ART. XVII.—*Vestiges of an Ancient Continent in Northeast Mexico;* by EMIL BÖSE.

(Continued from page 136.)

PART II. JURASSIC STRATIGRAPHY.

The strata of the region discussed here belong to the Upper Jurassic and the Cretaceous. As we shall see, the Jurassic has two different facies: one is to a certain degree similar to the normal marine development of northern Zacatecas, so ably described in the classical works of Dr. Carl Burckhardt, while the other one is entirely unknown in our geological literature.

As we shall have to describe the transition from the normal development to the one commonly represented, it will be best to recapitulate here briefly the subdivision of the Upper Jurassic of northern Zacatecas as described by C. Burckhardt. (Compare table.)

We may consider the development just described as the normal one, although the rocks do not appear to have been deposited in a very deep sea, but certainly far from the coast.

Another locality carefully studied by Burckhardt is that of San Pedro del Gallo in Durango, much farther northwest than those cited above. The subdivision of the beds there is as given on page 197.

This generalized section is rather interesting since the Jurassic beds appear to be much more shaly than in Zacatecas; in the Portlandian, as well as in the Kimmeridgian, black shales seem to predominate. Still greater is the difference in the Oxfordian. While in the south the Oxfordian is represented almost entirely by a gray hard Nerinea limestone, we see that in the north the upper portion of this horizon is represented by a thick mass of sandstone, quartzites, shales, marls, and relatively little limestone. This may indicate that these are deposits formed nearer to the coast, but the fauna is entirely marine, consisting of a great number of ammonites. These strata represent the upper Oxfordian, since they include the zones of *Peltoceras transversarium* and *P. bimammatum.*

Below this series are sandstones and quartzites of dif-

ferent colors, grey, brown, and red predominating, accompained by gray or red-spotted shales and limestones without fossils. These are underlain by a not

TABLE I.

Subdivision		Region of Mazapil		Sierras de Symon y Ramirez (Böse and Burckhardt)
		Sierra de la Caja	Sierra de Sta. Rosa	
Lower Cretaceous	Valanginian	Marls and limestones with Astieria		Marls and limestones with Astieria
	Berriasian	Gray limestones		Gray limestones
Transition beds between Cretaceous and Jurassic		Marly and shaly white limestones with Berriasella and Steueroceras		Gray and white shales and marls and marly and shaly limestone with Berriasella and Steueroceras
Portlandian	Upper	Black limestone intercalated in white marly and shaly limestones	Gray phosphatic limestone with Kossmatia	Black limestone in white shaly and marly beds. Proniceras
	Lower	Gray phosphatic limestone with Neumayria subrasilis	Reddish phosphatic limestone with Perisphinctes and Virgatites	Gray limestone bed in gray shaly beds with Aulacosphinctes
		Reddish phosphatic limestones with Mazapilites		Calcareous lenses in reddish shales with Oppelia and Mazapilites
		Clays with fossils	Clays with Waagenia	Reddish shaly, marly, and calcareous beds with Waagenia
Kimmeridgian		Black limestone with Haploceras fialar	Black limestone with Haploceras fialar	Black limestone and reddish shales with Haploceras
			Bluish to brownish shaly limestone with Aucella aff. pallasi	
		Yellowish brownish clays, shales, and marls with globular concretions of black limestone with Idoceras	Yellowish brownish clays, shales, and marls with globular concretions of black limestone with Idoceras	Not exposed
Upper Oxfordian		Gray limestone with large Trigonia	Gray limestone with Nerinea	Gray limestone with Nerinea
? Lower Oxfordian		Gray limestone with Nerinea	Gray limestone with Nerinea	Gray limestone with Nerinea

very thick mass of compact grey limestone with intercalations of chert containing many *Nerinea* and corals and some bivalves. The limestones sometimes alternate with brown quartzites and sandy shales or limestones. The

fossils of this portion seem to be identical with those of the Nerinea limestone of Mazapil. Below these limestones are more unfossiliferous sandstones, quartzites,

TABLE II.

Subdivision		Rock Character	Principal Fossils
Lower Cretaceous	Hauterivian Valanginian	Yellowish and gray limestones and marls(60-150 m.)	Astieria cf.sayni,Polyptychites cf.bidichotomus,Neocomites cf. neocomiensis,Bochianites
	Berriasian	Bed of brownish gray to yellowish limestone	Spiticeras uhligi,S.binodum,S.cf. negreli,S.laeve,S.serpentinum, Acanthodiscus euthymiformis,A.cf. perclarus,A.aff.hospes,Neocomites group occitanicus and neocomiensis
Transition beds between Cretaceous and Jurassic		Gray and yellowish argillaceous shales (40 m.)	Berriasella cf.calisto,B.cf.obtusenudosa,Steueroceras cf.permulticostatum
		Shales with intercalations of ferrug.limestones and balls of black limestone(50-100 m.)	Phylloceras cf.beneckei,Berriasella cf.storrsi,Steueroceras koeneni, S.aff.intercostatum
Portlandian	Upper	Black argillaceous shales with balls of black limestone(200 m.)	Berriasella aff.wallichi,Hoplites köllikeri
		Black argillaceous shales with thin beds of limestone or balls of limestone (100 m.)	Aucella group mosquensis,Hoplites aff.microcanthus,Kossmatia interrupta,Berriasella,Durangites numerous spp.,Simbirskites
		Shales with concretions of limestone	Holcostephanus aff.pronus,Berriasella aff.oppeli
	Lower	Not exposed	
		Waagenia beds not exposed	
Kimmeridgian		Black argillaceous shales with ball-like concretions of black limestone,very bituminous(up to 400 m.)	Phylloceras,Sowerbyceras,Ochetoceras,Neumayria,Streblites,Aspidoceras,Nebrodites,Idoceras, Aucella group pallasi
Upper Oxfordian		Marls,marly limestones,shale, reddish and greenish sandstone with intercalation of gray and greenish limestones(200-300 m.)	Upper beds with Ochetoceras canaliculatum,O.mexicanum,O.pedroanum, Perisphinctes virgulatus Lower beds with Neumayria pichleriformis,Perisphinctes durangensis, P.cf.promiscuus,P.aff.plicatilis, P.wartaeformis,P.trichoplocoides, P.elisabethaeformis
Nerinea limestone,probably lower Oxfordian		White and reddish sandstones and quartzites,gray limestones	Nerinea and Hexacoralla

shales, and marls, of different colors, the sandstones and quartzites being mostly whitish and sometimes red-spotted, the shaly rocks being mostly red, brownish, yellowish,

and greenish. The series below the upper Oxfordian is very thick, varying from 600 to 700 m. Judging from the description given by Burckhardt, these rocks are petrographically and in color very much like the continental Triassic of Texas and New Mexico, but there is no unconformity between them and the upper Oxfordian.

Burckhardt has made another interesting observation at San Pedro del Gallo, and that is the extreme variability in thickness of the Upper Jurassic. In some places the Kimmeridgian is about 400 m. thick, but at other places and at no great distance it is reduced to a few meters. The Portlandian attains a thickness of 600 m. east of San Pedro, while west of the village it is reduced to a few meters. Immediately north of the village the whole series of Kimmeridgian and Portlandian is represented by a few thin beds of shales between the upper Oxfordian and the lower Cretaceous.

Burckhardt thinks that these phenomena cannot be explained by erosions and transgressions, and that they might be better explained through variations in deposition and marine currents.

No Jurassic localities south of northern Zacatecas have as yet been studied in detail, but there is no doubt that many new localities will be found in the Sierra Madre Oriental. Burckhardt has studied the Lias and Upper Jurassic near Huayacocotla, Vera Cruz, but his results have not yet been published. How far the uninterrupted series of Upper Jurassic and Neocomian extends to the south is still a problem, but there is no doubt that it is present in a great part of central Mexico. Isolated Jurassic localities are known at many places, as may be seen in the list given by Burckhardt in his "Neue Untersuchungen über Jura und Kreide in Mexiko."[7] Here he cites Kimmeridgian ammonites as far south as the Isthmus of Tehuantepec.

Region East of Saltillo, Coahuila.—We now turn to a discussion of the stratigraphic conditions in the region which concerns this paper especially, that is, the mountains east of Saltillo and south of Monterrey, a country composed of high and steep ranges and deep and often narrow canyons, although in the southern portion there are wide and long flat valleys. We begin in the southern

[7] Centralbl. f. Min. Geol. u. Pal., Jahrg. 1910.

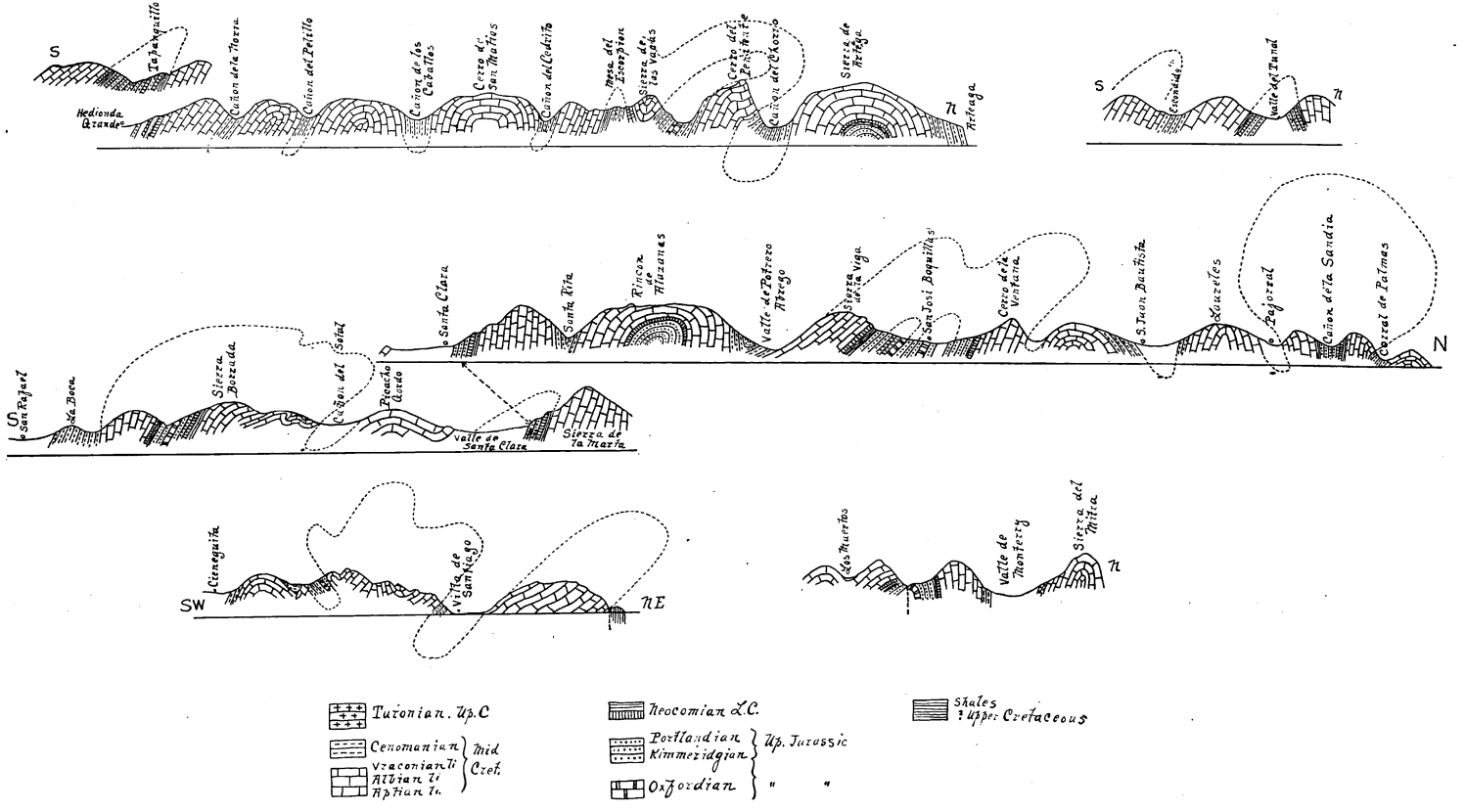

FIG. 2.—Cross-sections through the mountains between the valley of Hedionda Grande, Coahuila, and Monterrey, Nuevo Leon.

part of this area, since here we still find conditions similar to those of northern Zacatecas. The Upper Jurassic is well exposed in the Sierra Borrada, the geological continuation of the Cerro de Potosí, and in the Sierra de la Marta and Sierra de las Pintas, north of the aforesaid range. The localities in the Sierra Borrada belong to the Hacienda de San Rafael, those of the other two to the Hacienda de Ciénega del Toro.

We shall first discuss the conditions of the Sierra Borrada. The Jurassic occurs in the valley which descends from San Pablo and Tanquesitos to La Boca. The core of the anticline is strongly overturned toward the north and shows the succession of the rocks very well. The base is apparently a gray to light colored thick to medium bedded limestone. Above these limestones there are at least 100 m. of whitish argillaceous shales which frequently contain undeterminable bivalves; in their upper portion we find cannonball-like concretions of black limestone that often have *Idoceras* and some *Aucella*. Here Dr. Burckhardt determined the following species: *Idoceras complanatum* Burckh., *I.* aff. *complanatum* Burckh., *I.* aff. *zacatecanum* Burckh., I. sp. nov. (involute and with fine ribs).

These rocks which represent the Kimmeridgian are well exposed and fossiliferous in the Barrancas of Agua de Enmedio and Agua de los Galemos, as well as in the ridge between the two; also in the Agua de la Barranca. Above these strata with concretions follow about 250 m. of dark shales with zones of limestone and gray sandstones weathering brownish which contain oysters (*Gryphæa*); above these sandy beds occurs a gray greenish quartzitic sandstone about 10 m. thick, followed by dark calcareous shales with thin beds of black limestone. Still higher are thinly laminated limestones and argillaceous shales with some beds of black sandy limestones. This latter portion apparently represents the Portlandian, but I have not been able to find determinable fossils; later on we shall see that the corresponding beds of the Sierra de la Marta contain numerous Kossmatia, thus proving our supposition. That the strata above this series certainly belong to the Lower Cretaceous (Valangian) is shown by the occurrence of *Thurmannia*.

This facies extends probably far to the west. In the Sierra de Huachichil, which divides the Hacienda La Hedionda from Hacienda Huachichil, only the Lower Cretaceous is well exposed and it is rather fossiliferous, while the Upper Jurassic is covered by débris. Only the above described sandstones with *Gryphæa* are well exposed near the south foot of the pass which from Hedionda leads to Huachichil, and in the valley which leads from Hedionda to the Mesa de Tapanquillo, as well as at this last locality itself.

Very little different are the conditions in the Sierra de la Marta, where Kimmeridgian and Portlandian are well exposed. Cross-sections can be seen all along the southern foot of this range from the ranch Sta. Clara to San José and the Puerto de la Marta. The lower portion generally is not very well exposed but near the buildings of Sta. Clara occur dark gray marls, argillaceous shales with beds of limestone and cannonball-like concretions of black limestone; these frequently contain *Idoceras, Haploceras,* and a *Pseudomonotis* which occurs nearly everywhere in Mexico in this horizon. Above these Kimmeridgian beds again appear black calcareous shales at least a hundred meters thick; then follow gray and greenish calcareous sandstones and some sandy limestone containing large oysters (probably a large *Exogyra*). These beds are covered by shales partly similar to those below the sandstone, but containing at their base numerous ammonites belonging mostly to *Kossmatia* and thus representing the upper Portlandian (the best locality found is in the Arroyo de la Vibora with *Kossmatia victoris* Burckh.). Above these shales recur gray limestones with few and badly preserved ammonites (*Berriasella?*), that may represent the Transition series between the Jurassic and the Cretaceous, but I have not found well determined fossils. Then follows about 10 m. of gray shales alternating with thin beds of limestone, that frequently have *Thurmannia* and *Astieria,* thus proving that here begins the Valangian horizon of the Lower Cretaceous; the Berriasian may possibly be represented by part of the underlying limestones.

Farther east along the same anticline, and in the deep valley south of the Sierra de las Pintas, which is the

geological continuation of the Sierra de la Marta, we find that the lowest portion of the Upper Jurassic contains thick beds of white gypsum in gray brownish shales, above which follow the cannonball-like concretions with Kimmeridge ammonites (*Idoceras* and *Haploceras*) and containing coal or at least very carbonaceous beds. The whole series here seems to be more shaly, while the calcareous sandstones above the Kimmeridgian and below the upper Portlandian appear to be replaced locally by reddish quartzitic sandstone, having sandy ball-like concretions of about 5 cm. diameter.

Comparing this Upper Jurassic series with that of northern Zacatecas we find that it contains, below the upper Portland, a rather constant sandstone or sandy limestone member which therefore probably represents at least part of the lower Portlandian; a petrographically similar member is absent in the Zacatecas series. In the lower Kimmeridgian occur thick beds of gypsum and some coal beds, both also unknown in the Zacatecas series. Gypsum beds also occur near Sta. Clara (Sierra de la Marta) but the rocks between them and the beds with cannonball-like concretions are covered. Coal has not been found in this place, but according to a verbal communication of Dr. C. Burckhardt, coal also occurs in the Upper Jurassic much farther southeast at Aramberri, Nuero Leon.

All this indicates that our Upper Jurassic is deposited much nearer to a coast than the Zacatecas series and that the land must be sought toward the north and perhaps the northwest. This conclusion is corroborated by the development of the Jurassic a very little farther north and west. Not more than 20 km. north of the Sierra de la Marta occurs the deep valley of San José de Boquillas, limited on the south by the high Sierra de la Viga and on the north by the Sierra de la Ventana. This is the place where I first found the Upper Jurassic of these mountains.

The base here consists of a gray, not very perfectly bedded limestone with some flint concretions, very rarely a long *Nerinea,* and some badly preserved corals (exposed at the ranch buildings). Above this limestone, which certainly corresponds to the Nerinea limestone of Burck-

hardt, occur dark shales with ball-like and elongated concretions of black limestone containing numerous ammonites (*Idoceras*); the Haploceras beds, which are a little higher in the series, are also full of well preserved ammonites. They contain, according to Burckhardt: *? Craspedites* sp., *Idoceras* sp., *I.* of the group of *I. durangense* Burkh. (2 forms, *I.* aff. *balderum* Loriol (non Oppel), *Ochetoceras neohispanicum* Burckh.

Higher occur gray shales with fossils and on top of them dark, thin-bedded, shaly arenaceous limestones alternating with dark sandy shales. This series is twice folded but relatively well exposed in a stream bed which descends from the Sierra de la Viga to San José. Above the shales and limestones is a thick and medium bedded red and yellow quartzitic sandstone of at least 300 m. depth, in the middle of which occurs a conglomerate containing large pebbles and large *Exogyra*-like oysters, apparently of the same type as those found in the Sierra de la Marta. The sandstone is covered by thin-bedded limestones alternating with shales which probably belong to the Cretaceous but are badly exposed and do not show any determinable fossils. The same series can be followed east to the Laguna de Sanchez, the Oxfordian always forming the core of the anticline and ever again appearing in the valley. The anticline is strongly overturned toward the north.

Following the series toward the west, the red sandstone and conglomerates continue up to the valley of El Tunal, but here only the conglomerates with *Exogyra*-like oysters and the red sandstone above are exposed. In the upper portion of the sandstones occurs at least 50 m. of badly exposed gray sandy shales, overlain by gray sandstones with oysters. These are followed by thin-bedded limestone and shales apparently belonging to the Cretaceous. Further toward the west the lower beds are covered by Cretaceous limestones and these only are exposed in the high mountain between the Tunal and the canyon of Boca de Arteaga. In this latter cut the beds are again well exposed and the whole anticline shows the cross-section wonderfully clearly from the Middle Cretaceous limestones down to the Upper Jurassic. The section is as follows:

		m.
Gray laminated limestone and gray shales representing the lowest Cretaceous.		
1.	Brown quartzitic sandstone (2 m. is very coarse-grained)	18
2.	Dark sandy shales	2
3.	Hard yellow-brown quartzitic sandstone	12
4.	Black sandy shale alternating with thin-bedded yellow sandstone	1
5.	Yellow medium-bedded quartzitic sandstone	15
6.	Dark gray sandy limestone	0.5
7.	Gray laminated sandy limestone	4
8.	Series of yellow quartzitic and gray calcareous sandstone, partly very coarse-grained	21
9.	Fine-grained yellow sandstone	3
10.	Gray sandy shales weathering yellowish	0.5
11.	Gray to yellow calcareous sandstone	3
12.	Covered	4
13.	Hard medium-bedded gray calcareous sandstone	3
14.	Light to white soft sandstone	2.5
15.	Thick-bedded, almost massive, gray coarse-grained quartzitic sandstone	3
16.	White very coarse-grained quartzitic sandstone with large pebbles, almost massive	2
17.	Light coarse-grained sandstones and conglomerates with pebbles up to 10 cm. diameter, heavy-bedded	30
18.	Blue well-bedded calcareous sandstone with numerous but imperfectly preserved plants, weathering white	18
19.	Yellow quartzitic sandstone, well-bedded	5.5
20.	Blue calcareous sandstones weathering whitish, with numerous remains of plants	13
21.	Yellow brown quartzitic sandstone	3
22.	Calcareous sandstone like No. 20	2
23.	Light calcareous sandstone with plants	6
24.	Black-blue calcareous sandstone	5
25.	Brown calcareous sandstone	2
26.	Covered	6
27.	Greenish coarse-grained quartzitic sandstone with large quartz pebbles, thin-bedded	2
28.	Shaly brown sandstone	1
29.	Brown quartzitic sandstone, thick-bedded	1
30.	Dark sandy shale	0.25
31.	Light coarse-grained quartzitic sandstone	1.5
32.	Brown argillaceous shaly sandstone	0.5
33.	Light fine-grained quartzitic sandstone	3.5

34.	Brownish fine-grained quartzitic sandstone and bluish calcareous sandstone, imperfectly bedded .	23
35.	Black to olive colored sandstone	1
36.	Dark blue thin-bedded calcareous sandstone, weathering brown to olive colored	12
37.	Dark gray to greenish sandy shales and soft sandstones	17
38.	Gray blue calcareous sandstone	8
39.	Covered	21
40.	Light gray quartzitic very coarse-grained sandstone, partly conglomerate, thick-bedded	7
41.	Shaly, sandy, and thin-bedded fine-grained sandstone of dark greenish color	2
42.	Brown coarse-grained sandstone with regular intercalations of dark gray sandy shales	20
43.	Dark sandy shales alternating with very thin-bedded gray coarse-grained sandstone	7
44.	Dark gray to olive fine-grained sandstone	4
45.	Coarse conglomerate (mostly quartz)	0.3
46.	Blue calcareous sandstone with plants	0.75
47.	Gray sandy shale	0.25
48.	Fine-grained gray sandstone	1
49.	Gray coarse-grained sandstone	0.3
50.	Blue calcareous sandstone	3
51.	Gray brown fine-grained sandstone with plants	3
52.	Black sandy shales	8
53.	Light gray-green thick-bedded sandstone	3.5
54.	Dark gray-green thin-bedded sandstone	2
55.	Gray coarse conglomerate	0.5
56.	Dark sandy shales with sandy concretions and intercalated thin-bedded sandstone	5
57.	Dark calcareous and brown quartzitic sandstone, thick-bedded	3
58.	Dark sandy shale	0.20
59.	Gray-green fine-grained quartzitic sandstone	2
60.	Dark brown sandy shale	4
61.	Black sandy shales	7
62.	Coarse quartz conglomerate	0.5
63.	Gray-blue calcareous and quartzitic sandstones	4
64.	Covered	10
65.	Gray-yellowish fine-grained quartzitic sandstone in thick beds and very hard (base not exposed) more than	3
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This section represents only a part of the Portlandian, the Kimmeridgian not being exposed. It is given as an example of the development between Saltillo and Monter-

rey, but of course the sandstones and shales change in every section in color and thickness. For example, the 50 m. of shales of the Tunal are entirely missing in this section.

Following the anticline of the Sierra de la Marta toward the west, the Jurassic is again found well exposed in the Hacienda de las Vacas, a little south from the section described above. The base is formed by a gray limestone, apparently without fossils. Above this follow black argillaceous shales that in the upper portion have cannonball-like concretions of black limestone. These represent the Kimmeridgian. Higher occur thick-bedded coarse sandstones containing *Gryphæa* and alternating with dark sandy shales; then follows a mass of about 50 to 100 m. of gray sandy shales with thin beds of sandstone; these are succeeded by thick-bedded coarse calcareous sandstone with large pebbles and containing large *Exogyra*-like oysters. Then follow red and yellow quartzitic sandstones alternating with gray sandy shales. These are succeeded by calcareous shales with thin beds of limestone, mostly sandy; sandstone of brownish color; about 20 m. of gray shale, weathering brownish; thin-bedded limestone alternating with light gray shales; and finally, a medium-bedded somewhat siliceous limestone. These latter conditions are well exposed in the so called Mesa del Escorpion. The thin-bedded limestone, as well as the medium-bedded one, contains rare specimens of *Astieria* cfr. *astieri* d' Orb. and other species of *Astieria,* as well as *Neocomites* cfr. *neocomiensis.*[8] This find is of the greatest importance; since for the first time it determines the exact age of the sandstones above the Kimmeridgian. It proves that the sandstone represents the Portlandian and the Transition beds, while the shales above are probably the Berriasian, and the Valangian is still represented by an entirely marine facies. I had previously found a very few specimens of badly preserved ammonites that seemed to belong to *Astieria* in thin-bedded limestone above some gray shales which separate the limestone from the sandstone below (in the valley south of the canyon of Santa Catarina near Monterrey, a section which will be dis-

[8] I wish to express my warmest thanks to Messrs. Ricardo Dávila, Eduard Suess and Carlos Suess who helped to collect the few but important fossils of these beds. Mr. Carlos Suess found the first determinable *Astieria* cfr. *astieri* immediately above the shales.

cussed farther on), but the fossils were too badly preserved for final conclusions. At the Mesa del Escorpion, however, there is no doubt about the character of the fossils and the age of the rocks.

We have seen that toward the west the Portlandian is developed in a facies which belongs to a coastal region, but where shales with thin-bedded limestone still form an important member of the higher beds. We have also seen that very little farther north, at San José de Boquillas and in the Cañon de Arteaga, sandstone and conglomerate in the Jurassic above the Kimmeridgian and that the facies thus indicates the vicinity of the coast.

We shall now discuss another locality still farther north; this is the valley just south of the beautiful canyon of Sta. Catarina, at a distance of about 15 km. from Monterrey. Parenthetically I may remark that there is another exposure of Upper Jurassic in the Cañon de la Sandia near Pajonal, a region about halfway between the Cañon de Sta. Cartarina and San José de Boquillas. Here is a broad anticline eroded in the middle, the center of which consists of gray argillaceous shales with thin beds of limestone containing rare and badly preserved *Perisphinctes;* above the limestones occur a red coarse quartzitic sandstone, red, yellow, and gray shales, and above these the shales and limestones of the Lower Cretaceous. I have not yet been able to study this section. The section on the whole resembles that of San José de Boquillas; the exposures are very good and should be studied in detail.

The locality south of the Cañon de Sta. Catarina is also a wide anticline eroded to the core. The best exposure is on the north side of the valley. The base of the Jurassic is represented by the Oxford (Nerinea) limestone, entirely similar to that of San José de Boquillas and of Zacatecas. Above it occur gray shales which a little higher contain the well known cannonball-like concretions; in these we collected a number of ammonites, especially *Haploceras;*[9] Dr. Burckhardt determined the following species from this locality: *Haploceras fialar* Oppel, *H. transatlanticum* Burck., *H.* sp. ind. div., *Halobia*-like bivalve. The age of these beds is evidently upper Kimmeridgian.

[9] This excursion I made with Prof. Dr. L. Rutten, now of the University of Utrecht, Holland.

Still higher occur shales with thin beds of limestone; in one of the loose blocks I noted numerous *Aucella.* These shales are at least 100 m. thick, but they are very much folded and that perhaps makes them appear thicker than they really are. Above the shales follows red and yellow fine and coarse-grained sandstone, becoming more conglomeratic in the upper portion and containing near the middle beds of the *Exogyra*-like oysters. The sandstone is very well exposed also on the south side of the valley in the hill with the large cross. Here the sandstone is covered by gray yellowish or whitish-weathering shales, about 50 m. thick, on which lie thin-bedded limestones alternating with gray shales. In these limestones I found two impressions of ammonites which certainly belong to *Astieria,* but were not quite determinable.

This seems to be the northernmost Jurassic locality in northeast Mexico, with perhaps the single exception of the red sandstone and conglomerates in the Sierra de San Marcos south of Cuatro Ciénegas, which has been discussed in Part I of this paper.

Cretaceous Stratigraphy.

The Cretaceous beds so far observed in the region south of Monterrey and east of Saltillo belong to the Lower , the Middle and, rarely, to the Upper Cretaceous. There is no decided change of facies to be observed in these rocks, but they seem to be more or less uniform in the whole region, that in some places they are more calcareous than in others.

Lower Cretaceous.

Neocomian.—The base of the Cretaceous could not be determined with certainty, as no fossils indicating the existence of the Berriasian have been found. This horizon, which up to the present could be proven to exist in very few places in Mexico, is probably represented either by the lowest limestone beds above the Portlandian or by the shales which separate the Jurassic sandstone from the Valangian limestone.

Much better represented is the Valangian. It is quite rich in fossils, especially: *Astieria* cfr. *astieri* d'Orb., *Astieria* cfr. *symonensis* Böse Ms., *Astieria* cfr. *bangei* Böse Ms., *Thurmannia* cfr. *thurmanni* Pict. et Camp.,

Hoplites aff. *michaelis* Uhlig, *Neocomites neocomiensis* d'Orb., *Kilianella cfr. lucensis* Sayn, *Bochianites* sp., *Belemnites* sp.

In one locality I found a few specimens which reminded me of certain *Leopoldia,* and thus may represent typical Hauterivian, but this material has not as yet been studied.

The Valangian consists always of gray, yellowish-weathering shales alternating with beds of gray somewhat siliceous limestone, gray laminated limestones, and thin to medium-bedded gray limestones with intercalations of thin zones of gray shales. There is no rule as to the succession of these beds, as this varies in the different localities. In the Sierra de la Marta the succession is generally as follows: the base is formed by shales alternating with thin and medium-bedded limestone; above these follow gray thin to medium-bedded limestones, then gray, yellowish-weathering shales with few limestone beds.

In the Sierra de Huachichil the base is a medium-bedded limestone with thin beds of shale carrying principally *Hoplites* of different groups; then follows a zone of gray shales with thicker and thin beds of limestone; this zone contains mainly *Astieria.* The shales often hold numerous but badly preserved ammonites converted into limonite, which evidently was formed by the weathering of the original pyrite.

In the Sierra of the Hacienda de las Vacas the base is formed by thin-bedded limestones interbedded with gray shales, the higher portion being of medium to heavy bedded gray limestone.

In the valley south of the Cañon de Sta. Catarina the base is mostly gray, yellowish-weathering shale with some limestone beds; above follow gray shales interbedded with thin-bedded to laminated light gray limestones, and a little higher, medium-bedded gray limestone.

The locality richest in fossils is near Agua del Pocito in the cañon south of the Sierra de las Pintas and not very far from the former ranch of Guaponal (Hacienda de Ciénega del Toro). Here the ammonites form whole beds and are easily extracted from the matrix. The next best locality is that of Sierra de Huachichil at the southern foot of this mountain range between the Puerto de Huachichil and the Mesa del Tapanquillo. Here we find

the *Hoplites* forms predominating in the limestones, while *Astieria* species are more frequent in the higher shales.

In the Sierra Borrada (Hacienda de San Rafael) the base is more calcareous and shows few fossils (*Thurmannia, Hoplites*), while the shales above are not very thick but very rich in entirely compressed *Astieria.*

In the northern localities (Hacienda de las Vacas, Valley south of the Cañon de Sta. Catarina, etc.) the ammonites are rather scarce but sufficient to prove the age of the rocks.

The upper Neocomian, that is, Hauterivian and Barremian, is not represented by fossil-bearing rocks. In the Sierra de Huachichil, where the Lower Cretaceous is very well exposed, we find above the Valangian at least 300 m. of gray limestones with some intercalations of shales, and above these thin-bedded limestones alternating with lenses of dark chert, and finally thin-bedded limestones alternating with gray shales which evidently represent the higher beds of the Aptian. The upper Neocomian therefore appears to be represented by these rocks, but up to the present no characteristic fossils have been found. The rocks are similar to those which in Zacatecas and Durango (Symon) contain Hauterivian and Barremian ammonites, which I have cited in another publication.[10] These faunas as well as that of the Valangian of Symon I described and figured more than ten years ago, but the manuscript is only now being printed by the Instituto Geológico de México.

Aptian.—The main zone of the Aptian is probably represented by beds with *Monopleura* and *Requienia* that sometimes are found several hundred meters below the Caprina limestone but are not always fossiliferous. In many places we find at the base of the Middle Cretaceous limestones a zone of thin-bedded limestones alternating with very dark but light gray and reddish-weathering shales. Only at one place have I been able to find fossils in these rocks, and that is in the Cañon de Vallas of the Hacienda del Saucillo, some 10 km. northeast of Saltillo. In a zone only about 30 m. thick I found here very fossiliferous beds; they contain mainly ammonites: *Douvilleiceras, Dufrenoya* (aff. *texana?*), *Parahoplites* aff. *crassicostatus* d'Orb., and others, some echinoids probably

[10] Böse, Neue Beitr. z. Kenntn. d. mexikanischen Kreide, p. 620 ff.

belonging to *Enallaster* or *Toxaster*, and also a brachiopod, *Terebratula*. The fauna is evidently the same as the one found by C. Burckhardt[11] in the Rio Nazas valley of Durango. The beds are certainly of the same age and represent the Gargasian horizon of the upper Aptian.

Middle Cretaceous.

Albian.—This horizon is generally represented by hard, thick-bedded gray limestone with numerous nodules and even lenses of black chert. It has a thickness of about 1000 m. and often shows thin beds of gray shales, especially in the upper portion. About 100 m. below the top there occurs regularly a zone some 10 m. wide, of thin-bedded limestone alternating with gray shale and lenses of black chert; about 30 m. higher there is a similar but narrower zone. The thick-bedded limestone often contains numerous Carprinæ and Rudistæ, but in other cases it shows no fossils at all. In the northern part of the region especially between the Cerro de la Silla near Monterrey and Villa de Santiago, as well as still farther north in the Sierra de Lampazos, this limestone becomes darker and often contains *Hoplites* with long strong spines similar to the groups characteristic for the Albian.

The Albian limestone makes up practically all the high mountain ranges east of Saltillo and south of Monterrey. Since in most cases the beds are either vertical or overturned, it causes the formation of long sharp crests, and forms rounded masses of mountains with very steep flanks only where the anticlines are not deeply eroded.

Vraconian.—On top of the Caprina limestone we find almost always a series of thin-bedded limestone with long lenses of black chert from 5 to 20 cm. thick and thin layers of gray shale. These rocks are nearly secondarily folded in sharp knee folds or zigzag folds, their thickness being not more than about 100 m. The beds are extremely characteristic petrographically and can scarcely be confounded with others. They nearly everywhere carry numerous small fossils converted into chert,

[11] C. Burckhardt, Estudio geol. de los alrededores del Rio Nazas. Parerg. d. Inst. Geol. de México, vol. III, No. 2, 1909.
C. Burckhardt, Neue Untersuchungen über Jura u. Kreide i. Mexiko, p. 663 ff.

mainly *Inflaticeras* aff. *inflatum* Sow., *Turrilites* cfr. *scheuchzeri* Bosc, *T.* cfr. *costatus* Sow., and especially numerous *Crioceras, Toxoceras, Hamites, Hamulina,* and other genera with open spirals. This fauna[12] is very characteristic and has been found in many places. The horizon is well developed on the road from Villa de Santiago to Cieneguita (near this latter place), at Guaponal (Ciénega del Toro), at Arteaga near Saltillo, on the ranch Jaguey near Agua Nueva (Cañon de los Pelillos), and many other places.

Cenomanian.—This horizon consists mainly of gray, yellowish-weathering shales alternating with thin-bedded limestones, but often shows near the base a reddish or yellowish fine-grained and somewhat argillaceous sandstone. The thickness of the beds could not be determined, as they are strongly folded, but probably it is not less than some 300 m. The upper limit is not very sharp, but passes apparently into the Turonian, which horizon can be distinguished from it only through the fossils. The Cenomanian does not seem to carry any determinable fossils in this region, but the age can be well established because the underlying beds as well as the overlying ones contain characteristic faunas.

The Cenomanian exists practically in every syncline of the region here described; it is very well exposed near Arteaga, in the Cañon del Chorro (between Arteaga and the Hacienda de las Vacas), also in most of the canyons between the Sierra de Huachichil and that of Las Vacas; in the valley that leads from Cienega del Toro to Guaponal, in the valley of San Juan Bautista-Cieneguita, and at other places.

Upper Cretaceous.

Not much Upper Cretaceous seems to be present in the mountains here described; I have not seen anything younger than the Turonian and even this could be distinguished only at two places. This is rather astonishing, as Upper Cretaceous of an enormous thickness is well developed west of Saltillo, where it composes all the mountains and valleys.

[12] Compare E. Böse, Neue Beitr. z. Kenntn. d. Mexikanischen Kreide, p. 622. This large fauna with about 40 species was described by me some 10 years ago but is only now being printed by the Instituto Geologico de México.

Turonian.—This horizon is composed of thin-bedded dark limestone alternating with black shales and thinly laminated gray and black limestone. The only places in the mountains where I could distinguish it are the hills near San Juan Bautista southwest of Laguna de Sanchez and the Mesa de Tablas between Potrero de Abrego and Santa Rita. In these localities I occasionally found specimens of *Inoceramus labiatus.* West of the mountains, in the valley of Saltillo-Ramos Arizpe, the Turonian exists at the foot of the mountains, where it is about 300 to 400 m. thick and contains numerous specimens of *Inoceramus labiatus* Schloth. as well as some of the group of *Inoceramus hercynicus* Petr. It is well exposed in the deep artificial cuts near the upper ranch of Hacienda del Saucillo, about 10 km. northeast of Saltillo.

It is of course possible that the base of this horizon may be found also in the wide synclines of the mountains as perhaps in the valley and hills of Guaponal (Ciénega del Toro), but as the fossils there seem to be rather scarce, I have not been able to distinguish the beds and have treated them together with the Cenomanian.

Emscherian and *Senonian.*—These horizons have not yet been found in the mountains, but are well developed in the synclinal basin between Saltillo-Paredon-Torreon-Parras. The base always consists of about 300 m. of dark shale, often weathering gray to olive and containing thin beds of limestone. This mass represents the Emscherian and the Santonian, and fossils from it (*Inoceramus* cfr. *barabini, Exogyra ponderosa,* etc.) have been described by me in Boletin No. 30 of the Instituto Geológico de México.

Above this series we find alternating sandy shales, sandy limestones, and quartzitic sandstones, mostly of red and greenish colors, and often containing *Exogyra costata* Say. But as these horizons are of little importance for our present purpose, we need not enter into a detailed description of them. In the mountainous region here described, they have not been discovered and do not seem to exist, but they will be mentioned when we discuss the zone of disturbance between Saltillo and Monterrey.

(To be continued.)