

# THE BIOLOGIC CHARACTER AND GEOLOGIC CORRELATION OF THE SEDIMENTARY FORMATIONS OF PANAMA IN THEIR RELATION TO THE GEOLOGIC HISTORY OF CENTRAL AMERICA AND THE WEST INDIES.

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## INTRODUCTION.

The following paper presents: (1) biologic summaries for each of the formations for which paleontologic data are available, with brief discussions of the geologic age; (2) geologic correlation of the formations and the distribution of their age-equivalents in Central America, the West Indies, and the southeastern United States; (3) an outline of the paleogeography of middle America. A tabular statement of the age relations of the formations is given by Doctor MacDonald in the preceding paper of this volume, page 528.

The biologic summaries are based on the paleontologic memoirs in this volume, by Messrs. Howe, Berry, Cushman, Jackson, Canu and Bassler, and Pilsbry, Miss Rathbun, and myself. Dr. C. W. Cooke has furnished me notes on a few of the fossil Mollusca, and I have incorporated in my lists the molluscan species recorded by Messrs. A. P. Brown and H. A. Pilsbry. I deeply regret that not even a preliminary list of the mollusks that Doctor MacDonald and I collected is available. Although I believe such a list would not modify the opinions here expressed, it is needed as a supplement to the other biologic records, particularly in order to supply a basis for the correlation of deposits in which mollusks are the only abundant organisms. I trust this serious omission may be remedied before a great while.

Needless to say all of the paleontologists who have studied the fossils submitted to them have cooperated in trying to solve the problems of local and regional geologic correlation, and I wish to record my grateful appreciation of their efforts. I wish also to thank my friend, Dr. T. W. Stanton, of the United States Geological Survey, for much advice and kindly criticism.

## BIOLOGIC CHARACTER OF THE SEDIMENTARY FORMATIONS IN PANAMA.

### EOCENE.

The only geologic formation of Eocene age definitely recognized in Panama is exposed near Tonosi, Los Santos Province. At station

No. 6586c, near the mouth of Tonosi River, Doctor MacDonald collected a species of *Venericardia*, on which Dr. C. W. Cooke makes the following note: "A species of *Venericardia* from this locality is scarcely distinguishable from a specimen labeled *Venericardia planicosta* var. *horni* from Caliborne, Alabama, but it does not closely resemble specimens that I have seen from the Eocene of California, Washington, and Oregon." According to Doctor MacDonald's description of the section, this species of *Venericardia* occurs 690 feet below the bed in which *Lepidocyclina panamensis* Cushman and *L. duplicata* Cushman were collected. I believe that the latter bed is the correlative of the lower part of the Culebra formation, as will later be shown. Just below the Oligocene limestone in which occur the two species of Foraminifera mentioned are 650 feet of grayish, well-bedded, rather fine-grained sandstone; this is underlain by dark-gray, argillaceous, fossiliferous sandstone and shale, the latter underlain by dark-gray, argillaceous sandstone, in which the specimens of *Venericardia* were collected.

Doctor MacDonald collected the plant *Diospyros macdonaldi* Berry at station 6586b, in grayish, argillaceous sandstone with some darker shale beds, which immediately underlies the material in which the species of *Venericardia* occurs.

Dr. R. T. Jackson identifies as *Schizaster armiger* W. B. Clark, an echinoid collected by Mr. R. T. Hill at Bonilla, Costa Rica. The type of this species was obtained in a deposit of Jackson Eocene age at Cocoa post office, Choctaw County, Alabama. It should be noted that Mr. Hill says: "They [the rocks exposed] at Bonilla Cliff [Costa Rica] are upper Oligocene, like the Monkey Hill beds."<sup>1</sup> The determination of the Eocene age of this exposure is not positive.

On page 197 of this volume, in my paper on the fossil corals, I gave reasons for referring the typical part of the Brito formation of Nicaragua, that part exposed near Brito, to the upper Eocene, and correlated that part of the formation with the St. Bartholomew limestone of the Island of St. Bartholomew and the Jacksonian upper Eocene of the southeastern United States. The data and opinions referred to need not be repeated. The presence in northern Colombia of limestone containing small stellate *Orthophragmina*, indicating a probable upper Eocene, was also noted on page 197.

No fossil organisms were found in the Las Cascadas agglomerate or the Bas Obispo formation. As they both underlie the Bohio conglomerate, which is of Oligocene, probably lower Oligocene age, they are almost certainly of pre-Oligocene age. Although at present information is not available for precisely determining their age, it appears highly probable that they belong to the Eocene. However,

<sup>1</sup> Hill, R. T., The geological history of the Isthmus of Panama and portions of Costa Rica: Mus. Comp. Zool. Bull., vol. 23, p. 232, 1893.

Upper Cretaceous is not improbable as the age of the Bas Obispo formation.

## OLIGOCENE.

## BOHIO CONGLOMERATE.

This is the oldest formation in which fossil organisms were found within the Canal Zone. The fossil plant, *Taenioxylon multiradiatum* Felix, collected in a railroad cut on Bohio Ridge, is said by Doctor MacDonald to come from the Bohio conglomerate. Should the specimens really come from the Bohio conglomerate, it is probable that that formation is of Oligocene age. *Taenioxylon multiradiatum*, according to Professor Berry, is also found in the Culebra and Cucuracha formations, both of which are of Oligocene age, should the Aquitanian be considered uppermost Oligocene instead of basal Miocene.

## LIMESTONE ON HAUT CHAGRES.

H. Douvillé has published the following interesting note: "Un autre échantillon du Haut Chagres est représentées par un calcaire plus compacte prenant bien le poli; il renferme également de petites Nummulites et de grandes Lépidocyclines voisines de *L. chaperi*, mais en outre, de petites Orbitoïdes qui sont des *Orthophragmina* étoilées (*Asterodiscus*). C'est la même association que celle que nous avons signalée à la base du stampien [= Lattorfian], dans l'île de la Trinité. . . Nous avons ainsi dans le Haut Chagres un niveau stampien inférieur." <sup>1</sup>

This corresponds to a horizon within the Vicksburg group. It is probable that the rocks underlying part of the area around Alahajuela mapped by Doctor MacDonald as Emperador limestone are really of this age.

## LIMESTONE AT DAVID.

A similar foraminiferal fauna occurs in the river bed, just above the ice plant in David, station 6512; at station 6526, which, according to Doctor MacDonald's section, is on the bed immediately next below the one exposed at station 6512; and at station 6523, 2 miles north of David. The following are the species reported by Doctor Cushman:

## LARGER FORAMINIFERA FROM DAVID.

Name.	Station 6512.	Station 6526.	Station 6523.
<i>Nummulites davidensis</i> Cushman.....	×	×	.....
<i>Lepidocyclina macdonaldi</i> Cushman.....	×	.....	×
<i>duplicata</i> Cushman.....	×	.....	×
<i>panamensis</i> Cushman.....	×	.....	.....
sp.....	.....	×	.....
<i>Orthophragmina minima</i> Cushman.....	×	.....	.....
( <i>Asterodiscus</i> ) sp.....	×	.....	.....

<sup>1</sup> Soc. géol. France, Comptes rend. séance No. 16, 1915, p. 130, 1916.



*Taenioxylon multiraditatum* Felix was obtained at station 6523.

The limestone exposed at these three stations, which are all near one another, clearly belongs to one formation, and it seems to me to be of lower Oligocene (Lattorfian) age. However, Doctor Cushman because of the presence of *Orthophragmina minima* inclines to the opinion that it is of upper Eocene age.

*Lepidocyclina duplicata* was collected in association with *L. panamensis* at station 6586e, near Tonosi, in a bed I am considering of middle Oligocene (Rupelian) age (see p. 555).

#### CULEBRA FORMATION.

The principal localities at which collections were made from the Culebra formation were along the Canal from Miraflores locks to Las Cascadas. The local sections are described in Doctor MacDonald's article, pages 533 to 541 of this volume, and the position of each is indicated on plate 154. The United States National Museum station record numbers are 6009 to 6020c, as given at the column heads in the following table. Stations Nos. 6024a, 6025, 6026, are on the Panama Railroad, relocated line, and are platted on the map (pl. 154). Station No. 6837, on shales in the lower part of the Culebra formation, one-quarter of a mile south of Empire bridge, is not platted on the map.

The names of the specifically determined Mollusca from station No. 6019a-d, bed not identified, are taken from Brown and Pilsbry.<sup>1</sup> The specimens were obtained 65 and 85 feet below the "Pecten bed," which is the basal bed of the Emperador limestone. There are five of these species, only one of which, *Turritella altivira* Conrad, has been also reported from the Gatun formation. The generic names of the other Mollusca are mostly taken from my field notes. Doctor MacDonald and I obtained in the Culebra formation within Gaillard Cut, stations 6019a-f and 6020a-c, specimens representing about 70 genera of mollusks, but the species have not been identified.

*Orthis pugnax* (Heilprin), collected by Doctor MacDonald at station 5901, 2 miles south of Monte Lirio, formerly known as Mitchellville, was identified by Dr. C. W. Cooke. This is the same locality as station No. 6026, on the Panama Railroad, relocated line. *Lithothamnium vughani*, *Nummulites panamensis*?, *Lepidocyclina canellei*, and three species of corals were also collected at this locality.

<sup>1</sup> Brown, A. P., and Pilsbry, H. A., Fauna of the Gatun formation, Isthmus of Panama—II, Acad. Nat. Sci. Phila. Proc. for 1912, pp. 502, 503, 1912.









The identification of deposits within the Canal Zone as belonging to the Culebra formation needs brief discussion. The type sections are in Gaillard Cut, particularly at station 6020*a* to 6019*f* (see p. 538 of Doctor MacDonald's paper), and beds Nos. 1-5, inclusive, of the section on the west side of the cut between Empire and Culebra. The collections from 6020*c* to 6019*f* are typical of the upper part of the formation; those from 6012*a* typify its lower part, while those from 6012*c* and 6012*d* represent its upper part (p. 536 of Doctor MacDonald's paper). He refers the beds that were exposed at stations 6009 and 6010 to the lower part of the Culebra, and those at stations 6011 to the upper part. In Gaillard Cut *Lepidocyclina chaperi* occurs at station 6019*f*, and *L. canellei* at station 6019*a*; in other words both of these species occur in the upper part of the Culebra formation, the latter below the former. *Heterosteginoides panamensis* occurs at station 6011 in the upper part of the Culebra formation and apparently it was also obtained at stations 6015 and 6016 in the overlying Emperor limestone. As at station 6024*a*, on Rio Agua Salud, immediately beneath a coralliferous bed representing the Emperor limestone, *Heterostigenoides panamensis* and *Nummulites panamensis* were collected, both the stratigraphic relations and the fossils support the reference of the lower bed to the upper part of the Culebra formation. At Bohio switch, station 6025, *Lepidocyclina chaperi* and *Nummulites panamensis* were found in association. This bed also may be referred to the upper part of the Culebra formation. At station 6026, about 2 miles south of Monte Lirio, *Lepidocyclina canellei* and a species of *Nummulites*, apparently *N. panamensis*, were found associated with fossil corals closely related to the fauna of the Emperor limestone on one hand, and to that of the Antigua formation of Antigua on the other; and *Orthaulax pugnax* was collected there. The correlation of this exposure with the Culebra formation, probably about its middle part, seems as certain as it is possible to be in such matters. The principal locality for *Lepidocyclina canellei* was near the old town of Bohio, station 6027, now under water. It was here that Hill obtained his specimens of "*Orbitoides forbesi*," which are *L. canellei*, and it is probable that the type of the species came from the same place. The deposit here so rich in this species of Foraminifera is referred to the Culebra formation, as are also the beds in which it was obtained at Bailamonas and south of the switch at Mamei.

#### DEPOSITS OF THE AGE OF THE CULEBRA FORMATION NEAR TONOSI.

The only organisms of those collected by Doctor MacDonald in this area that have been studied are the Foraminifera and the corals. The following is a table of the larger Foraminifera:



## LARGER FORAMINIFERA FROM NEAR TONOSI.

Name.	Station 6586e.	Station 6587.	Other stations.
<i>Lepidocyclus panamensis</i> Cushman.....	×	×	6010?, 6012a?, 6012c?, 6512.
<i>duplicata</i> Cushman.....	×	.....	6523.

Stations 6010, 6012a, and 6012c are along the Canal (see pl. 154), on the Culebra formation; station 6512 is the river bed in David and station 6523 is 2 miles north of David, on a limestone probably of lower Oligocene age. It therefore seems that *L. duplicata* is of both lower and middle Oligocene age, while *L. panamensis* occurs in lower, middle, and upper Oligocene deposits.

The following is a list of the corals collected by Doctor MacDonald near Tonosi:

## FOSSIL CORALS FROM STATION 6587, TONOSI.

Name.	Distribution.
<i>Astrocoenia guantanamoensis</i> Vaughan.....	Antigua; Cuba.
<i>Favia macdonaldi</i> Vaughan.....	Antigua.
<i>Micrandra antiquensis</i> Vaughan.....	Antigua.
<i>Trochoseris meinzeri</i> Vaughan.....	Cuba.
<i>Diploastrea crassolamellata</i> (Duncan).....	Antigua; Cuba; etc.

The species after which Cuba is given in the column for distribution were collected by Mr. O. E. Meinzer near Guantanamo. These corals, which clearly belong to the coral fauna found in the Antigua formation of Antigua, supply additional evidence for correlating the foraminiferal limestones exposed at stations 6586e and 6587 with the lower part of the Culebra formation. By referring to my account of the successive coral faunas of the West Indies and Central America, pages 193 to 226 of this volume, it will be seen that, although I refer the coral fauna of the upper part of the Culebra formation to the upper Oligocene (= Aquitanian of European terminology), I consider that fauna as intermediate between the fauna of the Emperador limestone and Anguilla formation and that of the Antigua formation, because it contains a number of species in common with the latter formation. The coral fauna represented at Tonosi is, in my opinion, of middle Oligocene age, and belongs stratigraphically just below that found in the upper part of the Culebra formation.

## CUCURACHA FORMATION

The only fossils as yet identified from the Cucuracha formation are two species of plants, *Palmoxylon palmacites* (Sprengel) Stenzel and *Taenioxylon multiradiatum* Felix, from station No. 6845, which is on the green clays of Gaillard Cut, near the lava flow. The first of these species was obtained only in the Cucuracha formation; but the second occurs in the Bohio conglomerate and the Culebra formation.

## EMPERADOR LIMESTONE.

The type locality of this formation is in Empire village, and stations 6015 and 6016 are on it. As the two localities are very near together, with little or no lithologic or faunal difference, the fossils from the two localities are listed as from one in the following table. The position of the locality is shown on the map (pl. 154). Station 6017 is on the highway between Empire and Las Cascadas, about one mile from Las Cascadas. Nos. 6021 and 6673 are for the same locality, which is just north of Caimito switch, Panama Railroad, relocated line; station No. 6024 $b$  is on the same railroad, at the lower end of the culvert over Rio Agua Salud. Station No. 6255 is on the wagon road about one-half mile south of Miraflores; and station No. 6256 is Bald Hill, 1½ miles south of Miraflores (see p. 534 for Doctor MacDonald's description of the exposure).

The fossil plant, *Taenioxylon multiradiatum* Felix, was obtained at station 6523, which is about 2 miles north of David, where *Lepidocyclina macdonaldi* Cushman and *L. duplicata* Cushman were also collected. It is my belief that this specimen did not come from the Emperador limestone; for it is my opinion that the horizon is stratigraphically below the Culebra formation.

The specific names of the Mollusca and that of the echinoid, *Schizaster scherzeri* Gabb, from station No. 6019 $g$  are taken from the paper by Brown and Pilsbry already cited.<sup>1</sup> Doctor MacDonald and I obtained from the same bed species representing 32 genera of Mollusca, but they have not been identified.

Regarding the larger Foraminifera from stations 6015 and 6016, Dr. J. A. Cushman says: "The material from No. 6015 contains an orbitoid species, but the sections cut did not clearly reveal the internal structure. It has a papillate surface, and resembles *Lepidocyclina macdonaldi* and *L. panamensis*, but does not seem to be identical with either. Some of its characters, especially in its nearly diamond shaped chambers, it resembles *L. vaughani*, but the specimens of the latter are larger and they are not papillate. Although this appears to be a new species, I do not care to give a name to it without knowing its internal structure in greater detail, and suggest that it be listed as *Lepidocyclina* species.

"The material from No. 6016 apparently contains no orbitoids, but it contains *Amphistegina*, which superficially might be mistaken for an orbitoid."

*Heterosteginoides* sp., apparently *H. panamensis*, occurs at stations Nos. 6015 and 6016.

*Lepidocyclina vaughani* Cushman was obtained at two localities, stations Nos. 6021 and 6255.

<sup>1</sup> Acad. Nat. Sci. Phila. Proc. for 1912, p. 503.

The echinoid, *Clypeaster gatuni* Jackson, is worth a special note. The holotype is from the Gatun formation, station 5662, but two specimens were also collected at station 6237, in limestone referred by Doctor MacDonald to the Emperor limestone, in a swamp north of Ancon Hill and about 4 miles south of Diablo Ridge. This species extended from the Atlantic to the Pacific side of the Isthmus.

Doctor MacDonald and I obtained at station No. 6019g two poor crushed specimens of a gastropod that belongs to the genus *Orthaulax*.

A few remarks should be made on the reference of the limestone exposed at station 6021 near the old Caimito switch, to Emperor limestone. Only two identifiable species, *Lithothammium isthmi* and *Lepidocyclus vaughani*, were obtained at this place, but both were found elsewhere in the Emperor limestone. *Lithothammium isthmi* was also collected on Rio Agua Salud, station 6024b, in association with a coral fauna very nearly the same as that at the type locality of the formation; and *Lepidocyclus vaughani* was obtained in the Emperor limestone near Miraflores.

## FOSSILS FROM THE EMPERADOR LIMESTONE.

	6015, 6016	6017	5866b, 6019g, 6671	6021, 6673	6024b	6255	6256
PLANTAE.							
<i>Lithothammium isthmi</i> M.A. Howe .....				×	×		
FORAMINIFERA.							
<i>Polystomella macella</i> (Fichtel and Moll) .....	×						
<i>Amphistegina lessonii</i> d'Orbigny .....	×						
<i>Lepidocyclus</i> sp. ....	×						
sp. ....			×				
<i>vaughani</i> Cushman .....				×		×	
<i>Heterosteginoides</i> sp., apparently <i>H. panamensis</i> Cushman ..	×						
<i>Quinqueloculina undosa</i> Karrer .....	×						
MADREPORARIA.							
<i>Stylophora imperatoris</i> Vaughan .....	×				×		
<i>panamensis</i> Vaughan .....	×						
<i>goethalsi</i> Vaughan .....	×				×		
<i>macdonaldi</i> Vaughan .....	×						
<i>canalis</i> Vaughan .....	×						
<i>Pocillopora arnoldi</i> Vaughan .....	×						
<i>Astrocoenia portoricensis</i> Vaughan .....	×				×		
<i>Orbicella imperatoris</i> Vaughan .....	×	×					×
<i>canalis</i> Vaughan .....	×						
<i>Stylangia panamensis</i> Vaughan .....	×						
<i>Goniastrea canalis</i> Vaughan .....	×						
<i>Pavona panamensis</i> Vaughan .....	×						
<i>Acropora panamensis</i> Vaughan .....	×				×		
<i>saludensis</i> Vaughan .....	×				×		
<i>Astreopora goethalsi</i> Vaughan .....	×						
<i>Goniopora hilli</i> Vaughan .....	×						
<i>panamensis</i> Vaughan .....	×						
<i>imperatoris</i> Vaughan .....	×						
<i>canalis</i> Vaughan .....	×						
<i>clevei</i> Vaughan .....	×						
<i>Porites douvillei</i> Vaughan .....	×						
<i>toulai</i> Vaughan .....	×						
<i>panamensis</i> Vaughan .....	×						
<i>anguillensis</i> Vaughan .....	×						
( <i>Synaraea</i> ) <i>howei</i> Vaughan .....	×						
<i>macdonaldi</i> Vaughan .....	×						



## FOSSILS FROM THE EMPERADOR LIMESTONE—continued.

	6015, 6016	6017	5866b, 6019g, 6671	6021, 6673	6024b	6255	6256
ECHINOIDEA.							
<i>Clypeaster lanceolatus</i> Cotteau.....			×				
<i>gatuni</i> Jackson.....			×				
<i>Echinolampas semiorbis</i> Guppy.....			×				
<i>Schizaster scherzeri</i> Gabb.....			×				
BRYOZOA.							
<i>Holoporella albirostris</i> (Smitt).....	×						
<i>Ogivalina mutabilis</i> Canu and Bassler.....	×						
MOLLUSCA.							
<i>Murex (Phyllonotus) gatunensis</i> Brown and Pilsbry.....			×				
<i>Orthis</i> sp.....			×				
<i>Pyrgula micronematia</i> Brown and Pilsbry.....			×				
<i>Arca</i> sp.....			×				
<i>Ostrea gatunensis</i> Brown and Pilsbry.....			×				
<i>Pecten (Aequipecten) orygonum canalis</i> Brown and Pilsbry.....			×				
sp.....	×		×				
<i>Amusium soi</i> Brown and Pilsbry.....			×				
sp.....			×				
sp.....	×		×				
<i>Tellina vetula</i> Brown and Pilsbry.....			×				
<i>Semele chinolana</i> Dall.....			×				
<i>Chione (Lirophora) ulocyma</i> Dall.....			×				
<i>Dosinia delicatissima</i> Brown and Pilsbry.....			×				
<i>Crassatellites mediamericana</i> Brown and Pilsbry.....			×				
<i>Kuphus incrassatus</i> Gabb.....			×				
CRUSTACEA.							
<i>Microbrachium</i> , sp.....			×				
<i>Callinassa tenuis</i> Rathbun.....			×				
<i>Mursia macdonaldi</i> Rathbun.....			×				
<i>Parthenope panamensis</i> Rathbun.....			×				

## CAIMITO FORMATION.

No fossils were obtained in this formation at its type locality. Doctor MacDONALD collected fossil plants at station No. 6840, about 7 miles northeast of Bejuca, near Chame, Panama, in a yellowish argillaceous sandstone that seems to overlap agglomerates and is believed to represent the Caimito formation. Professor BERRY records the following species from this locality:

*Guatteria culebrensis* BERRY, also Culebra and Gatun formations.

*Hiraea oligocaenica* BERRY.

*Hieronymia lehmanni* BERRY.

*Schmidelia bejucensis* BERRY, also Culebra formation.

As two of the four species also occur in the Culebra formation, it appears that the deposit in which they were obtained is in age near the Culebra formation.

## MIOCENE.

## GATUN FORMATION.

The principal collections from the Gatun formation were made jointly by Doctor MacDONALD and myself at stations Nos. 6029a-b, 6030, 6033b-c, 6035, and 6036, the position of each of which is platted on the map (pl. 154), and the sections are described in Doctor Mac-



Donald's article, pages 542-544 of this volume. Four species of plants were collected in the Gatun borrow pits. No. 6003 is for the same bed as 6033b. Station No. 5659 is near Gatun. The localities for three of the species of Crustacea are as follows:

*Gatunia proavita* Rathbun, Cat. No. 113706, U.S.N.M., near Gatun.

*Callianassa hilli* Rathbun, Cat. No. 135218, U.S.N.M., Gatun formation; nothing more definite.

*Mursilia cristata* Rathbun, Cat. No. 135219, U.S.N.M. Gatun formation; nothing more definite.

## FOSSILS, EXCEPT MOLLUSCA, FROM THE GATUN FORMATION.

	Gatun bor- row pits.	5900, Gatun locks.	6029a.	6029b.	6030.	6033b, 6003.	6033c.	6035.	6036.
PLANTAE.									
<i>Guatteria culebrensis</i> Berry.....	×								
<i>Calyptanthus gatunensis</i> Berry.....	×								
<i>Rondeletia goldmani</i> Berry.....	×								
<i>Rubiactes izoreoides</i> Berry.....	×								
FORAMINIFERA.									
<i>Textularia subagglutinans</i> Cushman.....							×		
<i>panamensis</i> Cushman.....							×		×
<i>carinata</i> d'Orbigny.....									×
<i>Chrysalidina pulchella</i> Cushman.....									×
<i>Bolivina punctata</i> d'Orbigny.....							×	×	
<i>aenariensis</i> (Costa).....							×		×
<i>robusta</i> H. B. Brady.....								×	
<i>Bigennerina nodosaria</i> d'Orbigny.....									×
<i>Virgulina squamosa</i> d'Orbigny.....							×	×	×
<i>Nodosaria communis</i> d'Orbigny.....									×
<i>Cristellaria rotulata</i> (Lamarck).....							×	×	×
<i>vaughani</i> Cushman.....								×	×
<i>italica</i> Defrance.....								×	×
<i>Uvigerina canariensis</i> d'Orbigny.....								×	
<i>pygmaea</i> d'Orbigny.....								×	
<i>lenustrata</i> Reuss.....									×
<i>Globigerina bulloides</i> d'Orbigny.....				×			×	×	×
<i>dubia</i> Egger.....							×	×	×
<i>sacculifera</i> H. B. Brady.....							×	×	×
<i>aquilateralis</i> H. B. Brady.....							×	×	×
<i>inflata</i> d'Orbigny.....								×	×
<i>conglobata</i> H. B. Brady.....								×	×
<i>Orbulina universa</i> d'Orbigny.....								×	×
<i>Pulvinulina menardii</i> d'Orbigny.....							×	×	×
<i>oblonga</i> (Williamson).....								×	
<i>concentrica</i> Parker and Jones.....								×	
<i>Polystomella striatopunctata</i> (Fichtel and Moll).....			×						
<i>erispa</i> (Linnaeus).....				×					
<i>Nonionina depressula</i> (Walker and Jacobs).....							×	×	
<i>scapha</i> (Fichtel and Moll).....							×		
<i>Amphistegina lessonii</i> d'Orbigny.....			×	1	×				
<i>Siphonina reticulata</i> (Czjzek).....									×
<i>Quinqueloculina seminulum</i> (Linnaeus).....									×
<i>panamensis</i> Cushman.....									×
<i>Sigmoilina tenuis</i> Czjzek.....							×	×	×
<i>asperula</i> (Karrer).....								×	×
<i>Triloculina bulbosa</i> Cushman.....			×		×				
<i>projecta</i> Cushman.....								×	
<i>Biloculina bulloides</i> d'Orbigny.....									×
ECHINOIDEA.									
<i>Clypeaster gatuni</i> Jackson (Sta. 5662).....									
<i>Encope annectans</i> Jackson (Sta. 5846).....									
<i>platylata</i> Jackson.....			×						
<i>megatrema</i> Jackson.....					×				
<i>Schizaster panamensis</i> Jackson (Stas. 6008, 7294).....									

<sup>1</sup> Also 6029c.

## FOSSILS, EXCEPT MOLLUSCA, FROM THE GATUN FORMATION—continued.

	Gatun bor- row pits.	5900, Gatun locks.	6029a.	6029b.	6030.	6033b, 6003.	6033c.	6035.	6036.
MOLLUSCA.									
(See next following list.)									
CRUSTACEA.									
<i>Callianassa vaughani</i> Rathbun.....			×		×				
<i>crassa</i> Rathbun.....						×			
<i>hilli</i> Rathbun.....						×			
(?) sp.....									
<i>Gatunia proavita</i> Rathbun (also Sta. 5659).....		×			×				
<i>Mursilia ecristata</i> Rathbun.....									
<i>Balanus concavus</i> Bronn.....					×				
<i>Lepas injudicata</i> Pilsbry.....						×			
SELACHII.									
<i>Carcharias</i> sp. (Sta. 5899).....									
<i>Lamna</i> cf. <i>L. clegans</i> .....			×						
<i>Charcharodon</i> cf. <i>C. auriculatus</i> .....			×	×	×				

MOLLUSCA FROM THE GATUN FORMATION, ACCORDING TO BROWN AND PILSBRY.<sup>1</sup>

The collections, mostly Mollusca, considered in the first paper by these authors, "with the exception of a tooth of a shark and a few specimens of *Oliva* from Monkey Hill, all come from the excavations for the locks at Gatun. The *Oliva* taken at Monkey Hill is the same species found plentifully at the Gatun excavation. The specimens were collected from dumps and fills along the railway as well as from dumps in the vicinity of Gatun." In their second paper, collections from other localities near Gatun and from two horizons at Tower N, Las Cascadas, are included. The following list contains all the mollusca referred to the Gatun formation by Pilsbry and Brown. The names of those preceded by an asterisk were not in the collections submitted to those authors, and I have added the note "not at Gatun" after the names of those which were not collected at Gatun. The results of our field work and the subsequent paleontologic studies cause us to dissent from the stratigraphic interpretations of Messrs. Brown and Pilsbry, for they combine the Culebra formation, the Emperador limestone, and the Gatun formation into one formation. As the species described by Toula in his *Eine jungteriäre Fauna von Gatun am Panama-Kanal*<sup>2</sup> are included in the papers by Brown and Pilsbry, more detailed reference to his article is not necessary here.

<sup>1</sup> Brown, Amos P., and Pilsbry, Henry A., *Fauna of the Gatun formation, Isthmus of Panama*: Acad. Nat. Sci. Phila. Proc. for 1911, pp. 336-373, pls. 22-29, April, 1911; *Fauna of the Gatun formation—II*, *idem*, for 1912, pp. 500-519, pls. 22-26. December, 1912.

<sup>2</sup> K. K. Geol. Reichsanstalt Jahrb., vol. 58, pp. 673-760, pls. 25-28, Vienna, 1909. Toula in a second paper, *Die jungteriäre Fauna von Gatun am Panama-kanal*, K. K. Geol. Reichsanstalt Jahrb., vol. 61, pp. 487-530, pls. 30, 31, Vienna, 1911, published a supplement to his first paper issued in 1910, and the species described as new in this are not included in the papers by Brown and Pilsbry. This one of Toula's papers escaped my attention until the present volume was in proof, and as it was then too late to consider the synonymy of the species described in it, remarks on it are confined to this note.

- \*Bullina chipolana* Dall.  
*Volvulella micrtracta* Brown and Pilsbry.  
*Rigicula hypograpta* Brown and Pilsbry.  
*Terebra subsulcifera* Brown and Pilsbry.  
*gatumensis* Toula.  
*wolfgangi* Toula.  
*gausapata* Brown and Pilsbry.  
*Conus concavitectum* Brown and Pilsbry.  
*haytensis* Sowerby.  
*domingensis* Sowerby (?).  
*consobrinus* Sowerby.  
*granozonatus* Guppy.  
*aemulator* Brown and Pilsbry.  
*imitator* Brown and Pilsbry.  
*gaza* Johnson and Pilsbry.  
*molis* Brown and Pilsbry.  
*Pleurotoma albid* Perry.  
*\*Pleurotoma gertrudis* Toula.  
*vaningeni* Brown and Pilsbry  
*Drillia gatumensis* Toula.  
*isthmica* Brown and Pilsbry.  
*fusinus* Brown and Pilsbry.  
*zooki* Brown and Pilsbry.  
*consors* (Sowerby).  
*enneacyma* Brown and Pilsbry.  
*Cythara heptagona* (Gabb).  
*Cancellaria dariena* Toula.  
*decaptyx* Brown and Pilsbry.  
*Mitra longa* Gabb.  
*dariensis* Brown and Pilsbry  
 sp. undet.  
*Marginella gatumensis* Brown and Pilsbry.  
*leander* Brown and Pilsbry.  
*coniformis* Sowerby.  
*Oliva reticulata gatumensis* Toula.  
*Fasciolaria gorgasiana* Brown and Pilsbry.  
 sp. undet.  
*\*Glyptostyla panamensis* Dall (not at Gatun).  
*Solenosteira dalli* Brown and Pilsbry.  
*Phos gatumensis* Toula.  
*subsemicostatus* Brown and Pilsbry.  
*metuloides* Dall.  
*Metula gabbi* Brown and Pilsbry.  
*Nassa (Hima) praeambigua* Brown and Pilsbry (not at Gatun).  
*Anachis fugax* Brown and Pilsbry.  
*\*Strombina nira* Dall.  
*lessepsiuna* Brown and Pilsbry.  
*Murex messorius* Sowerby.  
*polynematicus* Brown and Pilsbry.  
*(Phyllonotus) gatumensis* Brown and Pilsbry.  
*Typhis alatus* Sowerby.  
*gabbi* Brown and Pilsbry.  
*Strombus gatumensis* Toula.  
 (?) sp. undet.  
*Distorsio gatumensis* Toula.  
*Malea camura* Guppy.  
*Sconsia laevigata* (Sowerby).  
*Pyrua micronematica* Brown and Pilsbry (not at Gatun).  
 near *popyratia* Say.  
*Cypraea henekeni* Sowerby var.  
*Buttium nugatorium* Brown and Pilsbry.  
*scotti* Brown and Pilsbry (not at Gatun).  
*Turbonilla bartschiana* Brown and Pilsbry.  
*Turritella mimetes* Brown and Pilsbry.  
*gatumensis* Conrad.  
*atitira* Conrad.  
*Petalocochnus domingensis* Sowerby.  
*Solarium granulatum gatumensis* Toula.  
*Natica guppyana* Toula.  
*bolus* Brown and Pilsbry.  
*canrena* (Linnaeus).  
*canalizonalis* Brown and Pilsbry.  
 (?) sp. undet.  
*Polinices subclausa* (Sowerby).  
*\*Lupia perovata* Conrad (not at Gatun).  
*Sigarcus gatumensis* Toula.  
*(Eunaticina) gabbi* Brown and Pilsbry.  
*\*Capulus (?) gatumensis* Toula.  
*Crepidula plana* Say.  
*Cheilea princetonia* Brown and Pilsbry.  
*Nucula (Acila) isthmica* Brown and Pilsbry  
*Leda balboae* Brown and Pilsbry.  
*Arca dariensis* Brown and Pilsbry.  
*dalli* Brown and Pilsbry (not at Gatun).  
*Glycymeris carbasina* Brown and Pilsbry.  
*canalis* Brown and Pilsbry.  
*acuticostata* Sowerby.  
*Pecten (Æquipecten) effusus* Brown and Pilsbry.  
*gatumensis* Toula.  
*(Plagiocentium) operculariformis* Toula.  
*\*Pecten levicostatus* Toula.  
*(Euvola) reliquus* Brown and Pilsbry.  
*ozygonum canalis* Brown and Pilsbry (not at Gatun).  
*ozygonum optimum* Brown and Pilsbry (occurrence at Gatun doubtful).



- Pecten (Cyclopecten) oligolepis* Brown and Pilsbry.  
 \*(*Amusium*) *lyonii* Gabb.  
     *toulae* Brown and Pilsbry.  
     *sol* Brown and Pilsbry (not at Gatun).  
     *luna* Brown and Pilsbry.
- Spondylus scotti* Brown and Pilsbry (not at Gatun).  
*Ostrea gatunensis* Brown and Pilsbry.  
*Crassatellites reevei* (Gabb) (occurrence at Gatun doubtful).  
     *mediaamericanus* Brown and Pilsbry (not at Gatun).
- Cardium (Trachycardium) stiriatum* Brown and Pilsbry.  
     \**dominicanum* Dall.  
     *dominicense* Gabb.  
     *durum* Brown and Pilsbry.
- Cardium (Laevicardium) serratum* Linnaeus.  
     \**dalli* Toulou.  
     \*(*Fragum*) *gatunense* Dall.  
     (?) *newberryanum* Gabb.
- \**Tellina dariena* Gabb.  
     \**gatunensis* Bagge.  
     \**rowlandi* Toulou.  
     \**lepidota* Dall.  
     *aequiterminata* Brown and Pilsbry.
- (*Eurytellina*) *vetula* Brown and Pilsbry (not at Gatun).  
     sp. undet.  
     sp. undet.  
 \**Semele sayi* Toulou.  
     *chipolana* Dall (not at Gatun).  
*Chione tegulum* Brown and Pilsbry.  
     sp. undet.  
     (*Lirophora*) *ulocyma* Dall.  
         • *ulocyma holocyma* Brown and Pilsbry.  
         \**mactropsis* (Conrad).
- Pitar centangulata* Brown and Pilsbry.  
     *cora* Brown and Pilsbry.  
     \**hilli* Dall.  
     \**circinata* (Brown).  
 \**Macrocallista maculata* (Linnaeus) (?).  
*Dosinia delicatissima* Brown and Pilsbry.  
 \**Callocardia (Agriopoma) gatunensis* Dall.  
     \**gatunensis multifilosa* Dall.
- Petricola millestriata* Brown and Pilsbry.  
*Clementia dariena* (Conrad).  
*Cyclinella gatunensis* Dall.  
 \**Mactra dariensis* Dall (not at Gatun).  
*Thracia (Cyathodonta) gatunensis* Toulou.  
*Corbula gatunensis* Toulou.  
     *sphenia* Dall.  
     *sericea* Dall.  
     (*Cuneocorbula*) *hexacyma* Brown and Pilsbry.  
     \**alabamiensis* Lea.  
     \**gregorioi* Cossmann.  
     *heterogenea* Guppy (not at Gatun).  
     \**viminea* Guppy (not at Gatun).  
*Teredo dendrolestes* Brown and Pilsbry.  
 \**Solecurtus gatunensis* Toulou.  
     *strigillatus* (Linnaeus).

Sixteen species included in the foregoing list have not been found at Gatun, and the occurrence there of two other species is doubtful. The number of identified species of mollusca from the formation, including two doubtfully determined, is 125.

Subsequent to the publication of the papers by Brown and Pilsbry, Cossmann<sup>1</sup> has described four additional species from Mindi out of material belonging to the Gatun formation. The species are as follows: *Euchilodon moierei* Cossmann; *Conus lavillei* Cossmann; *Uxia mio-caenica* Cossmann; *Marginella mindiensis* Cossmann.

#### PLIOCENE.

#### TORO LIMESTONE.

At Toro Point, the type locality of this formation, station No. 6037, Doctor MacDonal and I collected the types of *Epitonium (Sthe-*

<sup>1</sup> Cossmann, M., Étude comparative de fossiles miocéniques recueillis à la Martinique et à l'Isthme de Panama, Journ. Conchyl., vol. 61, pp. 1-64, pls. 1-5, 1913.



*norytis*) *toroënsis* Dall and of *E. toroënsis* var. *insigne* Dall.<sup>1</sup> In addition to these identifiable Mollusca, dissociated barnacle plates and comminuted milluscan shell fragments are abundant. The probably equivalence of this deposit with the coquina rock, which contains many fragments of *Pecten* sp., on the top of the hill at the west end of Gatun dam, is discussed by Doctor MacDonald on page 544 of his article immediately preceding the present one.

## PLEISTOCENE.

Although horizons in the marine Pleistocene deposits of America have not yet been discriminated on the basis of their contained fossils, it is my opinion that such discriminations will be made. As a contribution toward the biologic characterization of a Pleistocene deposit, the following list of fossils from the deposit in the swamp north and east of Mount Hope, stations Nos. 5850 and 6038, has been prepared. Two papers on the fossil mollusca from this locality have been published. The first is by Dr. W. H. Dall, in his paper just referred to; the second is by Messrs. Brown and Pilsbry.<sup>2</sup> The other lists are from the memoirs forming parts of this volume.

## FOSSILS FROM THE PLEISTOCENE OF THE CANAL ZONE.

## PLANTAE.

*Archaeolithothamnium episporum* M. A. Howe.

## MADREPORARIA.

*Oculina diffusa* Lamarck.  
*varicosa* Le Sueur.  
*Eusmilia fastigiata* (Pallas).  
*Astrangia (Phyllangia) americana* Milne Edwards and Haime.  
*Cladocora arbuscula* Le Sueur.  
*Solenastrea bournoni* Milne Edwards and Haime.  
*Favia fragum* (Esper).  
*Maeandra areolata* (Linnaeus).  
*Manicina gyrosa* (Ellis and Solander).  
*Agaricia agaricites* (Linnaeus).  
*var. purpurea* Le Sueur.  
*pusilla* Verrill.  
*Siderastrea radians* (Pallas).  
*siderea* (Ellis and Solander).  
*Acropora muricata* (Linnaeus).  
*Porites furcata* Lamarck.  
*astreoides* Lamarck.

## HYDROZOA.

*Millepora alcornis* Linnaeus.

## MOLLUSCA.

*Tornatina canaliculata* (Say). R.<sup>3</sup>  
*Cylichnella bidentata* (Orbigny.)  
*Atys sandersoni* Dall.  
*Bullaria occidentalis* (A. Adams). C.  
*Haminea canalis* Dall.  
*Haminea antiillarum* (Orbigny). R.  
*Terebra spei* Brown and Pilsbry.  
*Conus proteus* Hwass. R.  
*Drillia leucocyma* Dall.  
*ostrearum* Stearns.  
*harfordiana* (Reeve) var. *colonensis* Brown and Pilsbry. R.  
*Clathurella jewetti* Stearns. R.  
*Cythara balteata* (Reeve).  
*biconica* (C. B. Adams). C.  
*Marinula colonia* Dall. R.  
*Olivella myrmecoon* Dall. C.  
*Marginella cincta* Kiener C.  
*pallida* (Linnaeus). R.  
*minuta* Pfeiffer.

<sup>1</sup> Dall, W. H., New species of fossil shells from Panama and Costa Rica, Smithsonian Misc. Coll., vol. 59, No. 2, pp. 6, 7, 1912.

<sup>2</sup> Brown, A. P., and Pilsbry, H. A., Two collections of Pleistocene fossils from the Isthmus of Panama, Acad. Nat. Sci. Phila. Proc. for 1913, pp. 493-500, 1913.

<sup>3</sup> The abundance or rarity of the species is indicated by the letters R. (rare) and C. (common).

## FOSSILS FROM THE PLEISTOCENE OF THE CANAL ZONE—continued.

## MOLLUSCA—continued.

- Voluta alfaroi* Dall. R.  
*Fasciolaria* species. R. Specimen too young to determine.  
*Latirus cingulifera* (Lamarck). R.  
*Phos intricatus* Dall. R.  
*Engina turbinella* (Kiener). R.  
*Nassa vibex* Say.  
*Columbella mercatoria* (Linnaeus).  
*Anachis avara* (Say). R.  
     *samanensis* Dall. C.  
     *pulchella* (Kiener). R.  
*Aspella scalaroides* (Blainville). R.  
*Strombus bituberculatus* Lamarck.  
     *pugilis* Linnaeus.  
*Trivia pediculus* (Linnaeus). R.  
*Murex rufus* Lamarck. R.  
     *pomum* Gmelin.  
     *nodatus* Reeve. C.  
*Urosalpinx* species. R.  
*Eulina bifasciata* (Orbigny). R.  
*Cymatium vespaceum* (Lamarck). R.  
     *tuberosum* (Lamarck). R.  
*Cerithiopsis* species. R.  
*Bittium varium* Pfeiffer. C.  
*Cerithium literatum* (Born). R.  
     *algicola* C. B. Adams. C.  
     *medium* Dall. R.  
     *variabile* C. B. Adams.  
*Cerithidea varicosa* Sowerby. R.  
*Modulus modulus* (Linnaeus). C.  
     *catenulatus* Philippi. R.  
*Littorina angulifera* Lamarck. R.  
*Vermorel nigricans* Philippi (?). R.  
*Alabina cerithioides* Dall.  
*Alaba tervaricosa* Adams. R.  
*Rissoina laevigata* C. B. Adams var.  
     *browniana* Orbigny.  
     *striatocostata* Orbigny. R.  
     *cancellata* Philippi. R.  
     *elegantissima* Orbigny. R.  
*Crepidula convexa* Say. C.  
     *plana* Say. C.  
*Calyptrea candeana* Orbigny. C.  
*Natica pusilla* Say. R.  
*Siguretus perspectivus* Say. R.  
*Phasianella pulchella* C. B. Adams. C.  
*Turbo crenulatus* Gmelin. R.  
*Astraliun brevispina* (Lamarck). R.  
     *tuberosum* (Philippi) (?)  
*Tegula fasciata* (Born).  
*Fissuridea alternata* (Say).  
*Submarginula emarginata* (Blainville).  
     *rollandii* (Fischer).

## MOLLUSCA—continued.

- Acmaea punctata* (Gmelin).  
*Neritina viridis* Lamarck. C.  
*Tonicia schrammi* Shuttlworth. R.  
*Dentalium callithrix* Dall. C.  
*Cadulus vaughani* Dall. C.  
*Leda vulgaris*, new species. C.  
     *acuta* Conrad. R.  
*Yoldia perprotracta* Dall. C.  
*Arca umbonata* Lamarck. R.  
     *imbricata* Brugière. R.  
     *antiquata* Linnaeus. C.  
     *deshayesi* Hanley. C.  
     *campechiensis* Dillwyn. R.  
     *adamsi* Smith.  
     *occidentalis* Philippi. R.  
     *reticulata* Gmelin. R.  
*Scapharca pittieri* Dall. C.  
*Byssarca fusca* Brugière. C.  
*Melina ephippium* (Linnaeus). C.  
*Ostrea virginica* Gmelin. C.  
*Pecten ziczac* (Linnaeus). C.  
     *exasperatus* Sowerby. C.  
     *gibbus* (Linnaeus).  
     *gibbus dislocatus* Say. R.  
*Mytilus exustus* Lamarck. R.  
*Chama* sp. R.  
     sp. C.  
*Crassinella guadalupensis* (Orbigny). R.  
*Diplodonta mediamericana* Brown and Pilsbry. R.  
*Diplodonta soror* C. B. Adams. C.  
*Codakia orbiculata* (Montagu). R.  
     *antillarum* Reeve. C.  
*Lucina chrysostoma* Philippi. C.  
*Phacoides lintea* (Conrad). R.  
     near *crenulatus* (Conrad). R.  
     *antillarum* Reeve. R.  
     *leucocyma* Dall. R.  
     *pectinatus* (Gmelin). C.  
*Phacoides* species  
*Cuspidaria* (*Cardiomya*) *costellata* Deshayes. R.  
*Cardium serratum* Linnaeus. C.  
     *medium* Linnaeus.  
     *muricatum* Linnaeus. C.  
*Gafarium* (*Gouldia*) *cerina* (C. B. Adams). R.  
*Pitar subarresta* Dall.  
*Chione cancellata* (Linnaeus). C.  
*Tellina* (*Eurytellina*) *alternata* Say. C.  
     (*Cyclotellina*) *fausta* Donovan.  
     (*Angulus*) *versicolor* Cozzens.  
     *promera* Dall.

## FOSSILS FROM THE PLEISTOCENE OF THE CANAL ZONE—continued.

## MOLLUSCA—continued.

- Abra aequalis* (Say). R.  
*Corbula equivalvis* Philippi. C.  
*swiftiana* C. B. Adams C.

## CRUSTACEA.

- Macrobrachium* ? species.  
*Nephtrops costatus* Rathbun.  
 species.  
*Axiis* ? species.  
*Hepatus chilensis* Milne Edwards.

## CRUSTACEA—continued.

- Calappa flammea* Rathbun.  
*Leucosilia jurinei* (Saussure).  
*Leucosiidae*, genus and species indeter-  
 minable.  
*Arenaeus* species.  
*Panopeus antepurpureus* Rathbun.  
*tridentatus* Rathbun.  
*Uca macrodactylus* (Milne Edwards and  
 Lucas).  
*Parthenope pleistocenicus* Rathbun.

## CORRELATION OF THE SEDIMENTARY FORMATIONS OF PANAMA.

## TERTIARY FORMATIONS OF THE SOUTHEASTERN UNITED STATES.

A Table of the Tertiary geologic formations of the southeastern United States and their correlatives within that area, revised to the present date—October 15, 1917—is presented facing page 569. In 1912 I published a summary of the stratigraphy of the Tertiary formations of the Gulf and south Atlantic Coastal Plain, incorporating all data available up to that time,<sup>1</sup> and gave in the accompanying bibliography references to the principal literature. Since the summary referred to was printed a number of papers containing additional information have been published, and I have had the benefit of consulting the manuscripts of reports, to be mentioned later, not yet available in print. References to the later published and a few unpublished papers are as follows:

- BERRY, E. W., The physical conditions and age indicated by the flora of the Alum Bluff formation, U. S. Geol. Survey Prof. Paper 98, pp. 41-59, pls. 7-10, 1916.  
 ——— The physical conditions indicated by the flora of the Calvert formation, *Idem*, pp. 61-73, pls. 11, 12, 1916.  
 ——— The flora of the Citronelle formation, *Idem*, pp. 193-204, pls. 44-47, 1916.  
 ——— The flora of the Catahoula sandstone, *Idem*, pp. 227-243, pls. 55-60, 1916.  
 ——— The lower Eocene floras of southeastern North America, U. S. Geol. Survey Prof. Paper 91, pp. 481, 117 pls., 1916.  
 BRANTLY, J. E., A report on the limestones and marls of the Coastal Plain of Georgia, Georgia Geol. Survey Bull. 21, pp. 300, 11 pls., 1916.  
 COOKE, C. W., The age of the Ocala limestone, U. S. Geol. Survey Prof. Paper 95 (I), pp. 107-117, 1915.  
 ——— The stratigraphic position and faunal associates of the orbitoid Foraminifera of the genus *Orthophragmina* from Georgia and Florida, U. S. Geol. Survey Prof. Paper 108 (G), pp. 109-113, 1917.  
 ——— Correlation of the deposits of Jackson and Vicksburg ages in Mississippi and Alabama, Washington Acad. Sci. Journ., vol. 8, pp. 186-198.  
 ——— The Jackson formation and the Vicksburg group in Mississippi, Unpublished manuscript.  
 ——— and SHEARER, H. K., Deposits of Claiborne and Jackson age in Georgia, U. S. Geol. Survey Prof. Paper 120 (E), pp. 41-81, pl. 7, figs. 7-9, 1918.  
 CUSHMAN, J. A., Orbitoid Foraminifera of the genus *Orthophragmina* from Georgia and Florida, U. S. Geol. Survey Prof. Paper 108 (G), pp. 111-124, pls. 40-44, 1917.  
 DALL, W. H., On a brackish water Pliocene fauna of the southern Coastal Plain, U. S. Nat. Mus. Proc., vol. 46, pp. 225-227, 1913.

<sup>1</sup> Vaughan, T. W., Earlier Tertiary (Eocene and Oligocene), Texas, Louisiana, and Arkansas, pp. 723-731; South Atlantic and eastern Gulf Coastal Plain and north end of Mississippi Embayment, pp. 731-745; Later Tertiary (Miocene and Pliocene), Texas, Louisiana, and Arkansas, pp. 804-806; South Atlantic and eastern Gulf Coastal Plain and north end of Mississippi Embayment, pp. 806-813; in Willis, Bailey: Index to the stratigraphy of North America, U. S. Geol. Survey Prof. Paper 71, 1912.



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In the bibliography, except the one by Professor Berry on the flora of the Calvert formation, I have purposely omitted references to papers on that part of the Coastal Plain north of the South Carolina-North Carolina boundary line. The contributions to the paleontology and stratigraphy of the Tertiary formations of the south Atlantic and Gulf Coastal Plain during the past five years have been considerable, as the list of papers shows, but much more work has been done. Prof. E. W. Berry has completed a monograph of the middle and upper Eocene floras of southeastern North America, now awaiting publication as a Professional Paper of the United States Geological Survey; Dr. Joseph A. Cushman has a monograph of the Pliocene and Miocene Foraminifera of the Coastal Plain in press as a bulletin of the United States Geological Survey; Messrs. F. Canu and R. S. Bassler have submitted the manuscript for a very large volume on



the Eocene and lower Oligocene Bryozoa of the Coastal Plain for publication by the United States National Museum; Miss Julia Gardner has completed the manuscript of a monograph on the Mollusca of the Chipola marl, Oak Grove sand, and Shoal River marl members of the Alum Bluff formation; and Dr. C. W. Cooke has completed the field work of a geologic reconnaissance of the Coastal Plain of South Carolina, on a scale of 1:500,000. The results of all this unpublished work have been available to me, and I have utilized them in preparing the correlation table.

The only specific correlations that it seems desirable to discuss in this connection are those of the upper Eocene of Texas. Dumble, in his papers already cited, represents upper Claibornian deposits as being absent in Texas, referring his Fayette and Yegua formations to the lower Claiborne, while the Frio is placed doubtfully in the same division of the Claiborne. The Fayette overlies the Yegua, which is the same as the formation to which I applied the name "Cocksfield Ferry beds" in 1895.<sup>1</sup> In my papers cited below<sup>1</sup> I made it perfectly clear that that formation overlies the lower Claiborne deposits, to which Harris later applied the name St. Maurice formation, and underlies the marine fossiliferous Jackson as exposed on Red River at Montgomery, Louisiana, and that it must include the deposits in Louisiana that are the stratigraphic equivalent of the upper Claiborne, subsequently designated Gosport sand, of Alabama. There was no escape from this correlation at the time I made it, and it has subsequently been repeatedly corroborated by others. Although the basal part of the Yegua is probably the equivalent of the upper part of the lower Claiborne Lisbon formation, the greater part of the Yegua is of upper Claiborne age, and it is the Texas correlative of the Gosport sand of Alabama. Berry's unpublished studies of the middle and upper Eocene floras of southeastern North America supply further corroboration of this correlation, and he authorizes me to say that some of the upper beds of the Yegua may be of lower Jackson age.

So long ago as 1902 Miss Maury published the following statement regarding the Fayette sandstone:<sup>2</sup>

In 1895 Mr. William Kennedy<sup>3</sup> referred both the Fayette sandstone and the Frio, clays to the lower Claiborne because of the presence of *Venericardia planicosta* in the sandstones. Mr. Veatch, during the winter of 1902, has examined the sandstones and finds *Venericardia planicosta* is limited to the basal layers of the formation. These he refers to the Jackson.

<sup>1</sup> Vaughan, T. W., Stratigraphy of northwestern Louisiana, Amer. Geologist, vol. 15, pp. 205-223, pl. 9, 1895; A brief contribution to the geology and paleontology of northwestern Louisiana, U. S. Geol. Survey Bull. 142, pp. 65, 4 pls., 1896.

<sup>2</sup> Maury, Carlotta J., A comparison of the Oligocene of western Europe and the southern United States, Bull. Amer. Paleontology, vol. 3, p. 80, 1902.

<sup>3</sup> Kennedy, William, Eocene Tertiary of Texas, Acad. Nat. Sci. Philadelphia Proc. for 1895, pp. 92, 98, 1895.

I have visited, in company with Mr. Alexander Deussen, the fossiliferous exposures near Wellborn, Texas. I collected fossils and have studied them. I concur with Mr. Veatch in his opinion that they are of Jackson age. Mr. Deussen has traced the formation westward; it is persistent and persistently overlies the Yegua formation at least for some miles beyond Nueces River.<sup>1</sup> The Frio clay overlies the Fayette sandstone, and it contains *Ostrea georgiana*, a species that is abundant in the Jackson formation in Alabama and in the Barnwell formation, which is the correlative of the Jackson formation, in eastern Georgia. The Fayette sandstone and the Frio clay of Texas are the correlatives of the Jackson formation of Louisiana and Mississippi. The following table shows the stratigraphic equivalence:

*Correlation of the middle and upper Eocene of Texas.*

	Mississippi.	Louisiana.	Texas (east of Nueces River).
	Jackson formation.....	Jackson formation.....	{ Frio clay.
	{ Yegua formation.....	Yegua formation.....	{ Fayette sandstone.
	{ Lisbon formation.....	} St. Maurice formation.....	{ Yegua formation.
Claiborne group....	{ Tallahatta bauxstone.....		{ Cook Mountain formation.
			{ Mount Seiman formation.

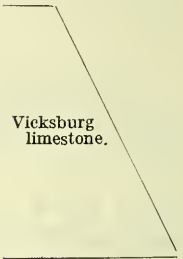
Southward and westward of a line, the location of which is indicated on Deussen's map,<sup>1</sup> there is a change in the strike of the formations. The line passes between Cotulla and Tilden and strikes from about N. 52° W. to S. 52° E.; northeast of it, the strike of the formations is S. 39° W., with a southeastward dip of 48 feet to 1 mile; southwest of it, the strike is N. 19° E., with a dip S. 19° E. of 36 feet to 1 mile. In 1912 Mr. G. C. Matson devoted some months to a field study of the area along Rio Grande seaward of the Eocene-Cretaceous contact, and I accompanied him during a wagon trip from Laredo to Samfordyce. As Mr. Matson has not been able to prepare a report for publication, it is fortunate that I made notes on the exposures we examined, and later the marine fossils collected were studied and identified by Dr. C. W. Cooke and myself. Through out much of its course between Laredo and Roma, Rio Grande is a subsequent stream—that is, its course is along the strike of the formations—and for miles the road is on very nearly the same geologic formation. However, only a short distance eastward from the river higher geologic formations are encountered. The most important difference of the successive formations, as compared with those farther east, consists in the slight development of the lignitiferous Yegua formation, which, apparently, is represented by shoal-water marine sands. The correlative of the Fayette sandstone was not

<sup>1</sup> U. S. Geol. Survey Water-Supply Paper 375, pl. 8, 1916.





Catahoula sandstone.



Jackson formation.

Claiborne group.	Yegua formation.
	St. Maurice formation.

Wilcox formation.

Midway formation.

definitely recognized, but Professor Berry has identified a Jacksonian flora, collected by Mr. Matson, "4½ miles north of Miraflores Ranch, 45 miles southeast of Laredo," and says in a letter: "I consider the Miraflores Ranch outcrops as Fayette sandstone and of lower Jackson age. I am sure that it is not upper Claiborne; in fact, I believe that a part of the Yegua in the Texas area is also lower Jackson in age."

The Frio clay is represented by clays that contain abundant specimens of *Ostrea georgiana*. The importance of these notes in this connection consists in showing that marine deposits of Jackson age extend to Rio Grande, but the strike veers southward in conformity with the trends of the shore of the Gulf of Mexico and of the mountains in eastern Mexico.

CORRELATION OF THE TERTIARY FORMATIONS OF THE SOUTHEASTERN UNITED STATES  
WITH EUROPEAN SUBDIVISIONS OF THE TERTIARY.

Eocene.

As the remarks to be made here are intended to be only a summary, no extensive account of literature will be given. However, it should be mentioned that Dr. W. H. Dall's correlation table, published nearly 20 years ago,<sup>1</sup> is valuable in that it gave a summary of opinion up to 1898 and served as a starting point for subsequent attempts of a similar kind. A comparison of the correlation table of the formations in the southeastern United States here presented with Doctor Dall's shows that during the past 20 years many modifications or changes in opinion have been rendered necessary because of the acquirement of new information.

The most recent discussion of the European equivalence of the lower Tertiary deposits of the Coastal Plain is that of Berry, who in his lower Eocene floras<sup>2</sup> presents the following table of the names applied to the European "stages":

Lower Eocene	{	Ypresian (Dumont, 1849).....	{ Marine facies=Cuisian. Lagoon facies=Laonnian.
		Sparnacian (Dollfus, 1880)=Upper Landenian (Mayer Eymar, 1857).	
Basal Eocene.	{	Thanetian (Renevier, 1873)=Heersian (Dumont, 1849), Lower Landenian (Mayer Eymar, 1857).	
		Montian (Dewalque, 1869)=Paleocene of Von Koenen and others. (Not of Schimper, 1874.)	

Berry says: "Together these stages correspond to the Eonummulitic of Haug (1911), to the Suessonian of D'Orbigny, and to the Paleocene of Schimper (1874), but not to the Paleocene of Von Koenen, Dollo, and others, which is limited to the Montian stage."

<sup>1</sup> Dall, W. H. A table of the North American Tertiary horizons, correlated with one another and with those of western Europe, with annotations, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 323-348, 1898.

<sup>2</sup> U. S. Geol. Survey Prof. Paper 91, pp. 140-152.

A PROVISIONAL CORRELATION TABLE OF THE TERTIARY FORMATIONS OF THE SOUTH ATLANTIC AND EASTERN GULF COASTAL PLAIN OF THE UNITED STATES.

Age of deposits.	North Carolina (south of Hatteras axis).	South Carolina (Santee drainage).	South Carolina and Georgia (Savannah drainage).	Georgia (Chattahoochee drainage).	Florida.	Alabama.	Mississippi.	Louisiana.	
	Fluocene.	Waccamaw marl.	Waccamaw marl.	Not recognized.		Caloosahatchee marl, Nashua marl, Alachua clay, and Bone Valley gravel (largely contemporaneous).	Citronella formation.	Citronella formation.	Citronella formation.
Miocene.	Duplin marl.	Duplin marl.	Duplin marl.		Jacksonville formation.	Choctawhatchee marl.	Pascagoula clay.	Pascagoula clay.	
	Unconformity	Unconformity	Unconformity						
		Edisto marl.	Marks Head marl.						
Oligocene.			Unconformity		Unconformity				
			Alum Bluff formation.	Alum Bluff formation.	Alum Bluff formation.	Alum Bluff formation.	Hattiesburg clay.	Hattiesburg clay.	
					Sheal River marl member.				
Eocene.			Chattahoochee formation.	Chattahoochee formation.	Tampa formation.	Chattahoochee formation.	Catchaula sandstone.	Catchaula sandstone.	
				Unconformity					
				Vicksburg formation.	Vicksburg group.	Marianna limestone (western Florida).	Marianna limestone (with Glendon limestone member).	Byram calc. marl.	Vicksburg limestone.
Eocene.	Castro Hayne limestone. Trent marl.	Cooper marl.	Barnwell formation.	Barnwell formation (with Twigg's clay member).	Ocala limestone.	Ocala limestone.	Ocala limestone.	Jackson formation (with Yazoo clay member and Moody's calc. marl member).	Jackson formation.
							Gesport sand.	Yegua formation.	Yegua formation.
		McBean formation.	McBean formation.	McBean formation.	(Buried.)	(Buried.)	Lisbon formation.	Lisbon formation.	St. Maurice formation.
Eocene.		Congaree shales of Sloan.	(Probably overlapped.)	Wilcox formation.	(Buried.)	(Buried.)	Tallahatta buhrstone.	Tallahatta buhrstone.	Wilcox formation.
		Williamsburg formation.					Chabonne group.	Chabonne group.	
		Black Mingo formation.	(Probably overlapped.)	Midway formation.	(Buried.)	(Buried.)	Hatchaigbee formation.	Hatchaigbee formation.	Wilcox formation.
Eocene.							Wilcox group.	Wilcox group.	
							Nabeola formation.	Nabeola formation.	Midway formation.
Eocene.							Suvarnochee clay.	Suvarnochee clay.	
							Clayton limestone.	Clayton limestone absent or replaced by sand.	





With regard to the age of the Midway flora, he says:<sup>1</sup> "The European floras most similar to that of the Midway (?) are those, likewise poorly represented in marine deposits, of the Montian and Thanetian stages in the so-called Paris Basin in northern France, Belgium, and southeastern England."

He concludes his discussion of the correlation of the Wilcox floras with the following statement:<sup>2</sup> "In view of the foregoing discussion, I have no hesitation in making the most positive statement that the Wilcox flora is largely of Ypresian age. This is rendered conclusive by the exact agreement between the flora of the overlying Claiborne group and that of the Lutetian of Europe, as brought out in my unpublished studies of the Claiborne flora."

The foregoing paragraph contains Berry's opinion in 1916 as to the equivalence of the Claiborne group of the southern United States with the Lutetian of western Europe. This is an old correlation, for it is the same as that made by De Lapparent.<sup>3</sup> More recent studies, not yet published, have led Berry to correlate the Claiborne flora of the southeastern United States with the Auversian of Europe, and he grants me permission to present his conclusion in this connection.

As a part of my discussion of the coral faunas of the Jackson formation and its correlatives, page 198 of this volume, I have expressed my opinion that the Jacksonian of Mississippi and Alabama is the equivalent of the Bartonian-Ludian of western Europe, thereby concurring in a previously expressed opinion of Haug, which is essentially the same as that of De Lapparent.<sup>4</sup> In fact, this opinion seems generally accepted by all geologists who have studied the subject.

#### OLIGOCENE.

That the Vicksburgian Oligocene is the equivalent of the European Tongrian<sup>5</sup>-Sannoisian-Lattorfian has long been recognized and needs only mention in this place.

As a part of the discussion of the coral faunas, pages 199-207 of this volume, I have correlated the basal part of the Chattahoochee formation with the Rupelian-Stampian of western Europe. This conclusion, which seems to me firmly established, is new for the marine Tertiary formations of continental North America.

That the Tampa formation of Florida is the equivalent of the European Aquitanian, which seems to include the Chattian, is generally acknowledged. This is the opinion of W. H. Dall and M. Cossmann,

<sup>1</sup> U. S. Geol. Survey, Prof. Paper 91, p. 11.

<sup>2</sup> *Idem.* p. 152.

<sup>3</sup> De Lapparent, A., *Traité de géologie*, p. 1454, 1900.

<sup>4</sup> *Traité de géologie*, ed. 4, p. 1473.

<sup>5</sup> Maury, Carlotta J., A comparison of the Oligocene of western Europe and the southern United States, *Bull. Amer. Paleontology*, vol. 3, No. 15, pp. 313-404, pls. 20-29, 1902. Here it should be noted that Tongrian has been used in two senses, one as the equivalent of the lower (Lattorfian) and the other as the equivalent of the middle (Rupelian) Oligocene. Miss Maury used it in the former sense.

and apparently Mr. R. B. Newton agrees with them.<sup>1</sup> The papers cited below contain the opinions referred to, and additional references to literature are given in the footnotes to Doctor Dall's paper. On page 211 of this volume, under my discussion of the successive American coral faunas of Tertiary age, the same opinion is expressed. Paleontologists are divided in opinion as to whether the Aquitanian should be referred to the Oligocene or to the Miocene.

From my experience with American faunas I incline to consider it as belonging to the older series. The Rupelian (basal Chattahoochee and Antiguan) fauna has much in common with the Sannoisian-Latterfian (Vicksburgian) faunas, on the one hand, and with the Aquitanian (Tampa) fauna on the other. The failure to discover *Lepidocyclina* at Tampa seems to me of no great value as evidence, for, so far as I am aware, no careful search for Foraminifera has been made in the "silex" bed. Should the specimens not have been destroyed by changes in the sediments subsequent to deposition, it is my expectation that either *Lepidocyclina* or *Heterosteginoides*, or both, will be found at Tampa, for in the Canal Zone both of those genera of Foraminifera are found in association with a fauna that I am correlating with the Tampa, and *Heterosteginoides* occurs in Anguilla. Mr. Newton, in his note cited, states that "Nummulites died out at the end of Oligocene time, being replaced by Lepidocycline Foraminifera in the succeeding Aquitanian and later stages of the Miocene period." This is an unfortunate remark, for the type-species of *Lepidocyclina* is *L. mantelli* (Morton) from the Vicksburgian Oligocene of the Gulf States. It is now known that in Georgia the genus ranges stratigraphically as low in the Eocene as a middle Jacksonian horizon, overlapping the upward range of *Orthophragmina*,<sup>2</sup> and it is probable that it ranges as low as the base of the Jackson formation in Mississippi and Louisiana. *Nummulites panamensis* in the Canal Zone occurs at a horizon very nearly the same as that of the "silex" bed at Tampa. There are important differences between the Tampa and the later fauna of the Chipola marl, which is considered by the students of Florida stratigraphy, except Doctor Dall, as the basal member of the Alum Bluff formation. However, it should be recognized that the presence of the Chipola marl considerably west of the type locality on Chipola River indicates a persistence that may warrant according it formational rank. I am definitely placing the Chipola marl and the higher members of the Alum Bluff formation in the Miocene.

<sup>1</sup> Dall, W. H., Note on the Oligocene of Tampa, Fla., the Panama Canal Zone, and the Antillean region, Malacolog. Soc. Proc., vol. 12, pp. 33, 39, 1916.

Newton, R. B., Remarks on Dr. Dall's paper, *idem*, p. 40.

<sup>2</sup> Generic determinations by Dr. Joseph A. Cushman.



## MIOCENE.

## ALUM BLUFF FORMATION.

In the foregoing paragraph and on pages 219-220, as a part of the discussion of the fossil coral-faunas, I have referred the Chipola marl member of the Alum Bluff formation to the basal part of the Miocene—that is, I correlate it with the base of the Burdigalian of European nomenclature. Unfortunately, information on the basal contact of the Chipola is not adequate. According to the description by Matson and Clapp<sup>1</sup> it conformably overlies the Chattahoochee formation. In 1900 I examined the exposure at the type locality, the McClelland farm on the west side of Chipola River, just south of Ten-mile Creek, Calhoun County, Florida, and corroborated the previous observations of Dall and Stanley-Brown that the marl immediately overlies limestone at the top of the Chattahoochee formation, but did not study the nature of the contact in sufficient detail. Although the evidence is not definite, it is probable that the contact is one of erosion unconformity.

As regards the Mollusca of the Chipola marl, Miss Julia Gardner, who has almost completed a monographic account of them, furnishes me the following statement: "The earlier investigation of the Chipola fauna indicated that 'about 50 per cent of the species in the Chipola beds are peculiar to them; of the others the larger proportion are common to the Tampa *Orthaulax* bed while in the subsequent Oak Grove sands about 24 per cent of the Chipola species survive.'<sup>2</sup>

"Further investigations have, as is usually the case, materially increased the percentage of peculiar forms and materially diminished the percentage of species common to other horizons. The work upon the Chipola fauna is not yet complete but there is every reason to suppose that at least 75 per cent of the species are restricted to the single horizon. Twenty-three of the Tampa gastropods have been considered identical with those from the Chipola. In 18 out of the 23 the resemblances between the Tampa and Chipola forms are too slight to justify their inclusion under the same specific name. Two other species must be discarded for the present, because it has been impossible to find the Tampa individuals referred to them. Only 3 of the 23 remain; *Strombus chipolanus* is represented in the Tampa beds by material too imperfect to determine with complete assurance; *Xenophora conchyliophora* is a species which has persisted with no perceptible change of character from the Upper Cretaceous to the Recent; *Tegula exoleta* apparently initiated in the Tampa persisted throughout the Miocene. The relation between the

<sup>1</sup> Matson, G. C., and Clapp, F. G., A preliminary report on the geology of Florida, with special reference to the stratigraphy, Florida Geol. Survey 2d Ann. Rept., pp. 102, 103, 1910.

<sup>2</sup> Dall, W. H., A monograph of the molluscan fauna of the *Orthaulax pugnar* zone of the Oligocene of Tampa, Fla., U. S. Nat. Mus. Bull. 90, p. 8, 1915.

Tampa and Chipola pelecypods promises to be similar to that between the gastropods. No identical species of any significance has been found, and except a single conspicuous element the entire aspect of the fauna looks forward to the later Tertiary and Recent rather than backward. The presence of *Orthaulax*, that bizarre group so closely associated with the Oligocene of the southeast coast and the Antilles, is the one strong band between the Chipola and the later Oligocene faunas. This archaic type survived the break at the close of the Tampa and continued in considerable abundance throughout the Chipola, but no trace of it has been found in the later formations.

“The affinity between the Oak Grove and Chipola is much closer than the percentage of identical species indicates. Only about 15 per cent of the Chipola forms are common to the Oak Grove, although about 35 per cent of the Oak Grove forms are common to the Chipola. The Chipola fauna is remarkably varied and includes two decidedly distinct facies and a third more obscurely differentiated assemblage. The Oak Grove fauna, on the other hand, is much more uniform; it includes fewer species and has a much larger relative number of individuals. The facies of the Chipola fauna at the type exposure on Chipola River is much more closely allied to the Oak Grove than is the facies developed in the lower bed at Alum Bluff, which contains a rather prominent brackish water element. The third assemblage, a marine fauna known only from Boynton Landing on Choctawhatchee River, has a rather large number of peculiar species. Except *Orthaulax*, the prominent genera of the Chipola fauna on the Chipola River and those of the Oak Grove fauna are the same, and a goodly percentage, probably the majority, of the prolific species of the Oak Grove have closely related analogues in the Chipola fauna as represented on Chipola River. The change following the Chipola was apparently sufficient to exterminate the archaic types, together with a large number of the newer forms. The hardier types, however, survived and were apparently able to flourish with increased abundance in the less densely populated waters of the Oak Grove.”

The Mollusca of this horizon are only remotely related to those of the Tampa formation, which is the stratigraphic equivalent of the upper part of the Chattahoochee formation, while they are closely related to those of the next higher zone, the Oak Grove sand. Because of the faunal kinship and the stratigraphic intergradation of the marl with the typical material of the Alum Bluff formation at Alum Bluff, it is classified with the Oak Grove sand as a member of the Alum Bluff formation.

Berry has described the small flora obtained in the Alum Bluff formation<sup>1</sup> in a paper by him already cited. The fossil plants at

<sup>1</sup> U. S. Geol. Survey Prof. Paper 98 (E), pp. 41-59, pls. 7-10, 1916.

Alum Bluff occur between 12 and 17 feet above the top of the Chipola marl. He says regarding this flora: "It is thus apparent that the Alum Bluff flora can be considered either Aquitanian or Burdigalian, with a slight preponderance of the evidence in favor of the Aquitanian, \* \* \* If the Alum Bluff formation is of Aquitanian or Burdigalian age—and one or the other alternative seems certain—the more or less academic question is raised whether it shall be classed as Oligocene or Miocene."

The floral evidence at least does not contradict considering the Alum Bluff as Burdigalian.

The matrix of the Chipola marl is particularly suited for the preservation of Foraminifera, and they are very abundant; but there are no orbitoid Foraminifera, neither *Lepidocyclina* nor *Heterosteginoides*.

The Bryozoa of the Alum Bluff formation, according to Messrs. Canu and Bassler, are of distinctly Burdigalian affinities. The fauna is particularly characterized by the introduction of certain species that persist until the present time. Two of these species are *Cupularia umbellata* DeFrance and *C. canariensis* Busk, both of which occur in the Chipola marl at its type locality, and both were collected by Doctor MacDonald on Banana River, Costa Rica, in deposits correlated with the Gatun formation, and both occur in the Bowden marl of Jamaica.

The evidence of the fossil corals and of the fossil vertebrates has been discussed on pages 219, 220 of this volume.

#### MARKS HEAD MARL AND CALVERT FORMATION.

The Marks Head marl at Porters Landing, Savannah River, Effingham County, Georgia, has been correlated by me with the Calvert formation of Maryland and Virginia.<sup>1</sup> The most recent discussion of the age equivalence of the Calvert with European horizons is that of Berry in a paper already mentioned.<sup>2</sup> He says, regarding the probable age of the formation: "Seven of the Calvert plants, or 26.9 per cent, are common to the Tortonian of Europe, and ten others, or 38 per cent, are represented in the Tortonian by very similar forms. In view of the fact that these floras spread into both regions from a common and equally accessible source, the evidence that the Calvert flora indicates a Tortonian age is as conclusive as intercontinental correlations ever can be."

According to this correlation of Berry, there is no Helvetian in the Atlantic and Gulf Coastal Plain of the United States.

<sup>1</sup> Vaughan, T. W., The Miocene horizons at Porters Landing, Georgia, Science, new ser., vol. 31, pp. 833, 834, 1910; and in Veatch, O., and Stephenson, L. W., Preliminary report on the geology of the Coastal Plain of Georgia, Georgia Geol. Survey Bull. 26, pp. 362-369, 1911.

<sup>2</sup> U. S. Geol. Survey Prof. Paper 98 (F), pp. 61-73, pls. 11, 12, 1916.



## CHOPTANK AND ST. MARYS FORMATIONS.

Miss Julia Gardner contributes the following statement on these formations: "Because of faunal similarity with the Calvert formation, both the Choptank and the St. Marys formations are also correlated with the Tortonian of Europe, though, of course, they represent horizons slightly higher than that of the Calvert. The Choptank fauna is little more than a sandy bottom facies of the Calvert and is the biologic expression of the physical conditions attending its close. About 60 per cent of the Choptank species are present in the underlying formation, while approximately 30 per cent persist into the overlying St. Marys.

"The St. Marys fauna, though similar to those of the lower formations of the Chesapeake group in the general make-up, is differentiated from them by an influx of new forms and by the absence of those species peculiar to the cooler waters of the Calvert and the sands of the Choptank. The more modern element includes not far from 35 per cent of the entire St. Marys fauna."

## YORKTOWN FORMATION AND DUPLIN MARL.

Miss Gardner has kindly prepared the following statement: "The change in the paleontologic character at the close of the St. Marys is much more significant than that preceding it. Although the percentage of new forms in the Yorktown is not remarkably large, the general facies shows a distinct advance over the St. Marys. The more primitive types, such as *Ostrea compressirostra*, had become extinct or they show an abrupt decrease in prominence, while a number of more advanced types such as *Arca lienosa*, which constitute conspicuous elements in the later faunas, are initiated at this horizon.

"The views advanced by Dall<sup>1</sup> on the approximate synchronicity of the Yorktown and Duplin faunas have been verified by subsequent investigations. Doctor Dall, in his discussion of Tertiary conditions along the East Coast, suggested the elimination of the cool inshore current of the earlier Miocene and the reestablishment of a Tertiary Gulf Stream as the probable cause of the subtropical aspect of the Duplin fauna. This late Miocene warm current apparently hugged the North Carolina shore even more closely than does the present Gulf Stream, but swung off into the open sea in the vicinity of Hatteras so that its influence upon the Yorktown fauna was almost negligible. The sea floor, on which the Duplin marl, as at present known, was deposited, was apparently more sandy than that on which the St. Marys and Yorktown formations were laid down, as the conspicuous abundance in Virginia and northern North Carolina of such a form as *Mulinia congesta* indicates dominantly muddy bottom in some

<sup>1</sup> Dall, W. H., Contributions to the Tertiary fauna of Florida, Wagner Free Inst. Sci. Phila. Trans. vol. 3, pt. 6, p. 1598, 1903.



portions at least of the area covered by deposits belonging to the Chesapeake group, while the profusion of *Oliva literata* and *Olivella mutica* give evidence of extensive sand flats in the area covered by the Duplin marl. Already in the late Tertiary, present day conditions had been approximated along the East Coast. The faunas of Virginia and North Carolina flourished in rather shallow inshore waters into which mud and sand were being freely carried, the waters of the Yorktown basin being slightly but not much warmer than those off the Virginia coast today; while the Duplin fauna was apparently in more direct communication with the Floridian life than are the present faunas off Hatteras and Cape Fear and indicate slightly warmer climatic conditions than do those of the Yorktown."

The Yorktown formation and the Duplin marl are the correlatives of the European stage next younger than the Tortonian, which would be the Sarmatian or Pontian or both.

#### CHOCTAWHATCHEE MARL.

The study that I made of the Mollusca from the Duplin marl as exposed at Porters Landing, Savannah River, Georgia,<sup>1</sup> and of Mollusca from exposures of the same formation in South Carolina, led me to the conclusion that the Choctawhatchee marl of Florida, exposed between Ocklocknee River, on the east, and Choctawhatchee Bay, on the west, is of very nearly the same, if not of the identical, age as the Duplin marl. Therefore, the Choctawhatchee marl and its correlative, the Jacksonville formation of east Florida, are about the same in age as the Sarmatian and Pontian of Europe.

The brackish water Pascagoula clay of the coastal area in Mississippi and Louisiana is probably of about the same age—that is, late Miocene.

#### PLIOCENE.

In the South Atlantic and Coastal Plain of the United States four formations, the Waccamaw marl of the Carolinas, the Nashua and Caloosahatchee marls of Florida, and the Citronelle formation of the Gulf States are definitely considered of Pliocene age. References to literature are not necessary, as they are given in the papers mentioned in the footnotes on pages 565, 566. At present correlation of these formations with the three recognized European stages, Plaisancian, Astian, and Sicilian is not warranted. According to Berry, the flora of "the Citronelle formation belongs in the later half of the Pliocene epoch and is directly ancestral to the Pleistocene and Recent floras of the same region."

<sup>1</sup> Georgia Geol. Survey Bull. 26, pp. 367-369, 1911.

## AGE OF THE SEDIMENTARY FORMATIONS OF PANAMA, AND THE DISTRIBUTION OF THEIR AGE-EQUIVALENTS IN CENTRAL AMERICA AND THE WEST INDIES.

## EOCENE.

The oldest deposit from which Eocene fossils were obtained is a dark-gray argillaceous sandstone near Tonosi. Here specimens of *Venericardia planicosta* closely resembling a variety found at Claiborne, Alabama, were collected. The evidence of one species is meager, but as much as there is points to the deposit being of Claibornian-Lutetian (or Auversian) age.

Deposits of Claibornian age extend as a belt from South Carolina across Georgia into Alabama, thence through Mississippi, eastern Arkansas, Louisiana, and Texas, and into Mexico.<sup>1</sup>

Although deposits of upper Eocene (Jacksonian) age have not been positively identified in Panama, they probably are there. Doctor Cushman inclines to the opinion that the limestone containing *Orthophragmina minima* at David is of upper Eocene age. Upper Eocene deposits occur in Nicaragua, St. Bartholomew, Jamaica, Cuba, in the southeastern and southern United States from North Carolina to Mexico, and probably in northern Colombia. The correlation and distribution of deposits of this age are discussed on pages 193-198 in the account of the fossil coral-faunas. They are the American representatives of the European Bartonian-Ludian-Priabonian stage.

It is highly probable that upper Eocene marine sediments are present on the island of Antigua. Hussakoff has described<sup>2</sup> a fossil fish, *Zebrosoma deani*, from a quarry belonging to Mr. Oliver Nugent. I did not visit this quarry but saw it from a distance. It is at a place known as Golden Grove, which is 1.4 nautical miles nearly due south from the Cathedral in St. John, about 400 feet east of the southern end of a north and south line, and is in a sandstone or bedded tuff that is stratigraphically below the middle Oligocene Antigua formation. I believe Hussakoff is correct in assigning a probably Eocene age to the fossil.

Although it is probable that deposits of upper Eocene age occur in a number of other West Indian islands, Haiti, Porto Rico, the Virgin Islands, St. Croix, Guadeloupe, Martinique, and Barbados, the available evidence is indecisive. Gregory<sup>3</sup> expressed the opinion in 1895 that the Scotland "beds" of Barbados are of lower Oligocene age.

According to Douvillé, in his latest paper<sup>4</sup> on the orbitoids of Trinidad, there are in that island deposits of Lutetian, Auversian, and

<sup>1</sup> See p. 565 of this volume.

<sup>2</sup> Hussakoff, L., *Zebrosoma deani*, a fossil surgeon fish from the West Indies, Amer. Mus. Nat. Hist. Bull., vol. 23, pp. 125, 126, pl. 7, 1907.

<sup>3</sup> Gregory, J. W., Contributions to the paleontology and physical geology of the West Indies, Geol. Soc. London Quart. Journ., vol. 51, p. 298, 1895.

<sup>4</sup> Comptes Rend., vol. 164, pp. 841-847, 1917.

Priabonian age. Miss Maury<sup>1</sup> correlates the basal bed of the exposure at Soldado Rock, Trinidad, with the Midway group of the Gulf Coastal Plain of the United States, but I am not convinced that the fauna is quite so old. In fact, the paleontologic evidence seems to me just about as strongly in favor of the horizon corresponding to one in the Wilcox group. Douvillé is of the opinion that most of Miss Maury's horizons are younger than the age she has assigned them. There are discrepancies between Miss Maury's and Douvillé's correlations that probably can be reconciled only by a critical study of Foraminifera positively known to be associated with the respective beds in which the Mollusca were collected. I have had considerable experience in checking M. Douvillé's results, and, except that he does not understand all of the stratigraphic nomenclature and is greatly confused as to some of the stratigraphic relations in the southeastern United States, I have usually found his deductions as to the age of formations valid. It seems to me that the table in his last paper on the Trinidad orbitoids is correct, except that it seems to me more appropriate to refer the Aquitanian to the Oligocene than to the Miocene.

#### OLIGOCENE.

##### LOWER OLIGOCENE.

The quotation, page 549, from Douvillé indicates the presence on the Haut Chagres of limestone of lower Oligocene (Lattorfian) age, as it contains specimens of *Orithophragmina* (*Asterodiscus*) species in association with *Lepidocyclina* species resembling *L. chaperi*.

Doctor MacDonald collected in the river bed at David, station 6512, *Lepidocyclina macdonaldi*, *L. duplicata*, *L. panamensis*, *Orithophragmina minima*, and *Nummulites davidensis*; at station 6526, in limestone which according to his section immediately underlies the limestone at station 6512, where he obtained *Lepidocyclina* species undetermined and *Nummulites davidensis*; and he found at station 6523, 2 miles north of David, *Lepidocyclina macdonaldi* and *L. duplicata*. These three localities represent very nearly, if not precisely, the same horizon, and have faunal characters very similar to those of the horizon in Trinidad that Douvillé correlates with the "Stampien inférieur," which, according to him, is Lattorfian. It therefore seems that the limestone in and north of David is of lower Oligocene (Lattorfian) age, and is the correlative of the Vicksburg group of the eastern Gulf States of the United States. Doctor Cushman's opinions as to the probable Eocene age of this limestone was given on page 550.

It is probable that the Bohio conglomerate is of this age, for it contains the Oligocene plant, *Taenioxylon multiradiatum* Felix, which

<sup>1</sup> Maury, Carlotta J., A contribution to the paleontology of Trinidad, Acad. Nat. Sci. Philadelphia Journ., ser. 2, vol. 15, pp. 25-112, pls. 5-13, 1912.



also occurs in the Oligocene of Antigua, and according to Doctor MacDonald the Bohio underlies the Culebra formation, the lower part of which seems to be of middle Oligocene age. However, the Bohio may be of middle Oligocene instead of lower Oligocene age.

Romanes reports from Manzanilla, on the Pacific coast of Costa Rica,<sup>1</sup> a cherty rock in which there are remains of Foraminifera, including *Gobigerina* and "a complex form allied to *Tinoporus*," which according to Dr. R. L. Sherlock is "most probably a species of *Orbitoides*." As the so-called species of *Tinoporus* from Trinidad, according to Douvillé, are referable to *Orthophragmina* (*Asterodiscus*), it appears almost certain that the "form allied to *Tinoporus*" mentioned by Romanes is a species of *Asterodiscus*. Dr. J. A. Cushman has examined Romanes's figure,<sup>2</sup> based on a photomicrograph of a thin section of the rock from Manzanilla, and writes me that it shows "*Orthophragmina* and abundant *Globigerina*, and that the rock may be similar to that at David and on Haut Chagres." The evidence is not entirely decisive, but the probability is very strong that the rock from Manzanilla, Costa Rica, is of lower Oligocene (Lattorfian) age as is that at David and on Haut Chagres. It is unfortunate that the box containing Mr. Romanes's most important specimens was lost in transit, but, notwithstanding this loss, he has made a valuable addition to the literature on the geology of Costa Rica.

Hill, in his description of a geologic section from San Jose, Costa Rica, to the coast at Port Limon, says: "At Guallava, the next station east of Las Animas, the Tertiary rocks are of Vicksburg age, according to Dr. Dall."<sup>3</sup> On page 275 of Hill's paper, Doctor Dall lists from this locality "the genuine *Orbitoides manielli*, *Phos*, *Dentalium*, *Plicatula*, *Anomia*, etc., all Vicksburg species."

Between Costa Rica and Mexico there is no definite evidence as to the presence or absence of lower Oligocene deposits, but as Sapper mentions *Nummulites* from Zacualpa, Yucatan, either Eocene or Oligocene occurs at this place;<sup>4</sup> and, judging from the indefinite statements of Sapper, deposits of either Eocene or Oligocene age underlie extensive areas in Chiapas and northern Guatemala.<sup>5</sup>

Felix and Lenk<sup>6</sup> report *Nummulites* and "*Orbitoides*" in northern Chiapas, from collections made by Karsten, and refer them to the Eocene, but sufficient data are not given to decide whether the

<sup>1</sup> Romanes, J., Geology of a part of Costa Rica, Geol. Soc. London Quart. Journ., vol. 68, pp. 130, 131, pl. 9, fig. 4, 1912.

<sup>2</sup> Idem., pl. 9, fig. 4.

<sup>3</sup> Hill, R. T., The geologic history of the Isthmus of Panama and portions of Costa Rica, Mus. Comp. Zool. Bull., vol. 28, No. 5, p. 232, 1898.

<sup>4</sup> Sapper, Carlos, La geographia física y la geologica de la Peninsula de Yucatan, Mexico Inst. geol. Bol. 3, p. 7, 1896.

<sup>5</sup> Petermann's Mittheil., Ergänzungs vol. 27, Ergänzungsheft. 127, p. 67, 1899.

<sup>6</sup> Felix, J., and Lenk, H., Ueber das Vorkommen von Nummulitenschichten in Mexico, Neues Jahrb. für Min. Jahrg. 1895, vol. 2, pp. 208-209, 1895.



deposits are of Eocene or Oligocene age. Aurelius Todd collected at Tumbala, Chiapas, station 6403 U.S.N.M. register, *Lepidocyclina* in quantity and a *Nummulites* possibly allied to a species described by Cushman from St. Bartholomew. Cushman says, "I should say that the material represents a lower Oligocene horizon."

*Lepidocyclina* and other Foraminifera that appears to be nummulitic were obtained by P. C. Steward and C. W. Washburne 500 meters southeast of Peçero, 8 leagues southwest of Ozuluama, Vera Cruz, Mexico, station 5462 U.S.N.M. register. Doctor Cushman says that at best some of this material is from strata of Oligocene age, but he does not express an opinion as to what part of the Oligocene it represents.

Lower Oligocene deposits probably occur in eastern Mexico, north of the Tamaulipas Range, for Dumble reports a *Pecten* recalling *Pecten poulsoni* Morton, specimens identified by Doctor Dall.<sup>1</sup> South of that range, the same author records "*Orbitoides papyracea*, *Cristellaria*, and *Nummulites*, from the Buena Vista to the Tancochin at Cerro del Oro."<sup>2</sup> The paleontologic evidence is indecisive, for the "*Orbitoides papyracea*" is certainly misidentified; but the specimens probably represent a large species of *Lepidocyclina*, of the kind abundant in the lower Oligocene and upper Eocene of the southeastern United States and in the middle Oligocene of Antigua and Georgia. The deposits from which the Foraminifera were obtained may be of upper Eocene or of upper or middle Oligocene age, but the probability is that they are lower Oligocene in age.

No marine Oligocene deposits are known in the State of Texas. Berry reports *Palmoxyloa texense* Stenzel, from 5 miles north of Jasper, Texas, from "beds of Vicksburg age,"<sup>3</sup> and states that "Unstudied material indicates the probable presence of this species at several localities in the Catahoula sandstone of Texas and in the Vicksburg limestone of Alabama." There is marine lower Oligocene in Louisiana at Rosefield, near Washita River; and east of Mississippi River it outcrops in a belt running from Vicksburg eastward to Georgia and Florida.

Marine deposits in Cuba have been questionably referred to the lower Oligocene, but a definite opinion must be withheld until Doctor Cushman has completed his study of the Cuban orbitoid Foraminifera.

The geologic formation in Jamaica to which Hill applied the name Montpelier white limestone<sup>4</sup> contains many Foraminifera,

<sup>1</sup> Dumble, E. T., Tertiary deposits of northeastern Mexico, California Acad. Sci. Proc., ser. 4, vol. 5, p. 188, 1915.

<sup>2</sup> Dumble, E. T., Some events in the Eocene history of the present coastal area of the Gulf of Mexico in Texas and Mexico, Journ. Geol., vol. 23, No. 6, p. 496, 1915.

<sup>3</sup> Berry, E. W., The flora of the Catahoula sandstone, U. S. Geol. Survey Prof. Paper 98 (M), pp. 235, 236, pl. 56, 1916.

<sup>4</sup> Hill, R. T., The geology and physical geography of Jamaica, Mus. Comp. Zool. Bull., vol. 34, pp. 137-144, 1899.

one of which was identified by Bagg as *Orbitoides mantelli*, and is definitely correlated by Hill with the Vicksburg deposits of Mississippi. The identification of *Orbitoides* (*Lepidocyclus*) *manicelli* is subject to doubt, and the doubt attaching thereto affects the validity of Hill's correlation. However, the fact that the Montpelier limestone overlies the upper Eocene Cambridge formation and that a stratigraphic break occurs between it and the Bowden marl is strong stratigraphic evidence in favor of the correctness of Hill's opinion. The stratigraphic evidence leads to the supposition that the orbitoidal Foraminifera belong to the genus *Lepidocyclus*, and their having been identified as *Orbitoides mantelli* indicates that they have the form of that species. From the available evidence I consider Hill's conclusion justified, but until the Foraminifera have been critically studied the correlation is only tentative.

Hill<sup>1</sup> presents a correlation of Tippenhauer's columnar section for the island of Haiti with the Jamaican formations. Tippenhauer gives very meager information on the paleontology of Haiti, but he does say that the yellow limestone, the formation overlying Eocene conglomerate, contains "*Orbitoides*."<sup>2</sup> Gabb mentions the abundance of "*Orbitoides*" in Santo Domingo,<sup>3</sup> but his statements are indefinite. It will later be made clear (p. 591 of this volume) that orbitoid Foraminifera are absent in Santo Domingo in deposits of the same age as and younger than the Bowden marl. The orbitoidal limestones of Santo Domingo are therefore older than the Miocene of Rio Gurabo, etc., and are probably of lower or middle Oligocene age, although they may be of upper Oligocene age. Additional stratigraphic and paleontologic work is needed before reliable conclusions on these matters are possible.

There is at present no information that suggests the presence of lower Oligocene marine deposits in the West Indies east and south of Haiti. At the base of the Pepino formation in Porto Rico and of the Antigua formation in Antigua there are erosion unconformities, indicating periods of uplift during the lower Oligocene. I have not been able to procure information on Guadaloupe or Martinique that would serve as a basis for an opinion on the age of the lower formations in these islands.

On the island of Trinidad lower Oligocene (Sannoisian and lower Stampian of Douvillé)<sup>4</sup> is well developed.

There is no information on northern South America.

<sup>1</sup> The geology and physical geography of Jamaica, p. 172.

<sup>2</sup> Tippenhauer, L. G., Die Insel Haiti, vol. 1, pp. 86, 87, 1892.

<sup>3</sup> Gabb, W. M., On the topography and geology of Santo Domingo, Amer. Philos. Soc. Trans., new ser., vol. 15, p. 96, 1873.

<sup>4</sup> Douvillé, H., Les Orbitoides de l'île de la Trinité, Comptes Rend., vol. 161, pp. 87-92, 1915; Les Orbitoides de l'île de la Trinité, Idem, vol. 164, pp. 841-847, 1917.

## MIDDLE OLIGOCENE.

As stated on page 203 in the discussion of the coral faunas, the Antiquan Oligocene must, in my opinion, be taken as the type formation and type locality of the middle (Rupelian) Oligocene of America. I have definitely correlated with this horizon the reef-coral fauna from Tonosi, Panama, station 6587, which I consider to be the stratigraphic equivalent of the lower part of the Culebra formation. *Lepidocyclus panamensis* and *L. duplicata* are associated Foraminifera. The presence of marine deposits of this age in Antigua, Porto Rico, Santo Domingo, Cuba, Florida, Alabama, and eastern Mexico has been mentioned on pages 199-207.

Messrs. Roy E. Dickerson and W. S. W. Kew have recently published a paper<sup>1</sup> in which they say: "most of the localities listed below appear to belong to the San Fernando formation of Dumble." This name is invalid, because it is preoccupied by the name of certain formations in Trinidad, and has been renamed San Rafael formation by E. T. Dumble. On page 205 of this volume I correlate it with the middle Oligocene Antigua formation, the basal part of the Chattahoochee formation, and the European Rupelian, on the basis of the corals, which possess no such heterogeneous stratigraphic affinities as the fossils recorded by Messrs. Dickerson and Kew. I will not here undertake to analyze the fauna they report, but will say that it contains names of species of upper Eocene (Jackson-Ludian), lower Oligocene (Vicksburgian-Lattorfian), upper Oligocene (upper Chattahoochee-Tampa-Aquitania), and lower Miocene (lower part of the Alum Bluff and the higher horizon represented by the Bowden marl-Burdigalian) age. In fact their list includes nearly every horizon from upper Eocene almost to middle Miocene. I will not attempt to explain this surprising paleontologic assemblage as the collections may represent a number of horizons, the species may be misidentified, or some of the species may have extraordinary stratigraphic ranges; and it will be mentioned that, as in at least one instance Cotteau made an error in stating the locality at which the type of a species was collected, there is some confusion for which Messrs. Dickerson and Kew are not responsible. An attempt will be made to remove in the forthcoming memoirs on West Indian paleontology as much of this kind of confusion as is possible.

West of Alabama in Mississippi and Louisiana there are plant-bearing beds of middle Oligocene age, for a considerable part of the Catahoula sandstone is certainly of that age, but that formation seems to include beds of lower, middle, and probably upper Oligocene age. No middle Oligocene deposits are known in Texas. There is no

<sup>1</sup> The fauna of a medial Tertiary formation and the associated horizons of northeastern Mexico, California Acad. Sci. Proc., vol. 7, pp. 125-156, pls. 17-26a, 1917 (date printed with title July 30, 1917; received by me Oct. 16, 1917).



information on Central American between Mexico and Panama, nor is there any on northern South America.

H. Douvillé<sup>1</sup> has referred the "couches de San Fernando" of Trinidad to what he designates "Chattien et Tongrien" or "Stampien supérieur." The species of Foraminifera occurring at this horizon, according to Douvillé, are *Nummulites* cf. *N. vascus*, *Lepidocyclina* (*Isolepidina*)<sup>2</sup> *pustulosa*, *L. (Isolepidina)* "du type ogival," *L. (Eulepidina)* *formosa*, *L. (Eulepidina)* cf. *L. dilatata*. The species in Panama that would represent about the same horizon, according to my interpretation, are *Lepidocyclina panamensis* and *L. multiplicata*, stations 6586e and 6587 (see page 555). *L. panamensis*, it should be stated, may range upward into the Emperador limestone, but this is not certain.

The evidence for Barbados is not altogether decisive. Franks and Harrison<sup>3</sup> present the following classification of the Barbadian formations:

Pleistocene and Pliocene.....	} Low-level reefs. High-level reefs. <i>Globigerina</i> -marls.
Miocene.....	Oceanic series. Break.
Eocene or Oligocene.....	Scotland beds.

The *Globigerina*-marls are referred to in the section on page 544 of the paper cited, as the Bissex Hill "beds." The only comment I will here make on this section is that it seems to me physically impossible to have a fringing reef conformably built on *Globigerina* ooze deposited in water 1,000 fathoms deep.

After bringing to bear on the problem of the age of the Scotland beds the information accumulated by R. J. L. Guppy, Harrison and Jukes-Browne, and others, as well as that obtained through his own studies, Gregory says:<sup>4</sup> "It is therefore advisable at present to correlate the whole of the beds in Barbados below the Oceanic Series with the San Fernando or Naparima marls of Trinidad. Guppy has recently referred these (and the lower part, at least, of the Scotland beds, goes with them) to the Eocene. They are, however, now generally assigned to the Oligocene, as, for example, by Heilprin."

A preceding paragraph of this paper contains Douvillé's correlation of the "couches de San Fernando" of Trinidad, with the "Stampien

<sup>1</sup> Les Orbitoïdes de l'île de la Trinité, Comptes. Rend., vol. 116, pp. 87-92, 1915.

<sup>2</sup> This subgeneric name is invalid, for it is proposed for *Lepidocyclina mantilli*, which is the type-species of *Lepidocyclina*. The name should be written *Lepidocyclina (Lepidocyclina) pustulosa* or [*Lepidocyclina*] *Lepidocyclina pustulosa*.

<sup>3</sup> Franks, G. F., and Harrison, J. B., The *Globigerina*-marls [and basal reef-rocks] of Barbados, with an appendix on the Foraminifera by F. Chapman, Geol. Soc. London Quart. Journ., vol. 54, pp. 540-555, 1898.

<sup>4</sup> Gregory, J. W., Contributions to the paleontology and physical geology of the West Indies, Geol. Soc. London Quart. Journ., vol. 51, pp. 255-310, pl. 11, 1895.



supérieur," which is Rupelian. Should the correlation of the Scotland "beds" with the San Fernando be valid, the Scotland "beds" are of the same age as the Antigua formation of Antigua, and corroborates the opinion expressed by Gregory.

Allusion will here be made to two species of fossil corals, that were submitted to me by Dr. J. W. Spencer and were said to have been collected in Barbados, near the Cathedral at Bridgetown; and I gave him the generic names used in his paper referred to below.<sup>1</sup> The specimens are no longer accessible to me, but I have photographs of the species I listed as *Astrocoenia* species, which is the species to which I have applied the name *Astrocoenia portoricensis*, page 350 (pl. 76, figs. 4, 4a, pl. 78, figs. 1, 1a) of this volume; and I have notes on the other species, referred to by me as *Siylophora*, species. The latter species, as well as *Astrocoenia portoricensis*, is exceedingly abundant in Antigua, where I collected between 60 and 70 specimens. It has six septa and a styloform columella, characters that led me to refer it to *Siylophora*, but as there are well-developed styles in the corners between many corallites, I am now placing it in *Siylocoenia*. As these two species not only occur in Antigua, but as the matrix, yellowish clay, in which the specimens were embedded is similar to that usual in Antigua, I have wondered if the specimens did not really come from that Island, and not from Barbados.

Messrs. Harrison and Jukes-Browne, it seems, became much excited over the reported occurrence in Barbados of the two species of corals mentioned above.<sup>2</sup> I will not enter the controversy between these authors and Doctor Spencer further than to say that if the two species whose tentative identification I gave Doctor Spencer actually came from Barbados, their evidence is decisive as to beds of the age of the Antigua formation being in Barbados, and that the evidence of the corals is in accord with Gregory's correlation of the Scotland "beds"; but if the specimens were obtained at the locality at which Doctor Spencer says he found them, the Scotland "beds" must be very near the surface in Bridgetown, and the veneer of the elevated coral-reef limestone decidedly thin. The area 2.75 miles northeast of Bridgetown is indicated on Messrs. Harrison and Jukes-Browne's geological map of Barbados as "limestone probably underlain here by Scotland beds." Careful search should be made for corals in the material underlying the elevated reef in Bridgetown, and if the older coral-fauna is there, additional specimens will almost certainly be found, for the two species reported from there are usually represented not by occasional but by numerous specimens, if present at all.

<sup>1</sup> Spencer, J. W., On the geological and physical development of Barbados; with notes on Trinidad, Geol. Soc. London Quart. Journ., vol. 58, pp. 354-365, 1902.

<sup>2</sup> Harrison, J. B., and Jukes-Browne, A. J., The geology of Barbados, Geol. Mag., vol. 9, pp. 550-554, Dec. 4, 1902.

According to Hill<sup>1</sup> this epoch is represented in Jamaica by an erosion unconformity that intervenes between the Montpelier white limestone and the Bowdon marl. The orbitoids and nummulites of Jamaica are greatly in need of critical study. It is entirely probable that part of Hill's Montpelier limestone is of middle Oligocene (Rupelian) age.

## UPPER OLIGOCENE.

It is my opinion, as expressed on a previous page (555), that the upper part of the Culebra formation and the Emperador limestone are the correlatives of the European Aquitanian, and on page 571 I have given my reasons for preferring to refer the Aquitanian to the upper Oligocene rather than to the basal Miocene. The reference of the upper part of the Culebra formation, in which *Lepidocyclina canellei* R. Douvillé and Lemoine and *L. chaperi* R. Douvillé and Lemoine occur, to the upper Oligocene is old, for it was first published by H. Douvillé in 1898.<sup>2</sup> Later<sup>3</sup> he refers the beds in which *L. canellei* is found to the upper Aquitanian, which he considers lower Miocene. M. Douvillé apparently is confused as regards the stratigraphic relations of *L. chaperi*, for the section, station 6019e-f, page 538, shows that it occurs stratigraphically above *L. canellei*, station 6019a, page 538, in Gaillard Cut.

As has been said, I correlate that part of the Culebra formation in which *Lepidocyclina canellei*, *L. chaperi*, *L. voughani*, *Heierosteginoides panamensis*, *Nummulites panamensis*, *Orbitolites americana*, and the corals listed on page 208, with the upper half of the Chattahoochee formation of Georgia and Florida and a part of the Tampa formation of Florida, and I consider it the American correlative of the European Aquitanian-Chattian.

The Emperador limestone is paleontologically very closely related to the underlying top of the Culebra formation. In fact, except in the Canal Zone, where they are separable because of lithologic differences, it seems to me doubtful if the horizons represented by them can be positively identified.

As a part of my discussion of the fossil corals it was necessary for me to discuss the geographic distribution of coralliferous deposits of this age in America. Besides those in Panama, marine deposits of the same age also occur in Anguilla, probably in Porto Rico, in Cuba, Florida, and Georgia, and H. Douvillé's researches on the Foraminifera of Trinidad show their presence on that island. It is probable that they are also present in Martinique, Santo Domingo, and eastern Mexico, but precise data are lacking.

<sup>1</sup> Hill, R. T., The geology and physical geography of Jamaica, Mus. Comp. Zool. Bull., vol. 34, p. 143, 1899.

<sup>2</sup> Douvillé, H., Sur l'âge des couches traversées par le Canal de Panama, Soc. Géol. France Bull., vol. 26, pp. 587-600, 1898.

<sup>3</sup> Douvillé, H., Les couches à orbitoïdes de l'isthme de Panama, Idem., séance du 20 décembre 1915, pp. 129-131, 1916.

Recently Dr. Sidney Powers has presented to the United States National Museum some specimens he collected at the entrance to Rio Dulce, Guatemala. The rock is a massive light-colored, fine-textured limestone, with a conchoidal fracture, and contains many poorly preserved fossils. Among the fossils are *Orbitolites* species; several corals, one of which resembles *Siderastrea*, another is probably a specimen of *Goniopora*, and a third seems to be a branching poritid coral that looks precisely like a coral obtained by Doctor MacDonald in limestone, referred by him to the Emperador limestone, in the swamp north of Ancon Hill and about one-quarter of a mile south of Diablo Ridge, Canal Zone; and there are specimens of *Ostrea*, *Pecten*, and *Lima*. This material is too poor to warrant a positive opinion, but it is worth noting, and it probably represents a horizon very near that of the Emperador limestone.

According to Hill's account of the stratigraphic succession in Jamaica, the correlatives of these uppermost Oligocene deposits are represented there by a stratigraphic break, the unconformity between the Montpelier white limestone and the Bowden marl.

#### MIOCENE.

The definite correlation of the Canal Zone Miocene with European horizons was first attempted by H. Douvillé in his paper, already cited, on the age of the deposits along the Panama Canal. He says regarding the deposits overlying those discussed in the foregoing remarks: "Leur âge est incontestablement Miocène."<sup>1</sup> He considers the lower part of these deposits as Burdigalian, the upper part as Helvetian in age. That part of the Gatun formation exposed at Monkey Hill is referred to the Helvetian.

The literature on the age of the Gatun formation is considerable, but a lengthy review of it appears unnecessary. The papers by Toula and by Pilsbry and Brown have already been cited on page 560 of this volume. Actually there is in most cases more apparent than real discrepancy between the correlations of the different investigators, due to the fact that the Alum Bluff formation, including the Chipola marl member at its base, has been referred to the upper Oligocene. The Alum Bluff formation is certainly of Miocene age, according to European usage, and is the American equivalent of the Burdigalian. All available evidence indicates that the lower part of the Gatun formation in the Canal Zone is the equivalent of the Alum Bluff formation of Florida and Georgia. Although the Gatun formation contains numerous species of Foraminifera, echinoids, and Crustacea, the fauna is predominantly molluscan, and the discrimination of zones within it must await the completion of the study of the careful zonal collections Doctor MacDonald and I

<sup>1</sup> Soc. Géol. France Bull., vol. 26, p. 599, 1898.



made. At present I have not strong evidence, but it is nevertheless my belief that, while the lower part of the formation is of Burdigalian, the upper part is of Helvetian age, as Douvillé in essence said so long ago as 1898. This would still signify that the Gatun formation is geologically older than the Miocene of the Chesapeake group in Maryland and Virginia and the Marks Head, Duplin, and Choctaw-hatchee marls of the Carolinas, Georgia, and Florida.

Deposits of old Miocene (Burdigalian = Alum Bluff) age are widely distributed around the perimeters of the Gulf of Mexico and the Caribbean Sea. The Gatun formation extends from Panama into Costa Rica on one side and into Colombia on the other. The lists of corals, Bryozoa, and Crustacea already given show the extension into Costa Rica. Pilsbry and Brown<sup>1</sup> say regarding a collection from near Cartagena, Colombia, that it is from beds "about equivalent in age to the Gatun in the Canal Zone." They record the following species:

*Fossil mollusks from near Cartagena, Colombia.*

<i>Conus proteus</i> Hwass.	<i>Polinices mammillaris</i> (Lamarck).
<i>molis</i> Brown and Pilsbry.	<i>Potanides avus</i> Pilsbry and Brown.
<i>imitator</i> Brown and Pilsbry.	<i>Turritella cartagenensis</i> Pilsbry and Brown.
<i>aemulator</i> Brown and Pilsbry.	<i>lloydsmithi</i> Pilsbry and Brown.
<i>gaza</i> Pilsbry and Johnson.	<i>subgrundifera</i> Dall.
<i>Turris cartagenensis</i> Pilsbry and Brown.	<i>tornata</i> Guppy.
<i>Drilla gatunensis</i> Toula.	<i>Petalococonchus domingensis</i> Sowerby.
<i>Cancellaria dariena</i> Toula.	<i>Dentalium solidissimum</i> Pilsbry and Brown.
<i>Mitra longa</i> Gabb.	<i>cartagenense</i> Pilsbry and Brown.
<i>Marginella medioeris</i> Pilsbry and Brown.	<i>Pitar (Hystreroconcha) casta</i> Pilsbry and
<i>Oliva sayana immortua</i> Pilsbry and Brown.	Brown.
<i>Strombina cartagenensis</i> Pilsbry and	<i>Yoldia pisciformis</i> Pilsbry and Brown.
Brown.	<i>Arca consobrina</i> Sowerby.
<i>lloydsmithi</i> Pilsbry and Brown.	<i>Glycymeris tunefactus</i> Pilsbry and Brown.
<i>Solenosteira dalli</i> Brown and Pilsbry.	<i>trilobocosta</i> Pilsbry and Brown.
<i>Murex gatunensis</i> Brown and Pilsbry.	<i>lloydsmithi</i> Pilsbry and Brown.
<i>pomum</i> Gmelin.	<i>Ostrea sculpturata osculum</i> Pilsbry and
<i>Typhis linguiferus</i> Dall.	Brown.
<i>Cassis monilifera</i> Guppy.	

In 1916, Mr. George C. Matson was engaged in geologic work in northern Colombia, near Usiacuri, and sent to the United States National Museum collections of fossils for use in comparing with those from the Canal Zone and Costa Rica. Dr. C. W. Cooke, before being detailed to other work, had prepared preliminary lists of the species of mollusks received up to the time he had to undertake other duties.

<sup>1</sup> Pilsbry, H. A., and Brown, A. P., Oligocene fossils from the neighborhood of Cartagena, Colombia, with notes on some Haitian species, Philadelphia Acad. Nat. Sci. Proc. for 1917, pp. 32-41, pls. 5, 6, 1917.



*Preliminary list of fossils from Colombia.*

(All determinations subject to revision.)

By CHARLES WYTHE COOKE.

7852. Las Sierras, between el Carmen and Zambrano; from surface on top of knoll. F. L. Wilde, collector, December 8, 1916.

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|---|--|
| <i>Conus</i> , probably <i>C. imitator</i> Brown and Pilsbry.<br>2 species. | <i>Turritella gatunensis</i> Conrad.<br><i>altilira</i> Conrad.<br><i>mimetes</i> Brown and Pilsbry.<br>species. |
| <i>Terebra gatunensis</i> Toula.<br><i>subsulcifera</i> Toula.              | <i>Architectonica gatunensis</i> (Toula).<br><i>Natica</i> , several species.                                    |
| <i>Drillia gatunensis</i> (Toula)?  | <i>Cheilea princetonia</i> Brown and Pilsbry?  |
| <i>Turris barretti</i> (Guppy)?   | <i>Crucibulum</i> species.   |
| <i>Cancellaria dariena trachyostraca</i> Brown and Pilsbry?<br>2 species.   | <i>Arca</i> .<br>species.  |
| <i>Oliva gatunensis</i> Toula?  | <i>Pecten</i> species.   |
| <i>Marginella</i> species.  | <i>Corbula</i> ( <i>Cuneocorbula</i> ) <i>hexacyma</i> Brown and Pilsbry.  |
| <i>Latirus</i> aff. <i>L. protractus</i> (Conrad).                          | <i>Chama</i> species.  |
| <i>Strombina gatunensis</i> (Toula).  | <i>Veneridae</i> , several species.  |
| <i>Distorsio gatunensis</i> Toula.  |  |

## Correlation: Gatun formation.

7873. About one-half kilometer east of Usiacuri, Colombia. G. C. Matson, collector.

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|--|---|
| <i>Septastrea matsoni</i> Vaughan.   | <i>Natica</i> species (very close to a species from Shell Bluff, Shoal River, Florida). |
| <i>Terebra</i> cf. <i>T. gausapata</i> Brown and Pilsbry<br><i>gatunensis</i> Toula.                 | <i>Natica</i> , 2 species.  |
| <i>Conus dalli</i> Toula.<br>2 species.  | <i>Neretina</i> species.  |
| <i>Turritidae</i> , several species.   | <i>Niso</i> species.  |
| <i>Cancellaria</i> , 3 species.  | <i>Pyramidella</i> species.   |
| <i>Olivella</i> , several species.   | <i>Architectonica gatunensis</i> Toula.   |
| <i>Mitra longa</i> Gabb?   | <i>Capulus</i> species.   |
| <i>Fusinus</i> species.  | <i>Calyptrea</i> species.   |
| <i>Latirus</i> species.  | <i>Glycymeris</i> new species.  |
| <i>Alectrion</i> species.  | <i>Arca</i> aff. <i>A. grandis</i> Brown and Pilsbry.                                   |
| <i>Columbellidae</i> , several species.  | <i>Arca</i> new species.  |
| <i>Murex</i> species.  | <i>Ostrea</i> species.  |
| <i>Typhis</i> species.   | <i>Pecten</i> species.  |
| <i>Turritella mimetes</i> Brown and Pilsbry.<br><i>altilira</i> Conrad.<br><i>gatunensis</i> Conrad. | <i>Amusium</i> large species.   |
| <i>Petaloconchus domingensis</i> Sowerby?  | <i>Venericardia</i> species.  |
|  | <i>Chione</i> species.  |
|  | <i>Corbula</i> , 2 species.   |
|  | <i>Mactra</i> species.  |

## Correlation: Gatun formation.

7855. Two kilometers west of Usiacuri, Colombia.

*Arca* aff. *A. grandis* Broderip and Sowerby.

Correlation: Probably Gatun formation.

7856. Three kilometers north of Usiacuri, Colombia.

<i>Oliva</i> species.	<i>Ostrea</i> species.
<i>Cancellaria</i> species.	<i>Pecten</i> species.
<i>Petalococonchus dominigensis</i> Sowerby?	<i>Anomia</i> species.
<i>Turritella gatunensis</i> Conrad.	<i>Basta</i> species.
species.	<i>Cardium</i> species.
<i>Glycymeris</i> species (also at 7873).	<i>Chione</i> species.
<i>Arca</i> aff. <i>A. grandis</i> Broderip and Sowerby	Barnacle.

Correlation: Probably Gatun formation.

7874. River bed at Usiacuri, Colombia. G. C. Matson, collector.

*Ostrea* species, like that at station 7859.

7857. Weathered surface of calcareous hard sandstone at San Antonio, 18 miles east of Tenerife, Colombia. Rogers and Wilson, collectors.

<i>Terebra</i> 2 species.	<i>Turritella altilira</i> Conrad.
<i>Turris</i> , like <i>T. albida</i> (Perry).	<i>Cerithium</i> , 2 species.
<i>Cancellaria</i> cf. <i>C. guppyi</i> Gabb.	<i>Chama</i> species, etc.

7858. Creek bed at San Antonio. Same bed as 7857.

<i>Cerithium</i> species.	<i>Scapharca</i> species.
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7859. Creek at San Antonio.

<i>Scapharca</i> cf. <i>S. chiriquiensis</i> (Gabb).	<i>Ostrea</i> species, etc.
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Other material was forwarded by Mr. Matson, but it has not been examined.

Marine deposits of similar age are found in Venezuela at Cumana and in Trinidad. R. J. L. Guppy has published two interesting papers<sup>1</sup> in which he compares the species found at Springvale, Trinidad, with species from Cumana (Venezuela), Jamaica, and Haiti. Douvillé, in his account of the orbitoids of Trinidad, places the "couches de Cumana à *Turritella tornata*" in the Burdigalian.

The "Oceanic Series" of Barbados (see p. 583 of this paper) is referred to the Miocene by all the recent students of that island. They are deposits supposed to have been laid down in water at least 1,000 fathoms deep, as they contain beds of radiolarian earth and specimens of a deep-sea echinoid, *Cystechinus crassus* Guppy.

H. Douvillé reports *Lepidocyclina giraudi* R. Douvillé from the "Burdigalien de la Martinique."<sup>2</sup> Subsequently (p. 591) Mollusca from Martinique, thought by M. Cossmann to represent a higher horizon, will be considered.

<sup>1</sup>Guppy, R. J. L., On a collection of fossils from Springvale, near Couva, Trinidad, Trinidad Agric. Soc. Paper No. 440, pp. 15, 1911; Fossils from Springvale, near Couva, Trinidad, Idem., Paper No. 454, pp. 10, 3 pls., 1911.

<sup>2</sup>Comptes Rend., vol. 161, p. 89, 1915.

Dall said, in 1903, regarding the age of the Bowden marl of Jamaica:<sup>1</sup> "It is perhaps with the Oak Grove sands, or between the Chipola and the Miocene, that the position of the Bowden fauna would be marked most plausibly against the Tertiary column of Florida formations."

This correlation has essentially been made by students of other groups of organisms, but instead of considering the Bowden of Oligocene age, they refer it to the Miocene. W. P. Woodring, in a recently published summary of his conclusions based upon a study of the Bowden pelecypods,<sup>2</sup> says: "Though many of the post-Chipolan elements are found among the characteristically tropical groups, yet the introduction of superspecific groups, some of which are not exclusively tropical, can hardly be disregarded. The Bowden pelecypods are distinctly younger than those of the Alum Bluff faunas, as these faunas are now known. It may be suggested that the Bowden fauna is Burdigalian, that is, lower Miocene in the sense of most American stratigraphers."

Dr. J. A. Cushman, from his study of the Foraminifera, and Messrs. Canu and Bassler from their investigations of the Bryozoa consider the Bowden fauna Miocene. My opinion, based upon the fossil corals (see pp. 212, 213 of this volume), is the same as that of the authors mentioned. Until the results of Miss Gardner's work on the Mollusca of the Alum Bluff formation are tabulated and comparisons made with the Bowden fauna, only approximate correlation is practicable. It is my opinion that the Bowden is equivalent to a horizon high in the Alum Bluff, perhaps about that of the Shoal River marl. In other words, the Bowden corresponds to upper rather than to lower Burdigalian.

There are in Santo Domingo at least three Miocene horizons, according to the results recently obtained there by Miss C. J. Maury.<sup>3</sup> She transmitted the Foraminifera, corals, echinoids, and Bryozoa to me for study in connection with the investigation of the stratigraphic paleontology of Central America and the southern United States, and Miss M. J. Rathbun has delivered to me a manuscript in which she has included descriptions of the fossil Crustacea collected by Miss Maury. Besides Miss Maury's report on the Mollusca, I am able to use Doctor Cushman's report on the Foraminifera, my own on the corals, Doctor Jackson's on the echinoids, Messrs. Canu and Bassler's on the Bryozoa, and Miss Rathbun's on the Crustacea. Miss Maury's zone H on Rio Cana is the same horizon as the Bowden; and she considers her zones G and I to be the same

<sup>1</sup> Dall, W. H., Tertiary fauna of Florida, Wagner Free Inst. Sci. Trans., vol. 3, pt. 6, p. 1582, 1903.

<sup>2</sup> Woodring, W. P., The pelecypods of the Bowden fauna, Johns Hopkins Univ. Circular, March, 1917, pp. 242-254, 1917.

<sup>3</sup> Maury, Carlotta J., Santo Domingo type sections and fossils, Bull. Amer. Paleontology, vol. 5, pp. 165-459, pls. 28-65, 1917.

horizon as her zone H. The age of the Santo Domingan corals is discussed on page 218 of this volume. The Foraminifera, among which are no orbitoids, and the Bryozoa, both groups abundantly represented, give essentially the same result as the corals. Messrs. Canu and Bassler consider the Bryozoa from zones H-I as of unquestionably Burdigalian age.

This same horizon, that of the Bowden, has been recognized at numerous places in Cuba, as has been stated in discussing the fossil coral faunas of Cuba (p. 218). It has been identified at Baracoa and Matanzas, and perhaps at Havana and Santiago. The lower (Alum Bluff) Miocene of the southeastern United States has been discussed at some length on pages 572-574. Marine deposits of this age occur in Florida, Georgia, and southern Alabama; in Mississippi they are represented by the nonmarine, plant-bearing Hattiesburg clay.

A fauna of very nearly the same, if not identical, age occurs on the Isthmus of Tehautepec. It has been particularly considered by Böse and Toulou.<sup>1</sup> Böse says, regarding the specimens collected by him: "Eine ganze Reihe von Arten steht solchen nahe, die nur aus dem Oligocän der Antillen bekannt worden sind." Although precise correlation of this material is not now practicable, it seems that a lower Miocene horizon is represented.

Dr. C. W. Hayes collected on the Pacific coast of Nicaragua, 75 miles northwest of Brito Harbor, station 6409, worn specimens of a species of bryozoan that Dr. R. S. Bassler says is apparently *Cupularia canariensis* Busk, which ranges from a horizon in the Alum Bluff formation to Recent. The matrix is a calcareous, sandy, consolidated marl, and was included by Hayes in his Brito formation. The age of these specimens is not older than, and it probably is, old Miocene. The Brito formation, therefore, includes deposits ranging stratigraphically from upper Eocene to lower Miocene, but the beds at the type locality are of upper Eocene age (see previous pp. 193-197).

It was stated on page 586 that H. Douvillé considered that part of the Gatun formation exposed around Mount Hope as Helvetian Miocene, and that I provisionally accept his determination. It is probable that some of the Miocene deposits of northern Colombia are also of this age. Information on Venezuela and between there and Martinique is lacking.

For Martinique we have the following statement from Cossmann:<sup>2</sup>

D'après un premier aperçu qui ne porte que sur une partie des Siphonostomes, il paraît à peu près certain qu'un grand nombre de Gastropodes se trouvent à la fois dans

<sup>1</sup> Böse, F., Zur jungtären Fauna von Tehautepec. I. Stratigraphie, Beschreibung und Vergleich mit amerikanischen Tertiärfaunen, K. k. geolog. Reichsanst. (Wien) Jahrb., vol. 60, pp. 215-255, pls. 12, 13, 1910.

Toulou, F., Zur jungtertiären Fauna von Tehautepec. II. Vergleichung hauptsächlich mit europäischen und lebenden Arten, Idem, vol. 60, pp. 255-276, 1910.

<sup>2</sup> Cossmann, M., Étude comparative de fossiles miocènes recueillis à la Martinique et à l'isthme de Panama, Journ. conchyliologie, vol. 61, pp. 1-64, pls. 1-5, 1913.



les deux grisements, et que leur âge est au-dessus des couches de Bowden à la Jamaïque, qui ont fait l'objet d'une étude de la part de Guppy. Ces dernières renferment une très belle faune dont j'ai pas mal de spécimens dans ma collection: sans aller jusqu'à partager complètement l'opinion de M. Dall qui les rapporte à l'Oligocène, je crois qu'elles représentent l'équivalent de notre Aquitanien, c'est-à-dire le Miocène inférieur, tandis, que les fossiles de la Martinique et de Gatun (Panama) seraient un peu plus récents, probablement du Miocène moyen. Enfin, d'après les matériaux que j'ai pu étudier à l'École des Mines, les fossiles de Saint-Domingue (Haïti), étudiés par Gabb et par Sowerby, représenteraient un niveau déjà plus élevé, celui du Miocène supérieur.

M. Cossmann considers this material from Martinique as younger than the Bowden fauna.

Precise information on the paleontology of the Tertiary formations of Guadeloupe is exceedingly meager, in fact it is almost nothing. Dr. J. W. Spencer submitted to me a specimen of *Stylophora*<sup>1</sup> collected by him in a limestone near Les Abîmes. Accurate identification of a species of *Stylophora* may be a proper basis for precise correlation, but the genus ranges from upper Eocene to middle Miocene (about Helvetian) in the West Indian Tertiaries. In 1849 Milne Edwards and Haime described a coral from the "Terrain tertiaire" of Guadeloupe, under the name *Thecosmilia ponderosa*, and subsequently transferred it to the genus *Montlivaltia*.<sup>2</sup> I have photographs of the type of this species, kindly sent me by my friend Dr Charles Gravier of the Muséum d'Histoire Naturelle, Paris. It belongs to the genus *Antillia* and is closely related to *A. bilobata* Duncan. *Montlivaltia guesdesi*, described by Duchassaing and Michelotti<sup>3</sup> from Guadeloupe and said to be associated with *Antillia ponderosa*, is also a species of *Antillia*. *A. guesdesi* is so similar to *A. bilobata* that Duchassaing and Michelotti placed the latter in its synonymy. As I have seen no specimens of *A. guesdesi*, I must base any opinions concerning it upon its authors' figures and descriptions. It seems to me different from *A. bilobata*, but as the distinction between the two consists in the relative number of teeth within 1 centimeter on the septal margins, and as the details of the figures of *A. guesdesi* may be inaccurate, it would be improper to insist that they are different. However that may be, there are in Guadeloupe two supposed, very nearly related species of *Antillia*, and they are actually or almost indistinguishable from species that occur in Santo Domingo at a horizon near or above that of the Bowden marl. The evidence for Guadeloupe, therefore, indicates the presence there of deposits of uppermost Burdigalian or Helvetian age. There may be Tertiary deposits both older and younger than the bed in which the specimens of *Antillia* were collected. Doctor Spencer's structure section across the island strongly suggests that such deposits are there.

<sup>1</sup> Spencer, J. W., On the geological and physical development of Guadeloupe, Geol. Soc. London Journ., vol. 57, pp. 506-519, 1901.

<sup>2</sup> Hist. nat. Corall., vol. 2, p. 312, 1857.

<sup>3</sup> Mém. corall. Ant., p. 69 (of reprint), pls. 5, fig. 13, 1860.

It has already been stated that the fossils obtained by Miss Maury in Santo Domingo at horizons higher than her zones G, H, and I are younger than the Bowden fauna. A line of demarcation between the Burdigalian and higher Miocene is not at present practicable, but it is almost, if not quite, certain that her upper zones are not older than Helvetian. This would still seem to indicate a horizon below the lowest formation of the Chesapeake group of Maryland and Virginia and the Marks Head marl of eastern Georgia, but the available data do not warrant a positive opinion. However, it appears that the higher Miocene deposits of the Santo Domingan section are represented in Florida and Georgia by the erosion interval between the deposition of the uppermost beds of the Alum Bluff formation and that of the overlying Marks Head marl.

The presence in Cuba of deposits, the La Cruz marl, of the same age as the Santo Domingan deposits above Miss Maury's zones H-I, was noted on page 219 of this volume.

It seems that there are in the southeastern United States no Miocene marine deposits of the same age as the upper part of the Gatun formation, the Santo Domingan deposits above Miss Maury's zones H-I, and the La Cruz marl of Cuba, unless some of the latter deposits are younger than is at present supposed.

Except for the Isthmus of Tehuantepec, there is no information on marine Miocene formations of this age in eastern Mexico, or in the area between Yucatan and Costa Rica. The extension of the Gatun formation into Costa Rica has already been discussed.

#### PLIOCENE.

The Toro limestone is the only formation within the Canal Zone that is supposed to be of Pliocene age. The determination of the age of this formation is necessarily by means of its stratigraphic relations, as only one identifiable species of fossil, *Epitonium toroense* Dall, was collected in it, but the stratigraphic relations, described by Doctor MacDonald on pages 544, 545 of this volume, are such that the formation can scarcely be of any age other than Pliocene.

The Pliocene deposits in the vicinity of Limon, Costa Rica, were first observed by W. M. Gabb,<sup>1</sup> who described a number of species from there, and they were later visited by R. T. Hill,<sup>2</sup> who made additional collections, on which Doctor Dall supplies notes published in the paper cited.<sup>3</sup> Doctor Dall has recently described an interesting species of *Pecten*, *P. pittieri*,<sup>4</sup> collected by Mr. H. Pittier at Moin Hill, near Port Limon. This species will be referred to in

<sup>1</sup> Gabb, W. M., Descriptions of new species of fossils from the Pliocene clay beds between Limon and Moén, Costa Rica, together with notes on previously known species from there and elsewhere in the Caribbean area, Acad. Nat. Sci. Philadelphia Journ., ser. 2, vol. 8, pp. 349-380, figs. on pls. 45-47, 1881.

<sup>2</sup> Mus. Comp. Zool. Bull., vol. 28, p. 234, 1898.

<sup>3</sup> The geologic history of the Isthmus of Panama and portions of Costa Rica, Mus. Comp. Zool. Bull., vol. 28, p. 274, 1898.

<sup>4</sup> Smithsonian Misc. Coll., vol. 59, p. 10, 1912.

a subsequent paragraph. Pliocene corals from this locality are considered on page 223.

Mr. George C. Matson collected at Barranquilla, Colombia, some fossils that belong to a fauna younger than that obtained around Usiacuri, and may be of Pliocene age. *Glycymeris*, *Ostrea*, *Pecten*, and *Lucina* are the genera represented.

The Bissex Hill "beds" of Barbados (see p. 583 of this paper) are considered Pliocene in age by Franks and Harrison; but I infer, from his remarks on the Foraminifera, that Chapman inclined to the opinion that they are of Miocene age. I strongly doubt any of the elevated, terraced coral reefs of Barbados being so old as Pliocene, but present evidence is not decisive. The only known extensive Pliocene coral fauna in America is that of the Waccamaw and Caloosahatchee marls of the southeastern United States. This is discussed on page 222 of this volume. I have studied both the specimens on which Gregory based his account of the Barbadian elevated-reef corals and a collection (see p. 255 of this volume) later sent me by Professor Jukes-Browne. All of the species seem to me inseparable from the species at present living in the Caribbean area, except one that was erroneously identified by Gregory as *Lithophyllia walli* (Duncan).

Pliocene deposits have been recognized at very few places in the West Indies; in fact, about the only locality at which there is reasonable surety of there being beds of this age is near Guantánamo, Cuba, where Mr. O. E. Meinzer collected *Pecten pittieri* Dall, identified by C. W. Cooke.

R. T. Hill considers the Jamaican formations, to which he applies the names Manchioneal and Kingston, as Pliocene, and it seems that he is correct, but the evidence adduced is not completely convincing. In other words, from the evidence available, Hill was justified in his age classification of the deposits mentioned, but their paleontology needs more detailed investigation.

The marine Pliocene of the southeastern United States has been considered on page 576 of this paper.

Heilprin was the first to call attention to the extensive Pliocene "gray or white shell limestone" of Yucatan.<sup>1</sup> His examinations were made "at several points in and about Merida, in numerous cuttings along the line of the Merida-Kalkini Railroad, on the line of the railroad connecting the capital city with Ticul, all along the traverse between Merida and Tunkas," and "at various points between Tekanto and Cilam." Sapper has published a rough out-

<sup>1</sup> Heilprin, Angelo, Geological researches in Yucatan, Acad. Nat. Sci. Philadelphia Proc. for 1891, pp. 136-158, 1891.





United States.	European time subdivisions.
Nashua marl, see marl (near-us).	Sicilian. Astian. Plaisancian.
Duplin marl, see marl (near-us).	Pontian. Sarmatian.
1.	
1.	Tortonian.
s Head marl.	
	Helvetian.
River marl member. Iroquois sand member. a marl member.	Burdigalian.
Iroquois formation.	Aquitanian. Chattian.
	Rupelian.
Iroquois calcareous marl. Iroquois limestone. Bluff clay.	Lattorfian (Sannoisian).
Iroquois limestone.	Ludian (Priabonian). Bartonian.
Iroquois sand formation. Iroquois chert formation. Iroquois chert formation.	Auversian. <sup>c</sup> Lutetian.
Iroquois chert formation. Iroquois chert formation. Iroquois chert formation.	Ypresian. <sup>c</sup>
Iroquois chert formation. Iroquois chert formation. Iroquois chert formation.	Spartan. <sup>c</sup>
Iroquois chert formation. Iroquois chert formation. Iroquois chert formation.	Thanetian. <sup>c</sup> Montian. <sup>c</sup>

and to the upper Eocene and placed

line map of the Pliocene area in Yucatan,<sup>1</sup> and he repeated Heilprin's lists of fossils.

No information is available for British Honduras, the Republic of Honduras, or Nicaragua.

The accompanying table presents the approximate stratigraphic equivalence of the Tertiary marine formations in Central America, the Antilles, the southeastern United States, and Europe. It will be noticed that the table indicates two great stratigraphic breaks, namely, one in lower and middle Eocene time, the other in upper Miocene time.

#### PRE-TERTIARY FORMATIONS IN CENTRAL AMERICA AND THE WEST INDIES.

The foregoing discussion of the marine geologic formations of Panama has included more or less consideration of all of those of Tertiary age, concerning which we have knowledge, in the southern United States, eastern Mexico, Central America, and the West Indies, and a few notes have been made on northern South America. Since the publication of Bailey Willis's Index to the stratigraphy of North America,<sup>2</sup> there has been no important addition to our knowledge of the pre-Tertiary formations of the West Indies and Central America. As this volume and the geologic map of North America it was prepared to accompany are both easily accessible to geologists, and as a review of the formations of those ages would be mostly repetition of information contained in that work, I will make only a few general remarks.

Rocks of supposed Archean age outcrop as follows: State of Oaxaca, Mexico, granites and gneisses; Chiapas and Guatemala, granites, talc, and chloritic schists; Nicaragua and Honduras, fundamental granite; Venezuela, granite from Puerto Cabello to Trinidad. Granitic débris was found in Eocene sediments in Costa Rica and along Rio Chagres in Panama by Hill. There is granite overlain by arkose below the Upper Cretaceous near the city of Santa Clara, Cuba, and marble and schists in the Isle of Pines.

Paleozoic rocks of undetermined age occur in northern Sonora, Mexico, and in Chiapas; in Guatemala there are formations of both pre-Carboniferous and Carboniferous age; Mierisch reports Devonian in northern Nicaragua; and Paleozoic rocks apparently are present in Honduras. The rocks, largely serpentine, forming the proto-axis of Cuba, and some of the formations in the Trinidad Mountains, Cuba, may be of Paleozoic age, but there is no definite proof.

Triassic deposits occur near Zacatecas, and perhaps at Miquehuana, State of Tamaulipas, Mexico; the Todas Santos formation in Chiapas and Guatemala is of Triassic age, and it appears, according to Mierisch,

<sup>1</sup> Sapper, Carlos, La geografía física y la geología de la Península de Yucatan, Mexico Instit. geolog. Bol. No. 3, pp. 57, 6 pls., 1896.

<sup>2</sup> U. S. Geol. Survey Prof. Paper 71, 1912.

TENTATIVE CORRELATION TABLE OF THE TERTIARY MARINE SEDIMENTARY FORMATIONS OF PANAMA.

American River subdivisions.	Panama.	Jamaica.	Other Antilles.			Mexico and Central America.	Southeastern United States.		European time subdivisions.	
Pliocene.	Toro limestone.	Manehonsal formation. Kingston formation.	Pliocene of Guantanamo, Cuba.			Pliocene of Yucatan and Limon, Costa Rica.		Waccamaw marl, Nashua marl, and Calcooshathee marl (nearly contemporaneous).	Sicilian, Astian, Plaisancian.	
Miocene.	Upper.						Yorktown formation, Duplin marl, and Choctawhatchee marl (nearly contemporaneous).	Pontian formation.		
							St. Marys formation.			
	Middle.			La Cruz marl (Cuba).	Upper horizon in Martinique.	Upper horizon in Santo Domingo.			Helvetian.	
	Lower.	Gatun formation.	Bowden marl.	Marl at Baracoa, Cuba.	Lower horizon in Martinique.	Zones G, H, and I in Santo Domingo.		Alum Bluff formation.	Shoal River marl member. Oak Grove sand member. Chipola marl member.	Burdigalian.
Oligocene.	Upper.	Emperor limestone. (Upper part of Culebra.)	Anguilla formation (Anguilla), and beds at many localities in Cuba.					Tampa formation.	Aquitanian. Chattian.	
	Middle.	Culebra formation. Lower part of Culebra and limestone at Tenosí.				San Rafael formation.	Chattahoochee formation.		Rupelian.	
	Lower.	Limestone with <i>Orthis</i> , <i>Obolus</i> , <i>Chapressa</i> and limestone at David (contemporaneous).	Bobio congl. <sup>b</sup>	Montpellier white limestone.			Deposits with <i>Fecten</i> and <i>P. zonalis</i> and large, discoid orbitoids.	Vicksburg group.	Byrum calcareous marl. Maranna limestone. Red Bluff clay.	Latterian (Sannoisian).
	Upper.	Cambridge formation. Richmond formation.		St. Bartholomew limestone (St. Bartholomew). Widely distributed in Cuba; also in Haiti.			Brito formation of Nicaragua (typical Brito).	Jackson formation.	Ocala limestone.	Ludian (Priaeanian). Bartonian.
Eocene.	Middle.	Eocene of Tenosí.					Claihorn group.	Claiborne group.	Gosport sand. Lithon formation. Tallahatta buhrstone.	Auverbian. <sup>c</sup> Lutetian.
	Lower.					Near the Texas border.	Wilcox formation.	Wilcox group.	Hatcheligglee formation. Basha formation. Tuscahoma formation. Nanañala formation.	Ypresian. <sup>c</sup> Sparnacian. <sup>c</sup>
							Midway formation.	Midway group.	Nahcoba formation. Sucarnochee clay. Clayton limestone.	Thancian. <sup>c</sup> Montian. <sup>c</sup>

<sup>a</sup> Reported by H. Douville and referred to "Stampien inférieur" = Vicksburgian = Latterian; Cushman thinks these deposits should be referred to the upper Eocene and placed opposite the St. Bartholomew limestone in the table.

<sup>b</sup> May belong stratigraphically somewhat higher.

<sup>c</sup> Correlation proposed by E. W. Berry.





also to occur in northern Nicaragua. Sapper records Triassic rocks from several areas in Honduras.

Jurassic limestone froms the axis of the Organos Mountain, Province of Pinar del Río, Cuba; and marine Jurassic is extensively developed in Mexico and west Texas.

The Lower Cretaceous, so greatly developed in Mexico and Texas, is not known in the West Indies or in Central America proper, that is, below the Isthmus of Tehuantepec, except in Honduras.<sup>1</sup>

With regard to the Upper Cretaceous, it will be said that the peculiar Upper Cretaceous fauna of Jamaica has been found in Cuba and St. Thomas. Hill has noted in Porto Rico "volcanic tuffs and conglomerates with interbedded Cretaceous rudistean limestone similar to that of Jamaica," thereby confirming a previous inference of Cleve that the horizon he recognized in St. Thomas also occurs in Porto Rico; and it is reported from the Island of Haiti. Quin figures a specimen of *Barrettia* from the "Blue-beach" formation of St. Croix (but without recognizing its affinities); and Sapper records *Barrettia* from northwest of Coban, Guatemala, and a somewhat similar fauna from Chiapas, Mexico. As Cleve years ago pointed out, this fauna is more closely related to that of Gosau, Austria, than to any in North America north of the Gulf of Mexico. Hill reports Rudistes and Inocerami from his San Miguel formation, Costa Rica, but Romanes<sup>2</sup> doubts the correctness of the identifications.

#### OUTLINE OF THE GEOLOGIC HISTORY OF THE PERIMETERS OF THE GULF OF MEXICO AND THE CARIBBEAN SEA.

The following pages will present only the broad outlines of the geologic history of the region of which Panama forms a part. The details for Panama are given by Doctor MacDonald in the manuscript of his report on the geology of the Canal Zone and adjacent areas, to be published by the Smithsonian Institution. Three manuscripts on the physiography and stratigraphy of Cuba are now in my possession. One of these is on an area adjacent to Guantánamo, by Mr. O. E. Meinzer; the second is on an area northwest of Guantánamo by Mr. N. H. Darton; and the third is a general account of the physiography and stratigraphy of the entire island and the Isle of Pines by myself. The paleontology of the different formations is considered in as much detail as available information permits. A similar account of the geology of the Lesser Antilles, by Mr. Robert T. Hill and myself, is nearly ready for press, and paleontologic monographs of the fossil biota of St. Bartholomew, Antigua, and Anguilla are almost complete. The geologic history of these

<sup>1</sup> Dr. T. W. Stanton has recently verified the age determination of these deposits. (Oral communication.)

<sup>2</sup> Romanes, James, Geology of a part of Costa Rica, Geol. Soc. London Quart. Journ., vol. 68, pp. 103-139, pls. 8, 9, 1912.

areas is discussed in the reports mentioned, which I hope may, within a few months, be submitted for publication by the Carnegie Institution of Washington.

The discussion of the age and geographic distribution of the different geologic formations on preceding pages partly prepares the way for an account of the paleogeography of the region under consideration; but before proceeding the geographic relations of the Three Americas should receive attention.

#### GEOGRAPHIC RELATIONS OF THE THREE AMERICAS.

This subject has attracted many investigators, some of whom considered only segments of the perimeters of the two American seas, the Caribbean Sea and the Gulf of Mexico, while others considered the relations between Central America and the West Indies to the continent of North America, on the north, and to the continent of South America, on the south. Some of the important facts in the alignment of the West Indies were recognized so long ago as 1848, for Schomburgh<sup>1</sup> called attention to the fact that in the Lesser Antilles there are an outer and an inner group of islands, the outer largely composed of calcareous rocks, the inner composed of volcanic rocks. Knowledge of the geographic and geologic relations within this region has grown gradually, and there have been so many contributors to it that no attempt will be made to credit each of them for what he has done. However, special acknowledgments should be made to R. T. Hill for his investigations in a number of the West Indian and Central American areas; to Carl Sapper for his exploration in Yucatan, Tabasco, Chiapas, Guatemala, parts of Honduras, and San Salvador; and to Karsten and Sievers for their work in northern South America. The footnotes<sup>2</sup> below gives the titles of some of the more important publications, and they contain references to earlier literature.

<sup>1</sup> Schomburgh, Sir R., History of Barbados, p. 532, 1848.

<sup>2</sup> Dollfus, A., and Mont-Serrat, E. de, Voyage géologique dans les républiques de Guatemala et de Salvador, pp. 535, 18 pls., 1868, Paris. See particularly pp. 250-258.

Felix, J., and Lenk, H., Ueber die tektonischen Verhältnisse der Republik Mexiko, Deutsch. geolog. Gesellsch. Zeitsch., vol. 44, pp. 303-323, pls. 19, 20, 1892.

Hill, R. T., Fundamental geographic relations of the Three Americas, Nat. Geog. Mag., vol. 7, pp. 175-181, 1896; The physical geography of Mexico [Abstract], Eighth Internat. Geog. Cong. Rept., pp. 765-766, 1905. (See also papers by Hill listed on p. 604, this volume.)

Karsten, Hermann, Géologie de l'ancienne Colombie bolivarienne, Venézucla, Nouvelle-Grenade et Ecuador, pp. 62, 1 map, 8 pls., 1886, Berlin.

Sapper, Carl, Grundzüge der physikalischen geographie von Guatemala, Petermanns Mitteil. Ergänzungsbd. 24, Ergänzungsheft 113, pp. 59, 4 maps, 1894; La geografia fisica y la geologia de la peninsula de Yucatan, Mexico Inst. geolog. Bol. 3, pp. 57, 6 pls., 1896; Das nördliche Mittel-Amerika, pp. 436, 8 pls., 1897, Braunschweig; Mittelamerikanische Reisen und Studien aus den Jahren 1888 bis 1900, pp. 426, 4 statistical tables, 4 maps and numerous unnumbered half-tone figs. and pls., 1902, Braunschweig; Über Gebirgsbau und Boden des südlichen Mittelamerika, Petermann's Mitteil., Ergänzungs Bd. 32, Ergänzungsheft 151, pp. 82, 4 pls., 1905.

Sievers, W., Karten zur physikalischen geographie von Venezuela, Petermanns Mitteil., vol. 42, pp. 125-129, pl. 10, pp. 149-155, pl. 11; pp. 197-201, pl. 15, 1896.

Suess, E., Les Antilles, La face de la terre (translated under the direction of E. de Margerie), vol. 1 pp. 724-737, 1897.

## GENERAL RELATIONS.

The boundaries of the Gulf of Mexico and the Caribbean Sea form a parallelogram (see pl. 73); those on the north and south extend along east and west lines, those on the east and west are northwest to southeast, while the basins are separated by east and west structures.

The bottoms of the continental slopes on both sides of the continents range between 2,500 and 3,000 fathoms in depth. On the east the 2,500-fathom curve is either at or near the base of the slope from off the Banks of Newfoundland southwestward to off Jacksonville, Florida, whence it bends toward the southeast, passing east of the Bahamas, north of Porto Rico, east of the Caribbean arc, east of Trinidad, and northeast of the Guianas. The 2,500-fathom contour lies farther offshore on the Pacific side than on the Atlantic side of North America, but is nearer shore from the Revilla Gigedo Islands, west of Manzanillo, Mexico, to off Guatemala, whence southward the 2,000-fathom contour is near the base of the slope until off Peru, where there is a drop to over 3,000 fathoms in the great Callao deep.

Land areas bound the Gulf of Mexico on the east, north, west, and south. The land on the west continues without interruption through Central America and northern South America, forming the western and southern boundaries of the Caribbean Sea. Between southern Florida and Trinidad there are relatively shallow-water connections with the Atlantic Ocean through passages between Florida and Cuba, and through passages between both the Greater and the Lesser Antilles to Trinidad. Depths of about 1,000 fathoms or somewhat more are found between Cuba and Haiti in the Windward Passage, and between Anegada and Anguilla in the Anegada Passage, but they are usually less than 500 fathoms.

The Gulf of Mexico is separated from the Caribbean Sea by the Yucatan Peninsula and Cuba, but connects with it through the Yucatan Channel. The deepest part of this basin, which is a simple basin, is slightly over 2,000 fathoms.

The Caribbean Sea is a compound basin, separated into two parts by the ridge that extends from Honduras to Jamaica. The northern division is almost subdivided by the Cayman ridge, which extends westward from the Sierra Maestra of Cuba. Depths of 2,500 fathoms are attained between the Caymans and Cape San Antonio, Cuba, while south of them depths exceeding 3,000 fathoms are recorded in the Bartlett deep. The southern division is a simple basin with depths ranging between 2,250 and 2,900 fathoms.

The data presented show that these two basins are land-locked, except that between Florida and Trinidad shallow passages between land areas connect with the Atlantic Ocean, that the two basins are separated by structures transverse to the continental trend in Yucatan



and Cuba, and that the Gulf of Mexico is a simple while the Carribbean Sea is a compound basin.

The major tectonic features surrounding and occurring within the basins will now be briefly considered.

#### TECTONIC PROVINCES.

In order to give an adequate conception of the relations of the two basins the general features of both the North and South American continents must be considered as well as the details of the land areas and submarine banks and ridges immediately adjacent to and within the region. The provinces germane to the area will be more particularly considered, while the boundaries of those more remote will be only indicated. Twelve major with several subordinate provinces may be discriminated as follows:

1. Bahamas.
2. Atlantic and Gulf Coastal Plain.
3. Mexican Plateau.
4. Oaxaca-Guerrero.
5. Yucatan.
6. Guatemala—Chiapas.
7. Cuba and northern Haiti.
8. Honduras, and its continuation to Jamaica, southern Haiti, Porto Rico, the Virgin Islands, and the outlying island of Saint Croix.
9. Costa Rica—Panama.
10. Andes.
11. Maritime Andes.
12. Caribbean Islands:
  - 12a. Barbadian Ridge.
  - 12b. Main Caribbean Arc.
  - 12c. Aves Ridge.

1. *Bahamas*.—The Bahama Islands and their accompanying shoals occupy a triangular area which lies east of Florida and north of Cuba and Haiti. The islands either occur on one of two large banks, the Little Bahama and the Great Bahama banks, or they rise to the southeast of the latter bank as isolated eminences separated by water as much as 1,000 fathoms in depth. Two bodies of water over 1,000 fathoms deep, Exuma Sound and The Tongue of the Ocean, indent the Great Bahama Bank. Water 1,000 fathoms in depth is close to the eastern shore of the Bahamas as far north as Elbow Cay on Little Bahama Bank. Eastward from the 1,000-fathom curve the bottom rapidly descends to a depth between 2,000 and 3,000 fathoms. The Bahama Islands are subaerial protuberants above the nearly level, slightly submerged surfaces of extensive plateaus which on one or more sides rise precipitously from oceanic depths.



2. *Atlantic and Gulf Coastal Plain*.—This plain extends beyond Rio Grande to the Sierra Madre, Mexico, and as far southward as Tampico. A narrow, more or less broken plain continues beyond Vera Cruz to the lowland plain of Yucatan, where it meets the transverse Oaxaca-Guerrero structural line.

Throughout its extent, notwithstanding irregularities in surface configuration, the Coastal Plain in general slopes from its landward margin to the edge of the Continental Shelf. The inner margin ranges from 300 to 600 feet in altitude between Maryland and central Texas; while in west Texas it attains a height of slightly more than 1,000 feet above sea level.

3. *Mexican Plateau*.—At least four provinces of major rank are recognized in the western Cordilleran region of the United States, according to Ransome,<sup>1</sup> namely: (1) The Rocky Mountains, (2) the Colorado Plateau, (3) the Nevada-Sonoran region, (4) the Pacific ranges. Nos. 1 and 2 are parts of the Laramide mountain system; No. 3 is the intermontane belt; and No. 4, the Pacific mountain system. Fenneman dissents from this classification in that he refers the Colorado Plateau to the Intermontane plateaus, along with the Nevada-Sonoran region,<sup>2</sup> and considers the Mexican "highland" as a part of his Basin-and-Range province lying south of the Colorado Plateau. Toward the south in trans-Pecos Texas the Colorado Plateau and the Nevada-Sonoran region of Ransome are delimited by a rather vague boundary from the Mexican Plateau, which Ransome also considers a part of the Laramide mountain system. The Mexican Plateau comprises the high plateaus and central mountains of Mexico. Southward from Rio Grande, below the mouth of Pecos River, it forms the western boundary of the Coastal Plain. The boundary, according to Hayes (oral communication), is a fault scarp which lies a little east of Monterey and trends east of south through Ciudad Victoria to Misantla, where volcanic mountains reach the shore and interrupt the continuity of the plain. The province is terminated on the south by a fault scarp beyond which are the east and west trending structural axis of Michoacan, Guerrero, and Oaxaca.

4. *Oaxaca-Guerrero*.—A structural axis extends through Michoacan, Guerrero, and Oaxaca, almost at right angles to the trend of the Mexican Plateau. The northern boundary of this province is the escarpment at the southern margin of the Mexican Plateau; the western and southern boundary is the Pacific Ocean; while the eastern boundary is the Isthmus of Tehuantepec. It is thus set off from the Mexican Plateau, and the Yucatan lowland.

<sup>1</sup> Ransome, F. L., *The Tertiary orogeny of the North American Cordillera and its problems*, *Problem of American geology*, pp. 239-295, New Haven, 1915.

<sup>2</sup> Fenneman, N. M., *Physiographic divisions of the United States*, *Assoc. Amer. Geographers Bull.* vol. 6, p. 41, 1916.

5. *Yucatan*.—This province consists of lowlands, under 600 meters in height, underlain by only slightly deformed Tertiary strata, except some problematic rocks west of Belize. The Yucatan Peninsula and Campeche Bank are comparable to the Floridian Plateau. They are developed along a structural axis almost at right angles to the continental trend. Campeche Bank projects northward from the shore line of the peninsula 170 nautical miles to the 100-fathom curve and has a width of nearly 360 nautical miles along an east and west line. On the east the depth of water between it and Cuba exceeds 1,000 fathoms and the axial trends are not coincident, but the axis of Yucatan Bank and that of the Province of Pinar del Rio, Cuba, curve so that they are nearly parallel, with a trough, Yucatan Channel, between them.

6. *Guatemala-Chiapas*.—This province lies between the Yucatan lowland on the north and Rio Motagua on the south. It is an upland dominated by east and west tectonic lines, and has been called the Guatemala-Chiapas Plateau by Tower.<sup>1</sup>

7. *Cuba*.—This province is coincident with Cuba and its submarine continuation, the Cayman Ridge. At least four subdivisions should be recognized: (1) The Isle of Pines, which is composed of mountains of schists and marbles with piedmont plains and marsh, separated from the main island by water less than 10 fathoms deep. (2) Organos Mountains of Pinar del Rio and the accompanying piedmont plains. The 1,000-fathom curve is less than 20 miles off the north shore. (3) Central Cuba, from the east end of Organos Mountains to Cauto River, is mostly a plain broken by some hills of serpentine and granite, and in Santa Clara Province, near Trinidad, mountains reported to be composed of Paleozoic sediments attain an altitude of about 2,000 feet. (4) Sierra Maestra and Cayman Ridge. This subprovince lies between the Cauto Valley and the south shore and is continued westward as the submarine Cayman Ridge, along the axis of which only the Cayman Islands project above water level. The axial trend is nearly east and west between Cabo Cruz, Cuba, and Little Cayman, whence it curves to the southwest and pitches toward the head of the Gulf of Honduras, which is an area of depression. Between the Caymans and the Isle of Pines the depth of water exceeds 1,000 fathoms, while the Bartlett deep to the south, separating Cuba and Jamaica, exceeds 3,000 fathoms in depth.

7a. *Haiti, northern part*.—The island of Haiti lies at the convergence of the trend of the axis of the central subprovince of Cuba and the Honduran-Jamaican axis. The dividing line in Haiti is from Port au Prince to Ocoa Bay. The area south of this line belongs to a Jamaican axis, while that to the north belongs to the central

<sup>1</sup> Tower, W. L., Investigation of evolution in chrysomelid beetles of the genus *Leptinotarsa*, Carnegie Inst. Washington Pub. No. 48, p. 50, 1906.

Cuban trend. The structural axes of the mountains in the northern and northeastern part of Haiti are from northwest to southeast and are parallel to the axis of elongation of Cuba from the Sierra Maestra to Santa Clara. In Cuba this trend is cut diagonally by the axis of the Sierra Maestra, which is bounded on the south by a tremendous fault scarp. Previous to this faulting it seems that central Cuba and Haiti formed parts of the same land area. The island of Haiti might be treated as separate from Cuba and Jamaica, but lying at the intersection of two tectonic trends.

8. *Honduras and the Jamaican Ridge.*—The Honduran Province in Central America is dominated by tectonic lines extending from southwest to northeast, of which the Telusa Mountains are representative. A line from the Gulf of Honduras along Motagua River to a point north of Jalapa, thence southwest to the Pacific coast, may be taken as the northern boundary and Rio San Juan and the southern side of Lake Nicaragua as the southern boundary.

From the northeast coast of Honduras and Nicaragua a great submarine plateau continues with depths of less than 1,000 fathoms to Jamaica. Above it rise numerous banks and keys and along its course are Thunder Knoll, Rosalind, Seranilla, and Pedro banks between the continental shore and Jamaica.

The principal old tectonic lines of Jamaica trend northwest to southeast. As these are parallel to the shore northwest of Cape Gracias a Dios and to the northeast edge of Mosquito Bank, there are evidently cross tectonic lines nearly at right angles to each other in this ridge.

A submarine ridge extends from the east end of Jamaica some 45 miles and overlaps on the south side a ridge which protrudes westward from the west end of Haiti. The two ridges, however, do not connect but are separated by water over 1,000 fathoms deep. The ridge representing an eastward submarine continuation of Jamaica indicates a third tectonic line in that island. The last-mentioned line nearly parallels the Bartlett deep, which lies to the north. The submarine slopes to the southeast are toward the bottom of the Caribbean basin.

9a. *Haiti (southern part), Porto Rico, and the Virgin Islands.*—The political division of Haiti designated Sud is dominated by east and west trending mountains, which parallel in direction the east and west axis of Jamaica. As the maximum depth between Haiti and Porto Rico is about 318 fathoms, they rise from a common, not greatly submerged bank. (See statement on preceding page in regard to considering Haiti as a separate Province.)

The main mountain mass of Porto Rico, the Sierra Central, the maximum altitude of which is 3,750 feet at El Yunque, trends east and west, paralleling in direction Sud, Haiti. There is coincidence



in the direction of elongation of the Jamaican bank, Sud (Haiti), and Porto Rico.

The relative truncation of the west end of Porto Rico, except the protuberant which forms Cabo de San Francisco, is striking and suggests faulting. The declivities both to the north and south of the island are great, over 4,000 fathoms in depth being reached within 40 miles of the north coast, while 2,000 fathoms are attained within a shorter distance from the south coast.

A submarine bank extending from the east end of Porto Rico to Anegada Passage is known as Virgin Bank. The depth of water between the islands rising above this bank is less than 20 fathoms, which is a minimum for the amount of submergence they have recently (geologically speaking) undergone. These islands are detached outliers of Porto Rico.

*Sb. Saint Croix.*—Although St. Croix is separated from the Virgin Islands by a depth as great as 2,400 fathoms and is joined to the St. Christopher chain by a ridge less than 1,000 fathoms deep, it possesses great similarity to members of the Virgin group. The west end is truncate and the submarine slope precipitous; the submarine slope to the north is also steep. There is clear evidence of faulting on the west and north sides. A ridge, largely of igneous rock, stands against the north shore from the west end of the island for some distance to the east. South of the ridge is a sloping, rolling, calcareous plain. The east end has a submarine continuation in a bank less than 50 fathoms deep. The tectonic axis is east and west, the rocks resemble those of the Virgins, and the zoogeography indicates former connection with them. For these reasons it seems probable that this island was formerly a part of the Porto Rican-Virgin Island land-mass and has been sundered from it by diastrophic processes. However, Saint Croix might be accorded separate status as a province, or referred to the St. Christopher axis; but it appears to me preferable to classify it with the Virgin Islands.

9. *Costa Rica-Panama.*—Between the Nicaragua-Costa Rican boundary and the mouth of Rio Atrato is an S-shaped land area which does not exhibit striking major tectonic lines, although some deformation axes are obvious in Panama. The region is largely one of vulcanism, present or past, which although occurring within definable limits does not follow continuous straight axes but occurs in a curving belt. The topography appears disordered, with volcanic protuberants here and there without perceptible system. The volcanic heaps range from a few hundred to nearly 10,000 feet in altitude.

10. *Andes.*—The south-north trending ranges of the Andes reach the shores of the Caribbean Sea between the Gulf of Darien and Venezuela, and send a spur, Cordillera de Merida, northeastward to



Porto Cabello where the main Andean trend is crossed by that of the Maritime Andes. The shore of the Caribbean Sea lies across the northern end of the Andes in a way similar to the manner in which the landward border of the Coastal Plain crosses the southwestern end of the Appalachian Mountains.

The islands Curaçao, Arube, and Bonaire, lie off the Venezuelan coast in the angle between the ends of the main Andes and the Cordillera de Merida.

11. *Maritime Andes*.—The Maritime Andes lie along the Venezuela coast from Caracas eastward. Trinidad and Tobago are outlying islands. On the south side of these mountains is the great Valley of the Orinoco.

12. *Caribbean Islands*.—These islands lie along triple arcuate ridges, the Barbadian Ridge, the main Caribbean Arc, and Aves Ridge, the second of which is double at its northern end.

12a. *Barbadian Ridge*.—As Barbados is connected undersea with Tobago Island by a ridge less than 1,000 fathoms deep, and as the depth between it and St. Lucia is less than 1,000 fathoms, there is a closed basin over 1,000 fathoms deep between the Barbadian Ridge and the main Caribbean Arc.

12b. *Caribbean Arc*.—The Caribbean arc is a ridge that extends from north of the Gulf of Paria to Anegada Passage. The islands occurring along it from the Grenadines to Dominica are entirely or predominantly volcanic. Guadeloupe is a compound island; the western half is volcanic, the eastern half with the outlying Marie Galante is mostly composed of calcareous sediments. North of Martinique the arc splits; along the inner fork are the volcanic islands Montserrat, the St. Christopher Chain, and Saba; along the outer fork are Antigua and Barbuda, and the St. Martin group. The latter islands are largely or predominantly composed of sedimentary rocks resting on an igneous basement of pre-Tertiary or early Tertiary age.

12c. *Aves Ridge*.—This ridge takes its name from Aves Island, which stands on a ridge running from the north coast of Cumana to Saba Island at depths slightly less than 1,000 fathoms, while water of greater depth occurs both east and west of it.

#### PALEOGRAPHIC SUMMARY.

There are many publications dealing with this subject, some of which, such as those of Gregory,<sup>1</sup> Hill,<sup>2</sup> and Guppy,<sup>3</sup> are specially

<sup>1</sup> Gregory, J. W., Contributions to the paleontology and physical geology of the West Indies, Geol. Soc. London Quart. Journ., vol. 51, pp. 255-310, pl. 11, 1895.

<sup>2</sup> Hill, R. T., Notes on the geology of Cuba, based upon a reconnaissance made for Alexander Agassiz, Mus. Comp. Zool. Bull., vol. 16, pp. 243-288, pls. 3-9, 1895; The geological history of the Isthmus of Panama and portions of Costa Rica, Idem., vol. 28, pp. 150-285, pls. 1-19, 1898; The geology and physical geography of Jamaica, Idem., vol. 31, pp. 1-226, 252-255, pls. 1-35, 1901; Pelé and the evolution of the Windward Archipelago, Geol. Soc. America Bull., vol. 16, pp. 243-288, pls. 43-47, 1905.

<sup>3</sup> Guppy, R. J. L., The geological connexions of the Caribbean region, Canada Inst. Trans., vol. 8, pp. 373-391, one plate, 1909.

devoted to the West Indies and Central America, or consider parts of the regions; others are devoted to the geologic history of smaller areas that are parts of the region and are too numerous for mention here, but many of them have been referred to in my papers on the fossil corals and the correlation of the geologic formations of Panama, forming parts of this volume; while still other works, for instance those by Schuchert<sup>1</sup> and Willis,<sup>2</sup> treat Central America and the West Indies only as parts of much larger areas.

Schuchert in his work cited undertakes to reconstruct for this region the distribution of land and sea; that is, connections and barrier between the Atlantic and Pacific Basins during Paleozoic time, basing his inferences upon the affinities of the Paleozoic faunas. As I can add nothing to what he says, I will not summarize his conclusions—the reader may consult his memoir.

#### LATE PALEOZOIC.

The great Appalachian revolution occurred in late Paleozoic-Permian time, and resulted in the northern boundary of the Gulf of Mexico—the southern Appalachian, the Ouachita, and Wichita Mountains.

The east and west trend in southern Mexico already existed or was developed about this time; while farther to the southeast, as Sapper has shown, Rio Motagua in Guatemala divides two chains of this age, one to the north, the other to the south, with spurs of a third chain farther toward the southeast. The nearly north and south trend of the Coxcomb Mountains in British Honduras, which are composed of sediments, apparently of pre-Paleozoic age indicates that the Yucatan protuberant had been outlined in Paleozoic, perhaps early Paleozoic time. Granitic débris in Costa Rica and Panama suggests old deformation along east and west lines in those areas. The east and west mountains of Venezuela have an old foundation and certainly date back to the Paleozoic in origin. There is evidence of old deformation in Cuba, rendering it highly probable, if not certain, that the major tectonic trends of Cuba are as old as Paleozoic. