.22 miles N. 30°E. of tip of Ursus Head; Mesozoic loc. 28521, 0.22 mile N. 62°E. of tip of Ursus Head. Ursus Cove on west side of Cook Inlet. *Buchia concentrica* (Sowerby).
14	USGS Mesozoic loc. 29899. On east tip of westernmost island 1 mile N. 40°E. of mouth of Douglas River, lat 59°64′20″ N., long 153°44′50″ W. Iliamna quadrangle, Alaska Peninsula. *Buchia concentrica* (Sowerby) and *Perisphinctes* (*Dichotomosphinctes*).
15	USGS Mesozoic loc. 25836. West side of Kaguyak Bay, Alaska Peninsula. *Buchia concentrica* (Sowerby).
16	USGS Mesozoic loc. 29248 at western base of Barrier Range north of Fultons Falls, about 1 mile S. 12° E. of loc. 29247 and 8 miles north of Katmai Bay, Mt. Katmai quadrangle, Alaska Peninsula. *Buchia concentrica* (Sowerby).
17	USGS Mesozoic loc. 29245. North side of Kashvik Bay about 1.7 miles east-northeast of head of bay and 3.3 miles S. 27° E. of Atmo Mountain, Karluk quadrangle, Alaska Peninsula. *Buchia concentrica* (Sowerby).
18	USGS Mesozoic locs. 3133–3136, 10825, 11333, 12276, 21353, and many others. Puale Bay area, Karluk quadrangle, Alaska Peninsula (Martin, 1926, p. 212–218). *Buchia concentrica* (Sowerby).
19	Many localities north and west of Wide Bay, Ugashik quadrangle, Alaska Peninsula (Martin, 1926, p. 212–218). *Buchia concentrica* (Sowerby.
20	USGS Mesozoic loc. 25696, 25698, 25708, 25710, 25711, 25713–25715. Chignik Bay area, Chignik quadrangle, Alaska Peninsula. *Buchia concentrica* (Sowerby).
21	USGS Mesozoic loc. M 1213. Knife Peak area west of Chignik Bay, Chignik quadrangle, Alaska Peninsula (Burk, 1965, p. 160, 176, 219). *Buchia concentrica* (Sowerby).
22	USGS Mesozoic loc. M 1197, M 1224, Staniukovich Mountain, Port Moller quadrangle, Alaska Peninsula (Burk, 1965, p. 160, 166, 219). *Buchia concentrica* (Sowerby).

