A NORTH AMERICAN EPICONTINENTAL SEA OF JURASSIC AGE

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INTRODUCTION

The following line of investigation is the out-growth of the study of the faunal and stratigraphical conditions as they are expressed in the Jurassic formation of the Freeze-Out Hills in southern Wyoming.[1] In making these investigations the writer has been led to test, in the light of new doctrines[2] and more recent observations, certain prevalent opinions bearing on Jurassic faunal geography. In connection with these investigations there arose also questions concerning which no definite statement

[1] LOGAN: Kansas Uni. Quart., April 1900.

[2] See papers by DR. T. C. CHAMBERLIN on: "A Source of Evolution of Provincial Faunas," JOUR. GEOL., Vol. VI, p. 598; "The Ulterior Basis of Time Divisions," *ibid.*, p. 449.

of opinion has as yet appeared in our geological literature. Among the lines of investigation which suggested themselves were the following: (1) The nature and extent of the interior Jurassic sea; (2) the relation of the interior fauna to other faunas; (3) the connection or connections of the sea with the ocean; and (4) the causes for the lack of communication between the Interior province and the Californian faunal province.

Some of these questions, notably the second and fourth, have already received a somewhat exhaustive discussion at the hands of a number of geologists. In the majority of cases, however, the conclusions formed have been connected with certain fundamental assumptions concerning the validity of which there is at present profound skepticism. As these new doctrines are more or less intimately associated with new fundamental hypotheses, a test of the one is in a measure a test of the other; but a discussion of original postulates does not fall primarily within the province of this investigation. Therefore the discussion will proceed along the lines already indicated and in the order above mentioned.

Nature and extent of the sea.— In order to present the data upon which our conclusions concerning the nature and extent of the Jurassic sea are based it will be necessary to give a summary of the stratigraphical and faunal conditions of the present known Jurassic areas. In collecting this data I have consulted the writings of a long list of geologists who have labored in this particular geological field.[1] On the whole it may be said that the results obtained by these men are strikingly harmonious; so that no grave difficulty should be met in any attempted logical interpretation of the facts.

These Jurassic areas will be discussed in the order which follows: (1) The South Central Wyoming area; (2) the Southeastern Idaho area; (3) the Northern Uinta area; (4) the Southern Uinta area; (5) the Southern Utah area; (6) the Black Hills area; (7) the Montana area; (8) the Canadian area; (9) the Aleutian

[1] For references see following discussion.

area. Many of these terms have been used in a loose geographic sense since the object is to include under one name all of the minor localities belonging to one areal province. The numbers on the map[1] indicate the position of these areas.

THE SOUTH CENTRAL WYOMING AREA

The Freeze-Out Hills.[2]—The oldest rocks recognized in the Freeze-Out Hills are the Carboniferous. They occupy the center of the partly dissected anticline and are overlain by the Red Beds which are composed of sandstones and reddish arenaceous clays and marls inclosing here and there lenticular masses of gypsum or gypsiferous clays. These beds are seemingly devoid of fossils and are apparently conformable with the overlying Jurassic beds of unquestionable marine deposition. At a point on the Dyer Ranch the following stratigraphical conditions of the contact between the Red Beds and the Jura were noted in ascending order:[3]

1. Base, near top of the Red Beds, reddish clay, 2′+;
2. White, indurated sandstone, 4″;
3. Clay, light red, 5″;
4. White sandstone with a reddish tinge, 1″;
5. Light red clay, 2″;
6. White, slightly indurated sandstone, 6″;
7. Shale, reddish changing to purple, 4′;
8. White fissile arenaceous limestone, 6′;
9. Arenaceous clay of a dull red color, 10′;
10. White laminated arenaceous limestone containing fossils, 6″.

This last stratum contains a characteristic Jurassic type, *Pseudomonotis curta* Hall. This is the first or lowest known fossil bearing horizon of the Jura in this area. Any division line between the Red Beds and the Jura placed lower than this fossil bearing stratum would be an arbitrary one as there appears to be no unconformity to mark the separation. To the beds occurring above the fossiliferous horizon the term Jura-Trias is no

[1] See p. 245. [2] LOGAN: Kansas Uni. Quart., April 1900.

[3] Quoted from paper mentioned above.

longer applicable as they are unquestionably Jura. As the Red Beds represent the whole interval of time from the Carboniferous to the Jurassic so far as evidence to the contrary is concerned the term Jura-Trias alone is not applicable to them.

Continuing the section already begun we have for number

11. Arenaceous clay of a somewhat shaly nature, 6′. This layer contains near the central horizon a more highly arenaceous stratum of greenish color. It has scattered through it at different levels some rather large brown argillaceous concretions. The entire stratum seems to be unfossiliferous but it may contain *Belemnites densus* as it is often difficult to determine whether this fossil does, or does not, belong to the lower beds, since, on account of its abundance in the upper beds, it is usually scattered superficially throughout the full extent of the outcrop.

12. White sandy clay, 4′. No invertebrate fossils were found in this stratum but the remains of marine saurians belonging to the genera, *Ichthyosaurus* and *Plesiosaurus* occur in considerable abundance.

13. Purplish fossiliferous clay containing calcareous nodules, 20′. The most abundant fossil in this stratum is *Belemnites densus* which occurs distributed throughout the layer while the other fossils are confined chiefly to calcareous concretions. From these concretions the following forms were obtained: *Pinna kingi* Meek; *Cardioceras? cordiforme* M. & H.; *Belemnites densus* M. & H.; *Astericus pentacrinus* M. & H.; *Astarte packardi* White; *Pleuromya subcompressa* White; *Pseudomonotis curta* Hall; *Tancredia bulbosa* White; *Goniomya montanaensis* Meek; *Tancredia magna* Logan; *Lima lata* Logan; *Belemnites curta* Logan; *Cardinia wyomingensis* Logan and *Avicula beedei* Logan. This stratum contains also the remains of *Plesiosaurs* and *Ichthyosaurs*. It is the most abundantly fossiliferous of the entire series. It is also one of the most persistent beds, and is everywhere characterized by the great abundance of *Belemnites*.

14. Greenish colored sandstone separating into thin layers, 2′ to 4′. This stratum is very persistent, contains considerable calcareous matter, and is easily recognized on account of its

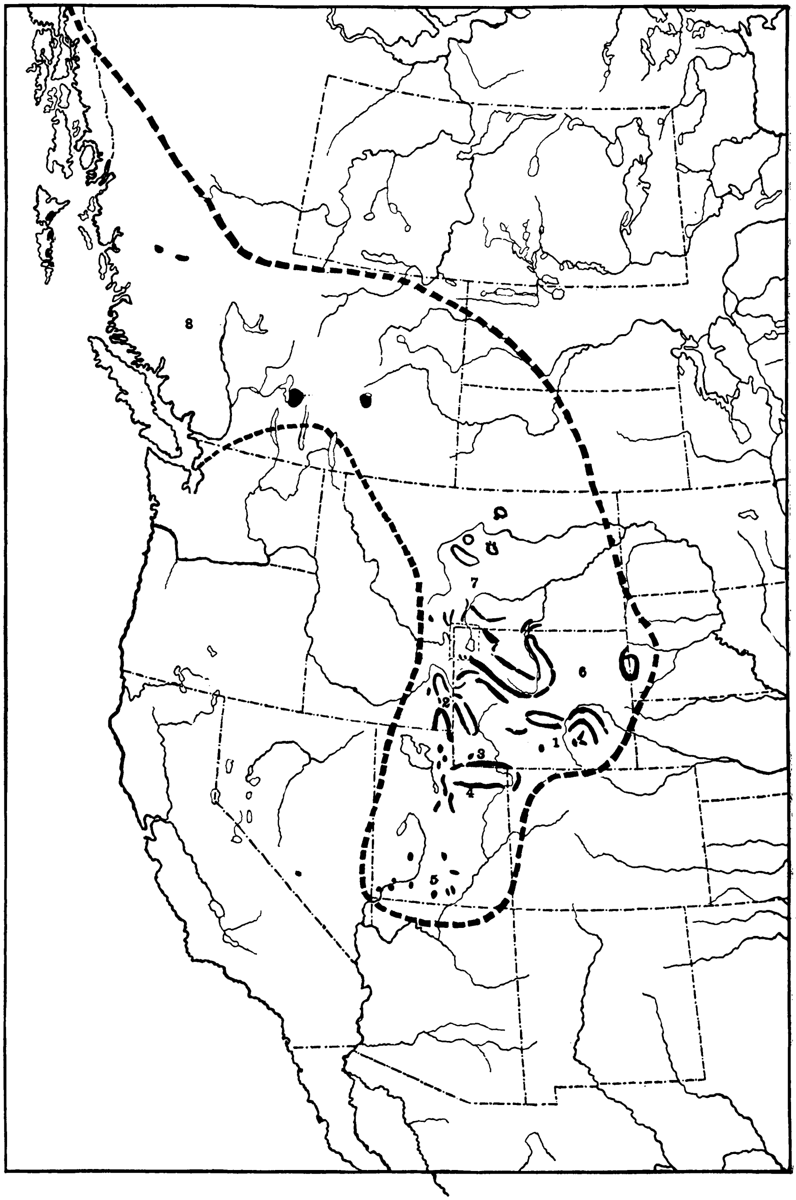

FIG. I.—Map showing the distribution of the Jurassic formation in the interior.

uniformly greenish color. The following fossils occur in it: *Camptonectes bellistriatus* Meek; *Camptonectes extenuatus* M. & H.; *Gryphea calceola* var. *nebrascensis* M. & H.; *Ostrea strigilecula* White and *Ostrea densa* Logan.

15. Purplish clay containing considerable arenaceous inclusions, 40′. The clay contains in the upper part a thin strata of sandy limestone in which the following fossils were found: *Pentacrinus astericus* M. & H.; *Asterias dubium* White; *Pseudomonotis curta* Hall; *Avicula macronatus* M. & H.; and *Ostrea strigilecula* White.

Como beds.—The last stratum is the uppermost one, containing marine fossils and probably closes the Jura. The succeeding layer varies so much in thickness within short distances that it may represent the slightly eroded surface upon which the Como beds were deposited.

16. Fine-grained, grayish-white sandstone, 10′ to 125′. The above stratum varies much in thickness within short distances. At one point on the Dyer Ranch it has a thickness of 10′, while a few miles southeast of that point it reaches a thickness of 125′. The sandstone composing the layer is of nearly uniform color and texture. Its induration is only moderate, and it weathers into many grotesque forms. Cross-bedding is well exhibited by it in many localities.

17. Purple to greenish colored clay, 60′. This is apparently an unfossiliferous layer except in the uppermost horizon, where species of *Dinosaurs* belonging to the genera *Brontosaurus* and *Morosaurus* occur. This is the lowest fossiliferous horizon of the Como beds and the beds included between this horizon and the layer marked 15 may represent the transition from marine to non-marine conditions.

18. Sandstone, grayish to light brown, 10′ to 20′. The above sandstone presents some very interesting stratigraphical phenomena. It has at the base a layer of conglomerate about 2½′ thick. The conglomerate is composed of small argillaceous and silicious pebbles, and is not very coherent. Something like two feet of sandstone rest upon the conglomerate; the

bedding planes of the sandstone are oblique to the beds above and below. Succeeding the sandstone above is 6″ of sandstone in very thin layers, with lignitic seams along its horizontal but wavy bedding planes. The above is overlain by 4″ of conglomerate followed by 1′ of sandstone with oblique bedding planes. Overlying this layer is a thin layer of sandstone in which the bedding planes are horizontal. The remainder of the stratum is made up of sandstones with the thicknesses and bedding planes as follows: 1′ oblique; 3″ horizontal; 2′ oblique; and finally 3″ horizontal.

The beds furnished in one place the trunk of a large fossil tree and a large number of fossil cycads. Fragments of wood were found in a number of places, but cycads in only the one. Fragments of a hollow-boned *Dinosaur* were secured from one place in the horizon.

19. Drab-colored clay, 30′ to 40′. This stratum contains the remains of *Brontosaurus* and *Morosaurus*. Otherwise it appears to be unfossiliferous.

20. Fissile, brownish sandstone, 4′ to 5′. No fossils were found in this sandstone, and a most characteristic feature about it is its uniformly brown color. It seems to be moderately persistent, as it was noticed in many places in the hills.

21. Bluish-green clay, containing very small concretions, 30′. In the bone quarries of this horizon, which furnished species of *Brontosaurus*, *Morosaurus* and *Diplodocus* were found specimens of *Lioplacodes* (*Planorbis*) *veternus* Meek, and *Valvata leei* Logan. This is the lowest horizon at which any of these non-marine invertebrates were noticed. It is very probable that they will be found in the beds below as they indicate similar conditions of deposition.

22. Brown to bluish-gray arenaceous limestone, 8″ to 1′. This stratum contains the following non-marine invertebrate forms: *Unio knighti* Logan; *Unio willistoni* Logan; *Unio baileyi* Logan; *Valvata leei* Logan; and *Lioplacodes* (*Planorbis*) *veternus* Meek. Species of the same genera have been described by Meek from a similar stratum of limestone in the Black Hills.

As these occupy much the same stratigraphical position they are very likely of the same age. The *Lioplacodes* seems to be identical with that described by Meek in the Geology of the Upper Missouri.

23. Drab-colored clay, 70′. Species of the genera *Brontosaurus*, *Diplodocus*, *Morosaurus*, *Stegosaurus* and *Allosaurus* occur in this horizon. Portions of species of all these genera were found in one quarry by the Kansas University collecting party of which the writer was a member. The clay is of that quality usually designated as joint clay. It contains, in places, iron and argillaceous concretions of small size. The iron and sometimes the bones are covered with small selenite crystals.

24. Grayish-white sandstone, 50′. This layer forms a conspicuous capping for the hills, and is the highest remnant of the anticline. It breaks up into large blocks, which lie scattered along the slopes of the underlying softer beds. Its erosion and disintegration is accomplished chiefly by sapping. No fossils were found in this stratum" (Dakota ?).

The maximum thickness of the Jura for this locality does not at the most exceed 100 feet. All of the fossils are found in a vertical range of but little more than half that distance, and yet the fauna includes all the characteristic species of the interior Jurassic province. The beds are heterogeneous and indicate constantly varying conditions of sedimentation.

The entire section is given in its minutest details so that an idea of the general character of the Como beds may be obtained. In many localities this formation has been included in the Jura, although the Jura is wholly marine while on the other hand the Como is wholly fresh water. On the whole the marine beds are more calcareous but there is usually at least one thin bed of limestone in the Como. The lithological characters of the beds do not always stand out so clearly that the evidence of fossils is not required to separate the beds.

Como Lake.[1]—The stratigraphical conditions of the formation at Lake Como are not essentially different from those of the

[1] LOGAN : loc. cit.

Freeze-Outs. The beds have the same lithological characteristics, being composed of sandstones, arenaceous clays, marls and impure limestones. They rest on the Red Beds and are overlain by about the same thickness of the Como (Atlantasaurus) beds. The latter formation is capped by an apparent continuation of the same quartzitic layer which forms the surface stratum in the Freeze-Outs. From this area the following species have been determined by the writer and others: *Asterias dubium; Pentacrinus astericus; Belemnites densus; Cardioceras? cordiforme; Pseudomonotis curta; Camptonectes bellistriatus; Ostrea strigilecula; Ostrea comoensis; Pinna kingi; Tancredia inornata; Pleuromya subcompressa; Astarte packardi;* and *Goniomya montanaensis.*

Rawlins Peak.—The Jurassic at this point exhibits about the same thickness and lithological characters as that of the Como area. The beds contain the following forms: *Camptonectes bellistriatus; Belemnites densus; Astarte packardi; Pseudomonotis curta; Ostrea strigilecula;* and *Pentacrinus astericus.*

Sweetwater.—In the Sweetwater Drainage area Endlich[1] gives 300 feet as the thickness of the jura at that place and states that it contains a Gryphea and a Belemnites.

East of the Wind River Range according to the same writer[2] the Jura has a thickness of 200 or 220 feet and consists at the base of dark calcareous shales, covered by beds of dark blue limestones. These are followed by yellow shales and marls with intercalations of thin sandstone layers. Yellow, pink and greenish marls close the section. The fossils obtained are species of *Belemnites*, *Gryphea*, *Rhynchonella*, *Lingula*, *Modiola*, *Pecten*, and others.

THE SOUTHEASTERN IDAHO AREA

In this area St. John[3] places the thickness of the Jura at 2000 feet. Since, however, only the lowermost beds are fossiliferous it is probable that the Jura should be restricted to that

[1] Ann. Rep. U. S. Geol. Surv., Vol. XI, 1877, p. 108.

[2] *Ibid.* p. 87.

[3] Ann. Rep. U. S. Geol. Surv., Vol. XI, 1877, p. 495.

horizon. The beds consist here as elsewhere of alternating beds of sandstone, shales, and limestones.

In the Lincoln Basin the following Jurassic fossils were collected: *Ostrea strigilecula; Belemnites densus; Pentacrinus, Ostrea, Gryphea, Camptonectes*, and *Pseudomonotis*.

At Meridian Ridge Peale[1] found 150 feet of bluish and gray limestones; bluish laminated limestones and bluish argillaceous shales and slates followed by 100 feet of reddish sandstone and bluish limestone containing *Pentacrinus astericus; Ostrea strigilecula; Camptonectes bellistriatus* and other forms. This thickness of 250 feet doubtless represents a conservative average for the entire district.

On the John Day (Gray) River[2] the following fossils were collected: *Pentacrinus astericus; Belemnites densus; Camptonectes bellistriatus; Gryphea, Trigonia*, and *Pleuromya;* and from another outcrop, *Pentacrinus astericus; Ostrea strigilecula*, and *Tancredia sp.* An outcrop in the Sublette Range furnished *Pentacrinus astericus* and *Camptonectes bellistriatus.*

The Jura at Bear Lake Plateau[3] contains *Pseudomonotis curta* and other forms. The fossiliferous beds consist of 90 feet of gray limestone and 80 feet of bluish-gray limestone with bands of sandstone. This group rests on 150 feet of limestone which may also be Jura but there is no faunal evidence of its age.

On Bear River in Southwestern Wyoming Meek[4] gives the following section for the Jura: "Ferruginous sandstone, in thin layers, dipping northwest about 80° below horizon, 40 feet; bluish laminated clays with, at top (left or west side), a two-foot layer of sandstone containing fragments of shells not seen in a condition to be determined, 125 feet; Clays and sandstones, below (20 feet); gray and brown pebbly sandstone above (25 feet), 45 feet; brownish and bluish clays, with some beds of white, greenish, and brown sandstone, 115 feet." From the second layer the following fossils were obtained: *Belemnites*

[1] Ann. Rep. U. S. Geol. Surv., Vol. XI, 1877, p. 536.

[2] *Ibid.* p. 544. [3] *Ibid.* p. 585.

[4] Ann. Rept. U. S. Geol. Surv., Vol. VI, 1872, p. 451.

densus, *Trigonia Quadrangularis*, and *Pleuromya weberensis?* This stratum of 125 feet is all of the section that can, with certainty, be assigned to the Jura, as the other layers are unfossiliferous.

The third and fourth layers correspond in character to the Como beds in other areas in Wyoming.

THE NORTHERN UINTA AREA

Flaming Gorge.[1]— In the Flaming Gorge the total thickness of the Jurassic is placed at 700 feet. Three hundred feet near the middle of the outcrop contains: *Camptonectes bellistriatus; Gryphea calceola; Pentacrinus astericus; Rynchonella gnathophora; Trigonia americana, Trigonia conradi; Ostrea strigilecula;* and *Belemnites densus.* In the absence of fossil evidence the portion of the outcrop lying above and below this horizon cannot with certainty be assigned to the Jura. Therefore it is possible that the three hundred feet represents the whole thickness of the Jura for this area.

South of Dead Man's Springs calcareous beds which are thought to represent the middle part of the Jura for that area contain: *Camptonectes bellistriatus; Myophoria lineata; Gryphea calceola;* and *Pentacrinus astericus.*

Vermillion Cliffs.[2]—From Vermillion Cliffs in Northwestern Colorado White determined the following Jurassic species: *Belemnites densus; Cardioceras cordiforme; Pentacrinus astericus; Rhynchonella gnathophora; Rhynchonella myrina; Ostrea strigilecula; Ostrea procumbens;* and *Modiola subimbricata.*

The limits of the Jurassic sea in a southeasterly direction do not appear to have been far from this point. Northwestern Colorado has up to this time been the only part of the state to which unquestionable Jura could be assigned.

On Sheep Creek a basal limestone yielded *Camptonectes bellistriatus; Myophoria lineata; Gryphea calceola; Pentacrinus astericus; Belemnites densus;* and specimens of *Ostrea, Trigonia,* and *Volsella.*

[1] KING: Geology of the 40th parallel, Vol. I, p. 290.

[2] WHITE: Geology of Northwest Colorado, U. S. Geol. Surv., Vol. XII, 1878.

THE SOUTHERN UINTA AREA

Ashley Creek.[1]—The thickness of the Jurassic beds on Ashley Creek is estimated to be about 750 feet. Of this thickness 50 feet are blue and drab colored shales and limestones carrying *Gryphea calceola*, *Pseudomonotis* (*Eumicrotis*) *curta* and *Belemnites densus.* This stratum corresponds to the more densely fossiliferous zone of other localities. As the vertical range of the fossils is not given it is difficult to say whether all of the 750 feet should be included in the Jura.

Near Peoria on the western end of the range a basal limestone contains *Pseudomonotis curta* and is followed by a group of shales and marls. No thicknesses are given for this area.

Wasatch Range.[2]—In Weber canyon of the Wasatch Range the Jurassic is estimated to have a total thickness of 1600 feet. The lower part which consists of yellow and bluish limestones and calcareous shales has a thickness of 600 feet. It contains the following fossils: *Cucullaea haguei; Pleuromya subcompressa; Myophoria lineata; Myophoria sp.* and *Volsella scalpra.* As the upper 1000 feet of arenaceous texture is unfossiliferous it is more than probable that it is not of Jurassic age. As the vertical range of the fossils is not given we have no means of ascertaining how much of the 600 feet may, also, belong to another period.

At the mouth of Thistle Creek in Spanish Fork Canyon the following fossils were found: *Lyosoma powelli*, *Camptonectes stygius* and *Pinna sp.*

THE SOUTHERN UTAH AREA

According to Dutton[3] the known Jura of Southern Utah has a thickness of from 200 to 400 feet. The formation consists of a series of calcareous and gypsiferous shales. The beds are distinctly fossiliferous and thin out toward the south, entirely disappearing in northern New Mexico and Arizona. A few fossils have been collected from a number of localities in the region.

[1] KING: Geology of the 40th Parallel, Vol. I, p. 292.

[2] KING: l. c. p. 293.

[3] Geology of the High Plateaus, Utah, p. 150.

From specimens collected on the Santa Clara River two miles below Gunlock White determined the following species: *Pentacrinus astericus* M. & H.; and *Trigonia sp.* Wh.; from near Kanara: *Pentacrinus astericus* M. & H.; *Camptonectes stygius* White; *Camptonectes bellistriatus* M. & H.; from the northern part of aquarius plateau; *Camptonectes platessiformis* White; *Trigonia montanaensis* Meek and *Gervillia sp.* White; from Potato Valley, Diamond Valley, and near Gunnison: *Pentacrinus astericus* M. & H.

From the geographic distribution of the Jura in this region it appears that the Jurassic sea did not extend far south of the southern boundary of Utah. It may be assumed also that its eastern as well as its western shore lines did not extend in this region much beyond the state boundaries. From this point the eastern shore line extends farther and farther east crossing the northwest corner of Colorado thence continuing toward the northeast and including the Black Hills area.

The thinning out of the beds toward the south may be due to the presence of a low land area at the south during this epoch. A high land area should give a thick shore deposit of a coarse, clastic nature. According to the above statements, however, the beds consist of calcareous and gypsiferous shales which indicate either a somewhat remote shoreline or a low bordering land area.

THE BLACK HILLS AREA[1]

The Jurassic formation forms one of the members in the rim of sedimentary rocks which encircles the crystalline area of the Black Hills. Here as in the central and southern areas the Jura rests upon the Red beds and is overlain by the Lower Cretaceous, the Como beds. Its thickness is in the neighborhood of 200 feet. It exhibits in general about the same lithological characters that are noticeable in the formation in the Southern Wyoming area. The beds consist of sandstones, arenaceous shales and marls, and thin beds of impure fissile limestone.

Whitfield[2] has determined the following species from this

[1] JENNEY: Nineteenth Ann. Rep. U. S. Geol. Surv., p. 593.

[2] Geology of the Black Hills, 1884.

area: *Asterias dubium* Whitf.; *Pentacrinus astericus* M. & H.; *Lingula brevirostris* M. & H.; *Rhynchonella myrina* M. & H.; *Ostrea strigilecula* White; *Gryphea calceola*, var. *nebrascensis* M. & H.; *Pecten newberryi* Whitf.; *Camptonectes bellistriatus* M.; *Camptonectes extenuatus* M. & H.; *Pseudomonotis curta* Hall; *Pseudomonotis orbiculata* Whitf.; *Avicula* (*Oxytoma*) *mucronata* M. & H.; *Gervillia recta* M.; *Grammatodon inornatus* M. & H.; *Mytilus whitei* Whitf.; *Volsella* (*Modiola*) *formosa* M. & H.; *Volsella pertenius* M. & H.; *Astarte fragilis* M. & H.; *Trapezium bellefourchensis* Whitf.; *Trapezium subequalis* Whitf.; *Pleuromya newtoni* Whitf.; *Tancredia inornata* M. & H.; *Tancredia corbuliformis* Whitf.; *Tancredia bulbosa* Whitf.; *Tancredia postica* Whitf; *Tancredia warrenana* M. & H.; *Dosina jurassica* Whitf.; *Psammobia? prematura* Whitf.; *Thracia? sublevis* M. & H.; *Neaera longirostra* Whitf.; *Saxicava jurassica* Whitf.; *Quenstedioceras* (*Cardioceras*) *cordiforme* M. & H.; and *Belemnites densus* M. & H.

In the Big Horn Basin region Eldridge[1] discusses the Jura as follows: "This, so far as the evidence obtained indicates, is, within the region under examination, wholly of marine origin. The thickness is between 400 and 600 feet, which is approximately maintained over the entire area of exposure. Shales constitute the mass of the formation in which from base to summit occur thin beds of sandstone and fossiliferous limestone of types characteristic of the Jura in the Rocky Mountain region. Gray is the predominating color of the shales, but throughout the formation red, purple, yellow, slate, and pink, in greater or less intensity, may be observed. At a number of localities a considerable amount of siliceous matter appears, in occurrence suggesting the action of hot waters.

"The sandstones are of slight importance. They are chiefly gray with a slight greenish tint. The lower beds, however, are red, shaly and transitional from the Trias, while near the summit are two of greater thickness, which, but for their tint and the overlying typical Jura shales, might be confounded with the Dakota.

[1] Bull. U. S. Geol. Surv. No. 119.

"The limestones are nearly all fossiliferous, and of the drab color peculiar to the Jura in the west. In thickness they vary from a few inches to 15 feet. Three or four in the lower 100 feet and one or two in the upper third of the formation are especially prominent."

The formation is said to be overlain by the Dakota sandstone. If this so-called Dakota sandstone is at the same horizon that it is in the Freeze-Out Hills, and it seems from the description very probable that it is, then the Jura so-called must include the Como beds. The description of the upper part of the formation fits the Como, while the lower part with its fossiliferous limestones is very characteristic of the Jura both north and south of this area. The Como or its stratigraphic equivalent is recognized both north and south of this region and there appears no good reason for its absence in this area.

THE MONTANA AREA

Castle Mountain.[1]—The Jurassic formation in this area is less than one half the average thickness for the interior. Its maximum thickness is only ninety feet. The formation consists of a basal sandstone overlain by a dense white limestone. The limestone layer is highly fossiliferous and contains the following well-known Jurassic forms: *Astarte packardi; Trigonia montanaensis; Pinna kingi; Pholadomya kingi; Ostrea sp.; Camptonectes extenuatus; and Gervillia montanaensis.*

The Jura of this locality rests upon upon the Carboniferous and the Red Beds are not represented. It is the belief of the writers that the beds are wanting altogether in Montana, or at least but sparingly represented.

Little Rocky Mountains.[2]—The total thickness of the Jura for this region is placed at 100 feet. The beds consist of shaly gray limestones which change to impure, marly shales and argillaceous limestones. They rest on limestones of Carboniferous age and the Red Beds are again absent.

[1] WEED and PIRSSON, Bull. 139, U. S. Geol. Surv., 1896.

[2] WEED and PIRSSON, JOUR. GEOL., Vol. IV, 1896.

The Jurassic limestones contain the following species: *Astarte meeki; Belemnites densus; Pleuromya subcompressa; Gryphea calceola*, var. *nebrascensis;* and a fragment of an undetermined Ammonite.

This is one of the most northerly areas from which Jura has been recorded for Montana. If the formation is present in the Bear Paw Mountains which lie to the northwest of this area it has not been differentiated.

Three Forks.[1]—The Jura has a thickness in this area of from 300 to 400 feet. The lower beds rest on a basal quartzite and consist of argillaceous limestones which carry characteristic Jurassic fossils. The middle and upper beds are more arenaceous than the lower beds and are non-fossiliferous. Under such conditions it is very questionable whether they should be assigned to the Jura. It is very probable that the thickness of the Jura in this area conforms more nearly to that assigned to it in other areas of Montana.

Livingston.[2]—The Jurassic formation of the Livingston area has a thickness estimated at 400 feet. It consists at the base of a massive, cross-bedded, ripple-marked sandstone. This sandstone is overlain by a layer of impure fossiliferous limestone containing *Pleuromya subcompressa* M. The limestone is followed by a bed of arenaceous limestones containing shell fragments. Since the lower layer is non-fossiliferous it may or may not represent a part of the Jura, but there is the possibility of an overestimation of thickness here as well as in the Three Forks area.

Although the thicknesses given for the Three Forks and Livingston area are not extremely large, yet they are nearly double that given for the other Montana areas. But as has been pointed out, this lack of harmony may be due to the inclusion of beds belonging to other formations. If the faunal relations are not carefully worked out in connection with the stratigraphy errors are likely to occur either in the direction of the overlying

[1] PEALE, U. S. Geol. Surv., Three Forks Folio, 1896.

[2] IDDINGS and WEED, U. S. Geol. Surv., Livingston Folio, 1894.

or the underlying beds. For the Jura in many localities, so far as physical characters are concerned, grades almost imperceptively into the Red Beds below and the Como above.

Judith Mountains.[1]—Weed and Pirsson give the following section as representing the Jura in the Judith Mountains. The base is separated from the Carboniferous by a sheet of porphyry.

		Feet.
1.	Limestone, dark gray, laminated, and shaly - - - - -	10
2.	Limestone, blue to gray in color, hard in texture, and carrying Ostreæ in 3 to 5-foot beds, separated by thinner platy beds -	12
3.	No exposure - - - - - - - - - - - - -	25
4.	Shaly, argillaceous, impure limestone, dove colored, weathering buff on joint faces and of typical Jurassic aspect - - - -	5
5.	Shaly beds, seldom exposed, carrying oolitic limestone. Green or sandy limestone of drab color - - - - - - - -	15
6.	Rough weathering limestone, fine grained, cross-bedded and fissile, carrying fossils - - - - - - - - - - -	5
7.	Sandy limestone like that above, but irregularly bedded and resembling sandstone; granular and saccharoidal in texture, carries shell fragments - - - - - - - - - - - -	4
8.	Irregularly platy, earthy-brown, gray limestone carrying shell remains of *Gryphea* and *Ostrea*, weathering dark brown, rarely granular - - - - - - - - - - - -	6
9.	Marly shales and limestone, dove colored, carrying fossils noted in following pages, seldom exposed, *Gryphea* most abundant here -	30
10.	No exposure, but débris of sandstone - - - - - -	60
11.	Ellis sandstone, variable, buff, platy sand rock; pink blotched at base with occasional shells; cross-bedded purple-brown outcrop. It is at the top a limestone full of black and white quartz sand grains and forms a dark brown ridge - - - - - - - - -	12

This section gives the total thickness of the Jura for this region at 184 feet, which is nearly double that of the Little Rocky and Castle Mountain areas.

The fossils collected from the horizon mentioned above are: *Ostrea strigilecula* White; *Gryphea calceola* var. *nebrascensis* M. & H.; *Modiola subimbricata* M.; *Cucullaea haguei* M.; *Pleuromya subcompressa* M.

[1] WEED and PIRSSON, Eighteenth Ann. Rept., U. S. Geol. Surv., III, p. 445.

Yellowstone Park.[1]—The thickness of the formation for this area is placed at 200 feet. It consists of sandstones, marls, limestones, and clays, and contains, according to Stanton,[2] the following species: *Pentacrinus astericus* M. & H.; *Rhynchonella myrina* Hall & Whitf.; *Rynchonella gnathophora* M.; *Ostrea strigilecula* White; *Ostrea engelmani* M.; *Gryphea planoconvexa* Whitf.; *Gryphea calceola* var. *nebrascensis* M. & H.; *Lima cinnabarensis* Stan.; *Camptonectes bellistriatus* M.; *Camptonectes bellistriatus* var. *distans* Stanton; *Camptonectes pertenuistriatus* Hall & Whitf.; *Camptonectes platessiformis* White; *Avicula (Oxytoma) Wyomingensis* Stan.; *Pseudomonotis Curta* (Hall)?; *Gervillia montanaensis* M.; *Gervillia* sp. Stan.; *Modiola subimbricata* Meek; *Pinna kingi* M.; *Cucullaea haguei* M.; *Trigonia americana* M.; *Trigonia elegantissima* M.; *Trigonia montanaensis* M.; *Astarte meeki* Stan.; *Astarte* sp. Stanton; *Tancredia? knowltoni* Stan.; *Protocardia shumardi* M. & H.; *Cyprina? Cinnabarensis* Stanton; *Cyprina? iddingsi* Stanton; *Cypricardia? haguei* Stanton; *Pholadomya kingi* M.; *Pholadomya inaequiplicata* Stan.; *Homomya gallatinensis* Stan.; *Pleuromya subcompressa* M.; *Thracia weedi* Stanton; *Thracia? montanaensis* (Meek)?; *Anatina (Cercomya) punctata* Stan.; *Anatina (Cercomya)* sp. Stan.; *Neritina wyomingensis* Stan.; *Lyosoma powelli* White; *Turitella* sp. Stan.; *Natica* sp. Stan.; *Oppelia?* sp. Stan.; *Perispinctes* sp. Stan.; and *Belemnites densus* Meek and Hayden.

THE CANADIAN AREA

In the Queen Charlotte Islands Whiteaves[3] noted the occurrence of the following species, which are common to the Jura of the Interior: *Pleuromya subcompressa* Mk.; *Astarte packardi* White; *Avicula (Oxytoma) mucronata* Mk.; *Gryphea calceola* var. *nebrascensis* M. & H.; *Lyosoma powelli* White; *Belemnites densus* M. & H.; *Belemnites skidgatensis* Whiteav.; *Grammatodon inornatus* Whiteav.; *Modiola subimbricata* Mk.; and *Camptonectes extenuatus* Mk.

Although Whiteaves recognized the interior affinity of these forms, he was inclined to put both groups into the Cretaceous

[1] U. S. Geol. Surv., Yellowstone Park Folio, 1896.

[2] U. S. Geol. Surv., Yellowstone Park Monograph, XXXII, p. 601, 1899.

[3] Geol. Surv., Canada, Mesozoic Fossils, Vol. I.

rather than the Jura. But the Jurassic age of these beds is now sufficiently well established not to require further discussion.

Not only is this fauna represented in the islands just mentioned, but it occurs also on the continent at some considerable distance inland. From fossils collected by G. M. Dawson on the Iltasyouco River in British Columbia about Parallel 53° and Longitude 126° West, Whiteaves[1] recognized the following species: *Pleuromya subcompressa* Mk.; *Pleuromya lævigata* Whiteav.; *Astarte packardi* White; *Trigonia dawsoni* Whiteav.; *Modiola formosa* M. & H.; *Gervillea montanaensis* Mk.; *Gryphea calceola* var. *nebrascensis* M. & H.; *Grammatodon inornatus* Whiteav.; *Oleostephanus loganianus* Whiteav.

These fossils were found in the felsites and porphyrites of the metamorphic rocks lying east of the Coast Range. They contain species common to both the Queen Charlotte and the Interior faunas.

From fossils collected by G. M. Dawson at Nicola Lake in British Columbia Hyatt[2] determined the Jurassic age of certain beds in that region lying above the Triassic. The fossils collected are: *Rhynchonella gnathophoria?; Pecten acutiplicatus* Gabb; *Entolium* sp. Hyatt; *Lima parva* Hyatt.

Just north of Parallel 51°, near the east end of Devil's Lake, which is situated on the eastern border of the Front Range of the Rockies, McConnell[3] found an outlier of Jurassic which contained the following fossils: *Avicula* (*Oxytoma*) *mucronata; Trigonia intermedia; Trigonarca tumida; Terebratula*, *Ostrea*, *Camptonectes*, *Lima*, *Cyprina*, *Ammonites*, and *Belemnites*. This locality serves as a connecting link between the Montana area and the localities to the west, as it is situated midway between the two. The above-named group of fossils contains one species and a number of genera common to the Interior and the Pacific Coast deposits.

[1] Loc. cit.

[2] Rept. of Geol. Surv., Canada, 1894, p. 51.

[3] Rept. of Geol. Surv. Canada, 1896, p. 17d.

THE ALEUTIAN AREA

Grewingk[1] was the first to announce the occurrence of beds of Jurassic age in Alaska. These beds were discovered at different places along the Alaskan Peninsula and the Aleutian Islands. From the distribution of these beds as mapped by Grewingk the Alaskan Peninsula and the Aleutian Islands must have been under water during Jurassic times.

In 1872 Eichwald[2] described an assemblage of fossils collected from these same beds and correlated them with the Northern Russia beds of the same age, but put both formations in the Lower Cretaceous. Some fossils were collected from the same region by Dall in 1883. These forms were described by White,[3] who after making a study of them and comparing them with Eichwald's descriptions, decided that the latter was wrong in his assignment of the beds to the Cretaceous. He found them to be closely allied to the Jurassic of Northern Russia. One species, *Aucella concentrica* Fisher, he considers either identical or only a variety of the Eurasian Jurassic form of that name.

Hyatt,[4] in speaking of these deposits, says: "The fauna of the Black Hills, acknowledged to be Jurassic by everyone but Whiteaves, is in part apparently synchronous with that of the Aleutian Islands and Alaska, as described by Eichwald and Grewingk."

The position of these beds and the relation of the fauna with the northern Eurasian fauna points clearly to an Arctic-Pacific connection by way of the Bering waters during this epoch. Moreover we now have an almost continuous faunal record extending from Alaska to southern Utah.

Conclusions.—An examination of the above sections will show that the thickness of the Jura in the interior is not very great. An average of ten localities gives a thickness of but little over

[1] Russian Kaiserl. Mineral Gesell., 1848–9.

[2] Geognostisch-Paleontologische Bemerkungen über die Halbinsel Mangischlak und die Aleutschen Insel.

[3] Bull. U. S. Geol. Surv. No. 4, 1884.

[4] Bull. Geol. Soc. Am., Vol. V, 1894, p. 409.

two hundred feet. In fourteen localities the thickness is under four hundred feet. These localities are scattered throughout the length and breadth of the interior province. In all the areas for which greater thicknesses have been recorded there are none in which the entire thickness could, without question, be assigned to the Jura.

The lithological character of the beds is much the same for all areas. The formation consists everywhere of essentially the same group of arenaceous clays, shaly marls, impure limestones and sandstones. The order of succession of the beds implies ever changing conditions of sedimentation. Thin beds of sandstone are overlain by thin beds of fossilferous clays, marls, or limestones; and these in turn are followed by another similar group.

The absence of any considerable thickness of limestone over a large area indicates that for no great period of time were the waters of the sea entirely free from clastic sediments. The presence of cross-bedded sandstone and ripple-marked layers at different horizons, the almost universal presence of *Ostrea* and other shallow water forms, together with the stratigraphic and lithologic characters just mentioned prove that the waters of the sea were not of great depth; that the sea was not of the abysmal type. It was not a sea comparable in depth to the Mediterranean but was a shallow epicontinental sea. From the geographic distribution of the known Jurassic the outlines of this sea were as indicated on the map[1] accompanying this paper.

From the character and extent of the sea it may be assumed that no extensive epeirogenic movement was necessary for its inauguration, providing the antecedent topographic conditions were favorable. In the northern part of the area there is evidence that a considerable period of erosion preceded the Jura, as the Red Beds are absent and the Jura rests on the Carboniferous. This period of erosion may have been sufficient to reduce the land area to approximate base level in which case a very slight warping would have been sufficient to let the waters of this

[1] See p. 245.

shallow sea in upon the continent. A very slight increase in the capacity of the ocean basin would suffice to draw the water off the continent at the close of the period. The increase in the capacity of the ocean may have been accomplished by a slight settling of the oceanic segment. The withdrawal of the waters of the epicontinental sea was doubtless the initial step in the movement which ended in the elevation of the Sierra Nevada Mountains; for the withdrawal took place at the close of the Oxfordian stage or during the Corallian and according to Diller[1] the orogenic movement which produced the Sierra Nevada and Klamath Mountains took place at the close of the Corallian. If these interpretations be logical ones we may assume that it required little or no bodily movement of the continent to produce either the inauguration of the Jurassic sea or its withdrawal from the continent. It may be asserted further that there is nothing connected with its history which is inimical to the doctrine that the continent had in general its present outline during Jurassic times and that the waters of the submerged portions were of an epicontinental nature.

The writer's study of the faunal conditions in the field has led him to the opinion that only one fauna is to be recognized in the Jurassic deposits of the interior province. A comparison of the fossils collected from the different areas just discussed serves to strengthen the opinion. Everywhere the formation is characterized by about the same group of fossils, of which the more characteristic ones are: *Pentacrinus astericus*, *Belemnites densus*, *Camptonectes bellistriatus*, *Pseudomonotis curta* and *Cardioceras cordiforme*. These forms all existed contemporaneously.

Stanton[2] discusses the view expressed by Hyatt[3] that more than one Jurassic fauna may be represented in the Interior and arrived at the following conclusion: "the stratigraphic relations and the geographic distribution of the marine Jurassic of the Rocky Mountain region are in favor of the idea that all of these deposits were made contemporaneously in a single sea."

[1] Bull. Geol. Soc. Am. Vol. IV, p. 228.

[2] U. S. Geol. Surv. Yellowstone Park Monograph XXXII, 1899, pp. 602–604.

[3] Bull. Geol. Soc. Am. Vol. III, 1892, pp. 409–410.

This fauna according to Hyatt belongs to the Oxfordian stage of the Upper Jura or Malm. In the Taylorville series of California he recognized the Callovian, the Oxfordian and the Corallian stages of the Upper Jura. But as has been stated above none but the middle stage has been recognized in the Interior.

Relation of the interior fauna to the northern eurasian fauna.—The discovery of beds of Jurassic age in the interior was first announced by Meek[1] in 1858. In correlating these beds with the Jura of the Old World he says: "The organic remains found in these series present, both individually and as a group, very close affinities to those in the Jurassic epoch in the Old World; so close indeed, that in some instances, after the most careful comparisons with figures and descriptions, we are left in doubt whether they should be regarded as distinct species, or as varieties of well-known European Jurassic forms. Among those so closely allied to foreign Jurassic species may be mentioned an Ammonite we have described under the name of *Ammonites cordiformis* which we now regard as probably identical with *Ammonites cordatus* of Sowerby; a *Gryphea* we have been only able to distinguish as a variety from *G. calceola* Quenstedt; a *Pecten*, scarcely distinguishable from *Pecten lens* Sowerby; a *Modiola*, very closely allied to *M. cancellata*, of Goldfuss; a *Belemnite*, agreeing very well with *B. excentricus*."

Since the publication of the above statements by Meek the paleontology of the European Jura has been more completely worked out and some of the faunas, particularly that of northern Russia, are found to have still closer affinities to the American interior fauna. The Jurassic faunas of America have also received many additions at the hands of the American paleontologists Gabb, Hyatt, Meek, Smith, Stanton, White, Whiteaves, and Whitfield. All of these studies have tended to strengthen the opinion just expressed.

The following comparison of forms which are so closely allied as to deserve, in many cases, to be called varieties of the same species will serve to show the close affinity of the interior

[1] Geological Report of the Exploration of the Yellowstone and Missouri Rivers.

American fauna to the fauna of northern Eurasia: *Belemnites panderanus* d'Orb. and *Belemnites densus* Mk.; *Astarte duboisianus* d'Orb. and *Astarte pakardi* White; *Avicula volgensis* d'O. and *Avicula mucronata* Mk.; *Pentacrinus scalaris* Goldf. and *Pentacrinus astericus* M. & H.; *Goniomya dubois* d'Orb. and *Goniomya montanaensis* Mk.; *Gryphea calceola*, Quen. and *Gryphea caceola* var. *nebrascensis* Mk.; *Cardioceras cordatus* Sow. and *Cardioceras cordiforme* Mk. The faunas taken as a whole exhibit the close relationship in a much more forcible manner than the comparison of a few species.

This northern Eurasian, or *Cardioceras* fauna is thought to have had its origin on the northern shores of the Eurasian continent, and to have migrated from there to American waters. This assumption is based on the sudden appearance of the fauna in America and its close affinities with older Eurasian faunas. The present geographic distribution of the fauna indicates a northern connection.

A later Jurassic fauna, the *Aucella* fauna, probably had its origin in the north and migrated to Pacific waters. This fauna, however, did not reach the interior province of America as the waters of the epicontinental sea had been withdrawn before its appearance. This later migration extended along the Pacific coast as far south as Mexico.

Both of the faunas just mentioned belong to the Upper Jura, but the Lias and Middle Jura are also represented in the Californian province. The Upper Jura, however, represents the maximum encroachment of the ocean on the American continent as well as on the Eurasian continent. It also marks the maximum expansion of marine life, induced doubtless by increased feeding grounds.

Connection of the sea with the ocean.—The question as to where the interior sea had its connection, or connections, with the ocean is important in estimating the extent of the submergence, That the sea had a Pacific Ocean connection there seems no longer room for doubt. The occurrence in the Queen Charlotte fauna of so many species common to the interior places the question beyond controversy. That there was communication between the Arctic and the Pacific is supported by the presence of Arctic species in the Pacific fauna. From the distribution of the Jurassic sediments as given in the preceding pages it may be asserted with a measurable degree of confidence that the connection between these two bodies of water was during Jurassic times as it is today by way of the Bering waters. As the presence of Jurassic deposits on the Alaskan Peninsula and the Aleutian Islands testify to the submergence of those areas, it may be assumed that communication between the two oceans was somewhat freer than at present.

The question which is now brought to mind is whether the interior sea had any other connection with the ocean. The character of the fauna excludes any hypothesis favoring a southern connection either with the Gulf of Mexico or the Pacific. If there had been such a connection a southern facies would be expressed in its fauna. Such evidence is entirely absent. The evidence against any other Arctic connection is largely negative, but as such is measurably strong. The investigations of American and Canadian geologists have failed to bring to light any Jurassic deposits in the North aside from those already described, although approximately the whole area where we should expect to find them has been gone over.

McConnell,[1] who made geological investigations in Athabasca and along the Finlay and Porcupine Rivers, found Cretaceous beds resting on Devonian and Carboniferous strata. The interval of time which elapsed between the Carboniferous and the Lower Cretaceous is not represented in this region.

Spurr[2] found the same conditions to obtain for the Upper Yukon region of Alaska and the neighboring British territory. The Lower Cretaceous rests on Devonian or Carboniferous rocks. As before stated this evidence is merely negative. Jurassic rocks may have been deposited and afterwards cut away. But,

[1] Geol. Survey of Canada, Vols. V and VII.

[2] Geol. of the Yukon Gold District, U. S. Geol. Surv., Seventeenth Ann. Rept., 1897.

in that case, we should expect to find remnants of the former beds unless it be assumed that a long interval of time preceded the deposition of the Lower Cretaceous. Paleontologic and stratigraphic evidence is not in harmony with this assumption. The Lower Cretaceous beds of California which are but slightly unconformable with the Upper Jurassic, having a closely related fauna, are correlated with the Lower Cretaceous of the region under discussion.[1]

In many places in the interior region the Lower Cretaceous rests conformably on the Jurassic. This fact has been fully brought out in the preceding pages. It cannot be affirmed that the interior sea first had its connection with the Arctic and then gradually spread its waters farther and farther west until it united with the Pacific. For if this were true we should find in the interior first a fauna composed wholly of northern species, followed later by a fauna containing both Arctic and Pacific types. But no such conditions find expression in the faunal relations of the interior. Only one fauna exists in the interior.

There exists at present no evidence which will support the view held by Neumayr,[2] that the whole of Alaska and all of that portion of British America lying north of the interior Jurassic area of the United States was submerged during this epoch. All that can be asserted positively is that the Aleutian Islands and Alaskan Peninsula, in part at least, a narrow margin along the Alaskan coast and a wider area in California and Mexico was under water, while an arm of the Pacific extended in upon the continent from the region of the Queen Charlotte Islands.[3]

Lack of communication between the provinces.—The Jura of California and Nevada contains a fauna which is very different from that of the interior, although the faunas are contemporaneous. To explain the difference between the two faunas Neumayr assumed that that they belonged to two distinct climatic provinces. He assumed that the interior fauna was a Boreal fauna

[1] Spurr, l. c., p. 183.

[2] See map p. 267, copied from Erdgeschichte, p. 336.

[3] See map p. 245.

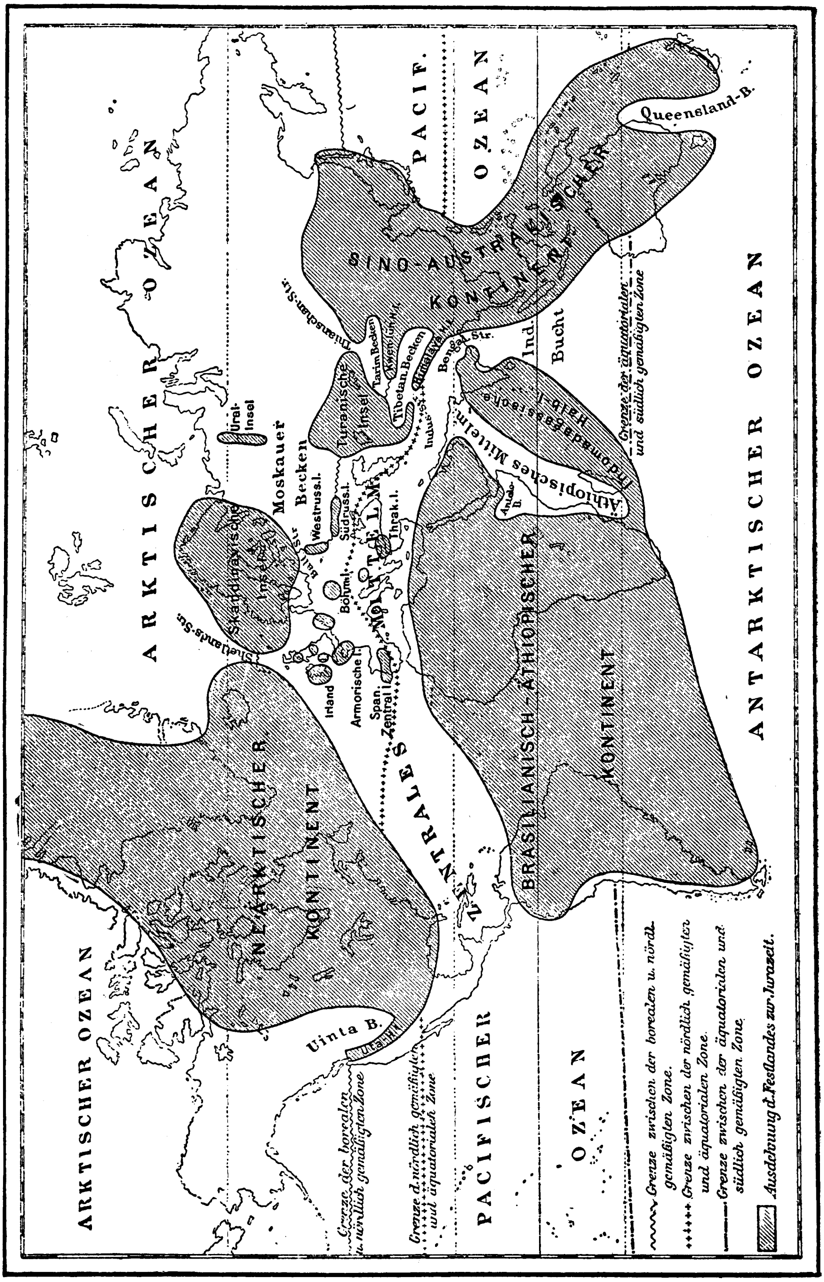
ARKTISCHER OZEAN
ARKTISCHER OZEAN
PACIF. OZEAN
SINO-AUSTRALISCHER KONTINENT
Queensland-B.
ANTARKTISCHER OZEAN
Ind. Bucht
Grenze der äquatorialen und südlich gemäßigten Zone
Indomadagassische Halb-I.
Äthiopisches Mittelm.
BRASILIANISCH-ÄTHIOPISCHER KONTINENT
Ural-Insel
Moskauer Becken
Turanische Insel
Tarim Becken
Tibetan Becken
Bengal. Str.
Skandinavische Insel
Shetlands-Str.
Westruss. I.
Südruss. I.
Thrak. I.
Irland
Armorische I.
Span. Zentral I.
NEARKTISCHER KONTINENT
Uinta B.
PACIFISCHER OZEAN
OZEAN
Grenze der borealen u. nördlich gemäßigten Zone
Grenze d. nördlich gemäßigten und äquatorialen Zone
Grenze zwischen der borealen u. nördl. gemäßigten Zone.
Grenze zwischen der nördlich gemäßigten und äquatorialen Zone.
Grenze zwischen der äquatorialen und südlich gemäßigten Zone.
Ausdehnung d. Festlandes zur Jurazeit.

FIG. 2.

which lived in an arm of the Arctic Ocean, and that the Californian fauna belonged to another climatic province, the north temperate.

In a recent discussion of the subject Ortman[1] has shown very conclusively that the faunal differences of Jurassic times, so far as the Eurasian continent is concerned, were not due to climatic zones. The distribution of the interior or Cardioceras fauna favors this view for the North American continent, The Cardioceras fauna is found distributed through a range of latitude extending from 37° to 80° north. Its southernmost extension is not as placed by Neumayr in the neighborhood of 46°, but is at least as far south as 37°, and is found in approximately the same latitude as the Californian province. Moreover, the later (for the American region) Jurassic fauna, the Aucella, has been reported from Mexico.[2] The Aucella fauna also had its origin in northern Eurasian waters. Its geographic range was from 80° north to 25° north. This means an extension of Neumayr's Boreal province to within 25° degrees of the equator! The great geographical range of this fauna indicates that there was little or no climatic restriction to its migration. In so far as the evidence can be deduced from the geographic distribution of the American Jurassic faunas the climate of the period may be said to have been more uniform than it is today.

The above facts are perhaps sufficient to show the weakness of the climatic-zone hypothesis. It now remains to suggest an alternative line of investigation. In seeking for the causes for the want of communication between the provinces it may be possible to draw some analogy from the faunal and topographic conditions as they exist today on the Pacific coast. There are at present on the Pacific coast, according to Fischer,[3] two faunal provinces, the Aleutian, corresponding in position to the Queen Charlotte of Jurassic times, and the Californian, corresponding to the Jurassic province of the same name. The line

[1] Am. Jour. Sci. Vol. I, 1896, p. 257.

[2] Nitikin, Neus Jahrb. Min. Geol. Pal., 1890, II, p. 273.

[3] Manuel Conchologie.

separating these two provinces is placed in the vicinity of Vancouver Island. The faunal interrelations of these two provinces are as follows: Of seventy-eight genera occurring in the two provinces nine are common to both ; of one hundred and four species six are common to both ; and of ten circumpolar species which have reached Vancouver Island and Puget Sound only four occur in California, and but one in Lower California. From these conditions it will be seen that communication between the two provinces is almost, if not quite, as thoroughly prohibited now as it was during Jurassic times. The question which now arises is what restricts communication between the two provinces at present? It cannot be said to be due to climate alone, for why in that case should the circumpolar species be found so far south? And why should they all be found in Puget Sound and not be found farther south? This seems to be an exception to the general rule that the climatic provinces of the present time are connected by transition zones. For the line of demarcation is moderately sharp.

Aside from the matter of climate there are two physiographic conditions which may be operative. The first of these lies in the extreme narrowness of the sumerged shelf lying to the north and west of Puget Sound. This shelf teeming with organisms already well established offers small inducement to migratory forms. And only the more hardy forms would be likely to survive the struggle for existence under such circumstances as are here postulated. Thus the change of species from one province to the other is necessarily slow.

There are good reasons for believing that throughout the Mesozoic era these topographic conditions of the Puget Sound region were much as they are at present. During the Horsetown epoch the Pacific shoreline, although it lay a considerable distance east of the present shoreline in California and Oregon, very closely approximated it in the Puget Sound area. The Chico also had a very restricted epicontinental area at that point as the Chico shoreline extended only to the eastern coast of Puget Sound. In California and Oregon, however, its eastward extension was far beyond that of the Horsetown.[1] The Jurassic beds do not occur in the Puget Sound region, and as they underlie the Horsetown elswhere, it is evident that the Jurassic shoreline at this point must have been at least as far west as the present shoreline.

A second cause for the lack of communication between the two provinces may lie in the position of the ocean currents. The Californian currents coming from the west along a line lying between the Queen Charlotte Islands and the island of Vancouver turns south at some notable distance from the coast, and after passing Vancouver bears toward the coast and flows on along the Californian province. The North Pacific current which flows east closely parallel to the Californian bears northward before reaching the Queen Charlotte Islands. Neither of these currents, since they do not cross the line separating the two provinces, is effective in establishing communication by carrying embryonic or larval forms which might under different circumstances be brought within their reach. This same distribution of ocean currents probably held during Jurassic times, as in general, the large land masses in this region, at least, had their present distribution.

The attractive feeding ground furnished by the epicontinental sea doubtless exerted its influence to prevent southern migration. When later the waters were drawn off the continent the accumulation of the great numbers of organisms on the coast may have been sufficient to force the migration southward. Or perhaps the interval of time was sufficiently long for some of these northern species to have forced their way into the Californian province during later Jurassic time. In either case we would have in the Upper Jurassic faunas of California a northern element, and this seems a well-established fact. Nevertheless, since this Upper Jurassic fauna has been reported from Mexico it is evident that communication was freer between the two provinces after the withdrawal of the waters of the epicontinental sea. And it is very likely that the movement which caused

[1] See map p. 271.

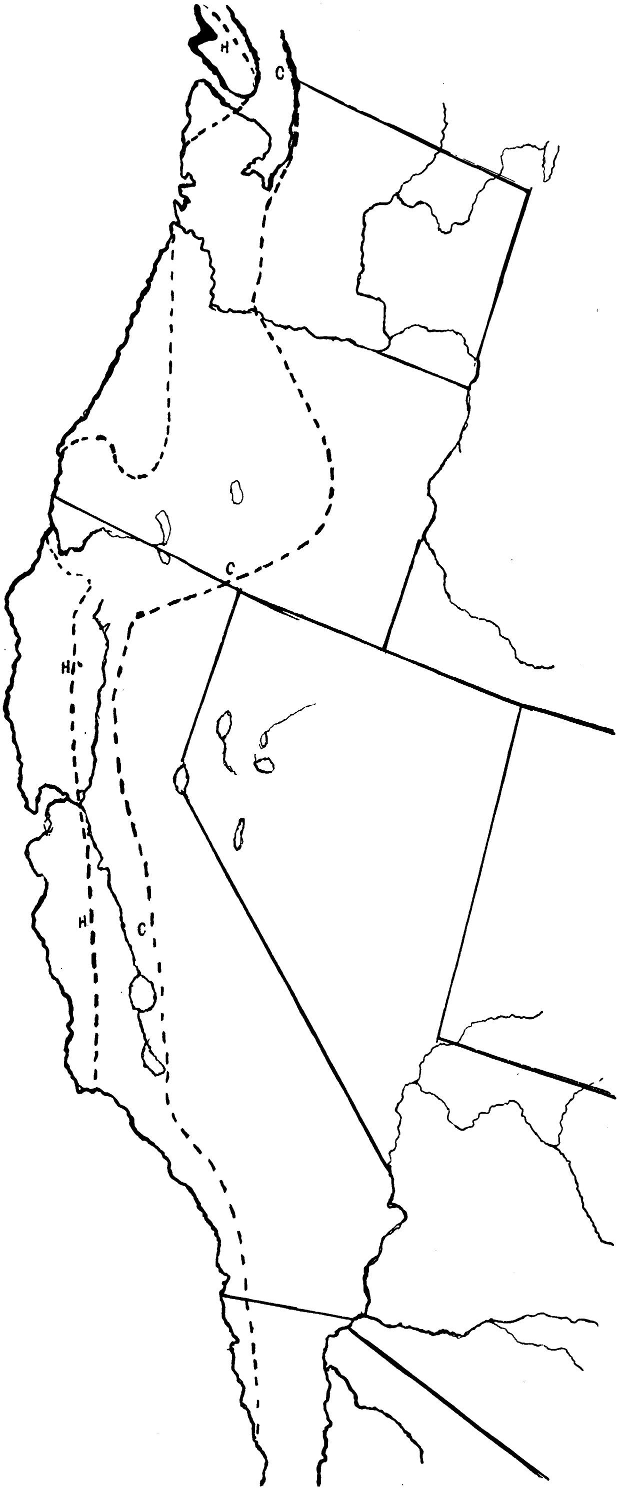

FIG. 3.—Map showing the approximate position of the Chico (C) and Horsetown (H) Shore lines (after Diller and Stanton).

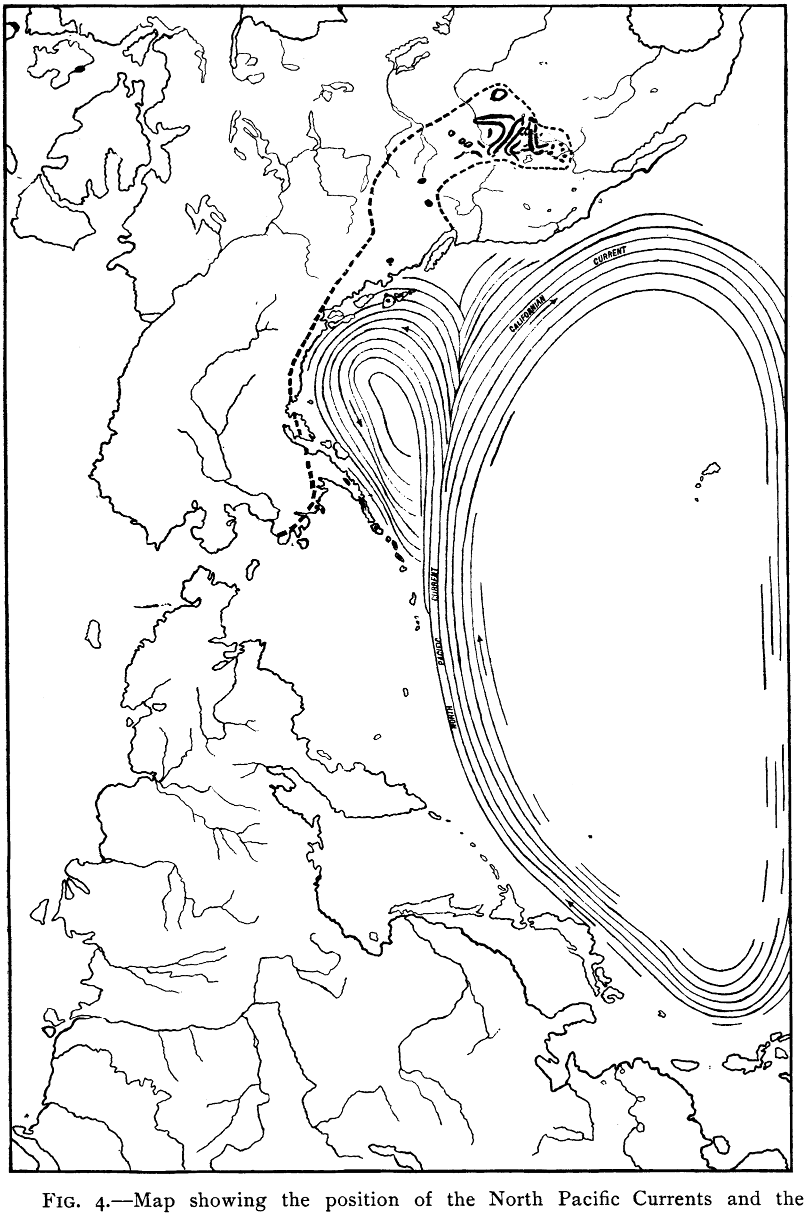

FIG. 4.—Map showing the position of the North Pacific Currents and the approximate outline of the Jurassic Sea.

the withdrawal also slightly depressed the barrier between the provinces.

Final conclusions.—It now remains to state briefly, in review, the conclusions to which the lines of investigation have led. They are as follows: 1. The Jurassic formation of the interior province of North America was not deposited in a body of water of even moderate oceanic depth, but in a shallow epicontinental sea.

2. This sea had but one connection with the ocean and that connection was with the North Pacific in the Queen Charlotte Island region; in general the outlines of the sea were as indicated on the map accompanying this article.

3. There was a connection, during this epoch, between the Arctic and Pacific by way of the Bering waters, and by this means circumpolar and Pacific faunal communication was established.

4. The Jurassic deposits of the interior contain but one fauna and if more than one period of time is represented it is not indicated by a change in the fauna.

5. The fauna of the interior is closely allied to the Cardioceras fauna of northern Eurasia.

6. Physiographic rather than climatic condition restricted communication between the Californian and interior provinces.

7. Nothing connected with the history of this Jurassic sea or its faunal relations is inimical to the view that during this epoch the North American continent had, in general, its present outline.

8. The geographic distribution of land and water, as postulated by Neumayr for this period, is not supported by the facts, in so far as the North American Jura is concerned.

W. N. Logan.