Locality in figure 8	Description
	Late Kimmeridgian to early middle Tithonian
1	USGS Mesozoic loc. 29131, headwaters of tributary to Thetis Creek, lat 68°42′30″ N., long 164°40′30″ W. *Buchia mosquensis* (von Buch); Mesozoic loc. 29132, south-flowing tributary to Epewik River, lat 68°38′20″ N., long 164°36′00″ W., northwest Alaska. *Buchia* cf. *B. mosquensis* (von Buch).
2	USGS Mesozoic loc. 22127. Kukpowruk River, lat 68°42′30″ N., long 163°14′ W. (Imlay, 1955, p. 78, 79). *Buchia rugosa* (Fischer).
3	USGS Mesozoic loc. 22776. Easternmost fork of Driftwood Creek, lat 68°40′ N., long 160°26′28″ W., northwest Alaska (Imlay, 1955, p. 78, 79). *Buchia rugosa* (Fischer) and *B. mosquensis* (von Buch).
	Late Kimmeridgian to early middle Tithonian—Continued
4	USGS Mesozoic loc. 23598. Ipnavik River, 2 miles south of Memorial Creek, lat 68°23′ N., long 157°15′ W., northwest Alaska (Imlay, 1955, p. 78, 79). *Buchia* cf. *B. mosquensis* (von Buch) and *B. concentrica* (Sowerby).
5	USGS Mesozoic locs. 22750, 22751, 22766, 22768, 22769. Lupine River from lat 68°49′30″ N. to 68°51′ N., long 148°17′30″ W. to 148°22′30″ W. (Keller and others, 1961, p. 195). *Buchia rugosa* (Fischer), *B. mosquensis* (von Buch), and *B. concentrica* (Sowerby).
6	USGS Mesozoic loc. 22746. Small divide nearly 1 mile east of Nosebleed Creek, lat 68°52′ N., long 148°08′ W., northeast Alaska (Keller and others, 1961, p. 195). *Buchia rugosa* (Fischer).
7	USGS Mesozoic loc. 21027, Shaviovik River, main fork of most easterly branch, lat 69°22′ N., long 146°32′ W. (Imlay, 1955, p. 79, 80). *Buchia rugosa* (Fischer) and *B. mosquensis* (von Buch). Mesozoic loc. 24028 from Kavik River, lat 69°24′45″, long 146°37′30″ W., northeast Alaska. *Buchia rugosa* (Fischer) and *B. concentrica* (Sowerby).
8	USGS Mesozoic locs. 29872, 29897, and 30076. Ridge south of Joe Creek, 11.5 miles N. 75° W. of point where creek crosses International Boundary, Table Mtn. quadrangle, lat 68°58′ N., long 146°38′ W., northeast Alaska. *Buchia rugosa* (Fischer).
9	USGS Mesozoic loc. 16085. Head of Lost Creek, lat 62°36′ N., long 142°59′ w., area between Slana and Nebesna, eastern Alaska Range. *Buchia rugosa* (Fischer).
10	Many USGS Mesozoic localities in the McCarthy C–5 quadrangle, Wrangell Mountains (MacKevett, 1969, p. A41, A45–A49). *Buchia rugosa* (Fischer) from upper part of Root Glacier Formation.
11	USGS Mesozoic locs. 3271, 3309, 8851, 10095, 10169, 27068, 27071–73, 27334, and 27335 from Pybus Bay area in southeastern part of Admiralty Island, southeast Alaska (Loney, 1964, p. 97). *Buchia rugosa* (Fischer).
12	USGS Mesozoic locs. 11401 and 11935 from north end of Kupreanoff Island between Hamilton Bay and Keku Strait, southeast Alaska (Martin, 1926, p. 379, 380). *Buchia rugosa* (Fischer).
13	USGS Mesozoic locs. 9528–30 on Gravina Island, southeast Alaska. *Buchia rugosa* (Fischer) and *B.* cf. *B. mosquensis* (von Buch).
14	Many localities in the Talkeetna Mountains A–1 quadrangle, Cook Inlet region. *Buchia rugosa* (Fischer) and *B. mosquensis* (von Buch).
15	USGS Mesozoic locs. 20714 and 27092. Near top of ridge, 2,800 feet west of Discovery Creek, 2 miles S. 69° E. of Mt. Hamilton, and 18.3 miles S. 53° W from confluence of Buckstock and Aniak Rivers. Coordinates 19.6, 3.00 in Russian Mission quadrangle, Kuskokwim region, southwest Alaska. *Buchia rugosa* (Fischer) and *B. mosquensis* (von Buch).

Locality in figure 8	Description
	Late Kimmeridgian to early middle Tithonian—Continued
16	USGS Mesozoic loc. 24257. Thirty-two miles S. 80°45′ E. from Kwinhagak and 55 miles N. 58° 25′ E. from Platinum, Goodnews quadrangle, Kuskokwim region, southwest Alaska. *Buchia* cf. *B. rugosa* (Fischer).
17	USGS Mesozoic locs. 24957, 25839, 29250, 29253, M 5341, M 5345, and M 5348. Cliffs on south side of Kamashak Bay extending 2–10 miles west-northwest from the mouth of Douglas River, lat 59°03′45″ N. to 59°04′30″ N., long 153°49′30″ W. to 154°02′ W., Iliamna quadrangle, head of Alaska Peninsula. *Buchia rugosa* (Fischer) and *B. mosquensis* (von Buch).
18	USGS Mesozoic loc. 24955 from sea cliff on west side of mouth of Douglas River, coordinates 19.98–1.32; Mesozoic loc. 25832 on westernmost of two offshore islands 0.6 mile N. 35° E. of mouth of Douglas River; Mesozoic loc. 25833 near mouth of Douglas River, coordinates 19.8–0.9, Iliamna quadrangle, head of Alaska Peninsula. *Buchia rugosa* (Fischer) and *B. mosquensis* (von Buch).
19	USGS Mesozoic locs. 24956, 29249, 29254 on west shore of Kaguyak Bay. Mesozoic loc. 24956 is 1 mile north of abandoned village of Kaguyak, coordinates 0.82, 10.38; Mesozoic loc. 29254 is on small island 0.7 mile S. 18° E. of abandoned village, Afognak quadrangle, Alaska Peninsula. *Buchia mosquensis* (von Buch) and *B. rugosa* (Fischer).
20	USGS Mesozoic locs. 25276–25278 and M 2076. On northeast side of Grosvenor Lake, lat 58°41′ N., long 155°7′–10′ W., Mt. Katmai quadrangle, Alaska Peninsula. *Buchia rugosa* (Fischer) and *B. mosquensis* (von Buch) range from just below Chisik Conglomerate Member of Naknek Formation (loc. M 2076) to 530 feet above (loc. 25277).
21	USGS Mesozoic loc. 29247. About 9 miles north of Katmai Bay at western base of Barrier Range near Fultons Falls and about 7.7 miles N. 54° E. of Topographers Peak, Mt. Katmai quadrangle, Alaska Peninsula. *Buchia mosquensis* (von Buch).
22	USGS Mesozoic loc. M 5295. SE¼ sec. 32 (estimated), T. 42 S., R. 59 W., about 8.4 miles N. 30° W. of mouth of Thompson Creek on Chignik Bay, Chignik quadrangle, Alaska Peninsula. *Buchia rugosa* (Fischer) and *B.* cf. *B. mosquensis* (von Buch).
23	USGS Mesozoic locs. M 1199, M 1244, M 1204 from Staniukovich Mountain between Herendeen Bay and Port Moller, Alaska Peninsula (Burk, 1965, p. 31, 160, 219). *Buchia mosquensis* (von Buch) and *B. rugosa* (Fischer).
24	USGS Mesozoic loc. M 1234 from Lake Creek area southwest of Herendeen Bay, Alaska Peninsula (Burk, 1965, p. 31, 160, 219). *Buchia rugosa* (Fischer)?
25	USGS Mesozoic loc. 29898. Black Hills area about 40 miles west of Herendeen Bay on north side of Alaska Peninsula. *Buchia rugosa* (Fischer).

Locality in figure 9	Description
	Late middle to late Tithonian
1	USGS Mesozoic loc. 26390. Middle fork of Okpikruak River, lat 68°32′30″ N., long 153°30′30″ W., north-central Alaska. *Buchia* cf. *B. fischeriana* (d'Orbigny).
2	USGS Mesozoic loc. M2531. Kemik Creek, 3.6 miles upstream from junction with Shaviovik River, Sagavanirtok quadrangle, lat 69°27′ N., long 147°08′ W., northeast Alaska. *Buchia unschensis* (Pavlow).
3	USGS Mesozoic locs. 30078 and 30079. On Joe Creek, 10.6–11 miles west of Canadian border and 300 feet or less higher stratigraphically than Mesozoic loc. 30076, which has furnished *Buchia rugosa* (Fischer). Table Mountains quadrangle, northeast Alaska. *Buchia unschensis* (Pavlow).
4	USGS Mesozoic loc. 18349. Jacksina River, 1 mile southwest of mouth, just south of Nebesna, eastern part of Alaska Range, eastern Alaska (Moffit, 1943, pl. 2; 1954, p. 131). *Buchia* cf. *B. fischeriana* (d'Orbigny).
5	USGS Mesozoic loc. 8811, near mouth of Gold Run Creek, a southern tributary of Glacier Creek (Capps, 1916, p. 52, fig. 9 on p. 100); Mesozoic loc. M5377, south side of Bonanza Creek, 5.4 miles N. 57° E. of junction with Chathenda Creek in SW¼ sec. 15, T. 4 N., R. 20 E.; Mesozoic loc. M5386, upper part of Chathenda Creek, 6.5 miles N. 75° E. of outlet of Little Beaver Lake at elevation of 5,300 ft.; Mesozoic loc. M5425, Coarse Money Creek, 1 mile upstream from its junction with Bonanza Creek, SW¼ sec. 17, T. 4 N., R. 20 E.; Mesozoic loc. M5563, south side of Chathenda Creek, 5.2 miles N. 46° E. of outlet of Little Beaver Lake, SE¼ sec. 22, T. 4 N., R. 20 E.; Mesozoic loc. M5564, Chathenda Creek, 5.3 miles N. 46° E. of outlet of Little Beaver Lake. All localities in central and west-central part of the Nabesna A–2 quadrangle in eastern part of Alaska Range. *Buchia fischeriana* (d'Orbigny).
6	USGS Mesozoic loc. M1215. Northeast Creek area north of Amber Bay, Alaska Peninsula (Burk, 1965, p. 160, 178, 220). *Buchia piochii* (Gabb).
7	USGS Mesozoic loc. M 5297. Ten miles N. 76° W. of mouth of Thompson Creek on Chignik Bay, north-central part of sec. 12 near sec. 1 (estimated), T. 43 S., R. 60 W., Chignik quadrangle, Alaska Peninsula (Burk, 1965, p. 160, 176, 219). *Buchia piochii* (Gabb).
8	USGS Mesozoic loc. M 1211. Granville Portage area near Ivanoff Bay, Alaska Peninsula (Burk, 1965, p. 160, 170, 219). *Buchia piochii* (Gabb).
9	USGS Mesozoic loc. M 1238. Staniukovich Mountain between Herendeen Bay and Port Moller, Alaska Peninsula (Burk, 1965, p. 160, 166, 219). *Buchia piochii* (Gabb).
10	USGS Mesozoic loc. M 1236. Lake Creek area west of Herendeen Bay, Alaska Peninsula (Burk, 1965, p. 160, 162, 219). *Buchia piochii* (Gabb).

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Floods of June and July 1990 in and near Las Vegas, Nevada

By Otto Moosburner

The most significant and intense storms of a rather "wet" summer in the Las Vegas metropolitan area occurred on June 10 and July 15–16, 1990. Although the mean annual precipitation in the area is about 4 inches, occasional floods, caused by intense rains in a rapidly urbanizing area, do occur.

Precipitation on June 10, from a moist unstable air mass associated with Tropical Depression Boris, totalled more than 1.5 inches in parts of Las Vegas immediately east and southeast of the downtown area. Most of the precipitation occurred within 1 hour. Maximum 15-minute intensities exceeded 3 inches per hour at several locations. Flooding was generated almost totally in and confined to the urbanized area as shown by the precipitation distribution (fig. 31).

The July 15–16 storm occurred west of the urbanized area in the headwaters and alluvial-fan areas of the Flamingo Wash drainage (fig. 32). Total rainfall in excess of 1.5 inches was recorded at a number of locations (an unofficial storm total of 2.5 inches was reported at one location). The storm generally lasted less than 2 hours.

Flamingo Wash is ephemeral, originates in the Spring Mountains west of Las Vegas, and drains generally eastward through central Las Vegas to join Las Vegas Wash in east Las Vegas. Las Vegas Wash flows to Lake Mead, an impoundment on the Colorado River. Since 1966, when flow records along Flamingo Wash began, five major floods have occurred—in 1975, 1983, 1984, and two in 1990. The magnitudes of major Flamingo Wash floods are listed in table 27. Because of changes in channel-measuring conditions, flood discharges have not been determined at consistent locations.

The maximum discharge in Flamingo Wash on June 10 was small west of the urbanized area (site 1, table 27), but it increased substantially through town (site 5, table 27). Discharge remained high in Las Vegas Wash at the outlet of Las Vegas Valley (4,050 cubic feet per second at site 6). On July 16, the maximum discharge west of Las Vegas was extremely high (site 1, table 27) but attenuated greatly to 512 cubic feet per second in Las Vegas Wash at the outlet of Las Vegas Valley.

Two deaths were attributed to the June 10 flooding—a woman drowned in her vehicle as she attempted to drive across a flood channel, and a man was swept into a manhole from which the cover reportedly had been removed. A woman died in the early morning hours of July 16 in Flamingo Wash when she was swept downstream from her vehicle while attempting to ford the flow. The June 10 and July 16 floods caused $8.7 million in damage to public facilities (Las Vegas Review-Journal, August 1990).

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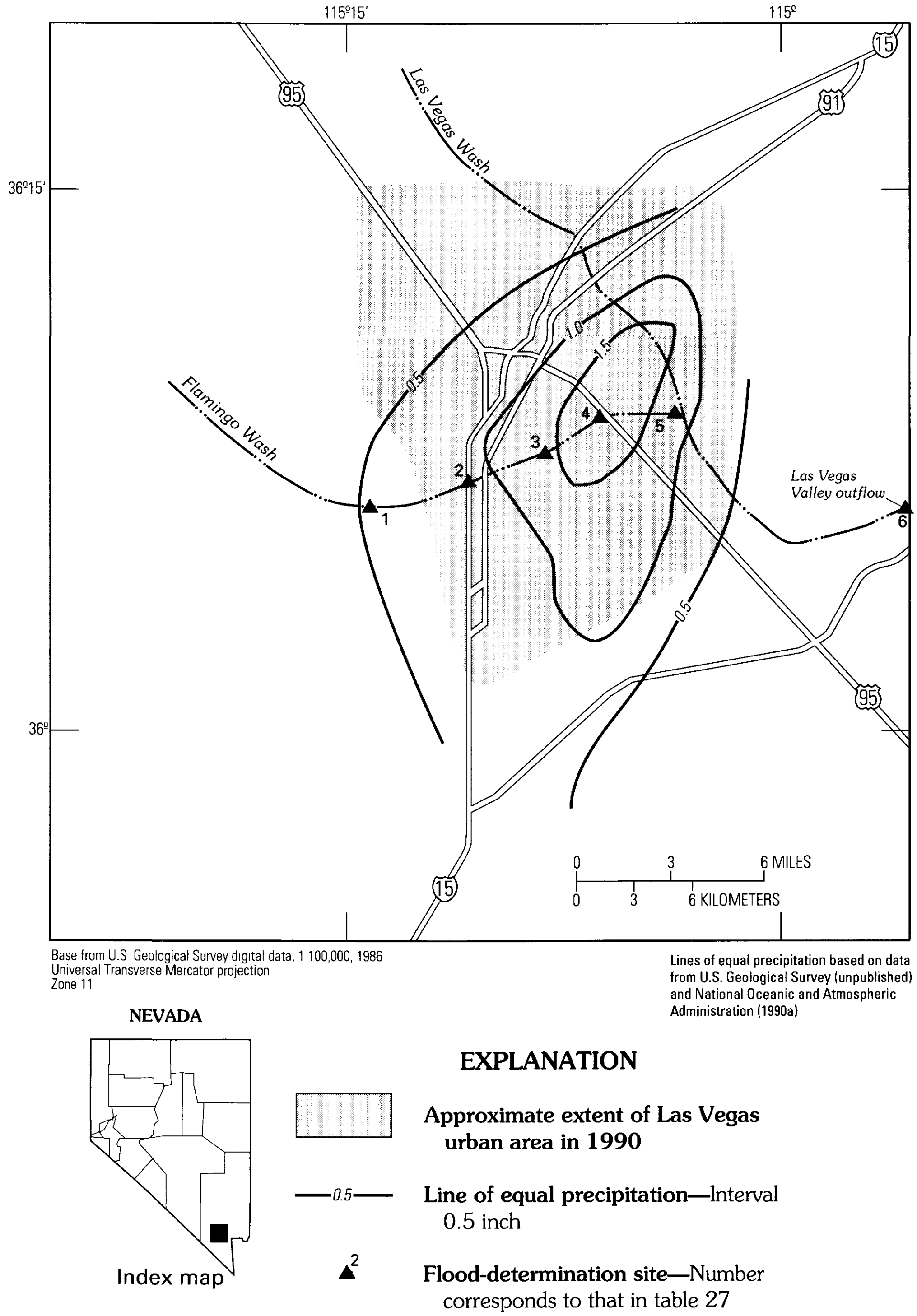
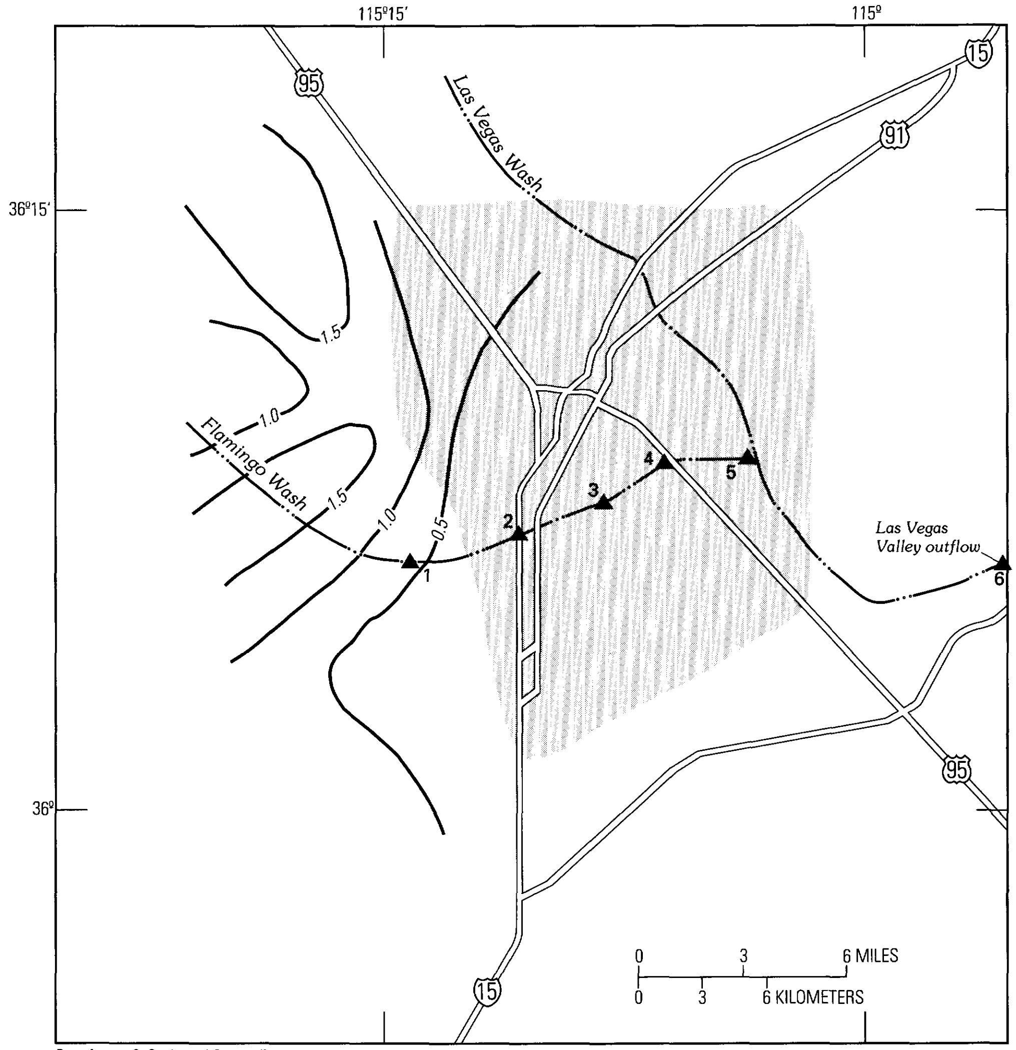


Figure 31. Location of flood-determination sites on Flamingo Wash, 1975–90, and lines of equal precipitation for storm of June 10, 1990, in and near Las Vegas, Nevada.



Base from U S Geological Survey digital data, 1 100,000, 1986
Universal Transverse Mercator projection
Zone 11

Lines of equal precipitation based on data from U.S. Geological Survey (unpublished) and National Oceanic and Atmospheric Administration (1990b)

EXPLANATION

Approximate extent of Las Vegas urban area in 1990

—0.5— **Line of equal precipitation**—Interval 0.5 inch

▲2 **Flood-determination site**—Number corresponds to that in table 27

Figure 32. Location of flood-determination sites on Flamingo Wash, 1975–90, and lines of equal precipitation for storm of July 15–16, 1990, in and near Las Vegas, Nevada.

Table 27. Maximum stages and discharges prior to and during floods of June and July 1990 in and near Las Vegas, Nevada

[mi^2, square miles; ft, feet above an arbitrary datum; ft^3/s, cubic feet per second; --, not determined or not applicable. Source: Data from U.S. Geological Survey reports or data bases]

Site no. (figs. 31 and 32)	Station no.	Stream and place of determination	Drainage area (mi^2)	Maximum prior to June 1990: Period	Year	Stage (ft)	Discharge (ft^3/s)	Maximums during June and July 1990: Date (month/day)	Stage (ft)	Discharge (ft^3/s)	Discharge recurrence interval (years)
1	09419673	Flamingo Wash near Torrey Pines Drive near Las Vegas	94	1988–90	1989	11.54	115	6/10	--	357	--
								7/16	21.41	3,920	--
2	09419675	Flamingo Wash at Las Vegas	[1]98	1966–81, 1985–89	1975	7.23	3,910	--	--	--	--
3	09419677	Flamingo Wash at Maryland Parkway at Las Vegas	106	1969–87	1983	12.15	4,700	--	--	--	--
4	09419678	Flamingo Wash near mouth at Las Vegas	117	1969–87	1984	--	4,000	--	--	--	--
5	09419678.1	Flamingo Wash at Nellis Blvd. near Las Vegas	215	--	--	--	--	6/10	15.90	4,100	--
								7/16	--	3,260	--
6	09419753	Las Vegas Wash above Three Kids Wash below Henderson	[1]2,180	1988–90	1989	6.99	299	6/10	11.28	4,050	--
								7/16	--	512	--

[1]Approximately.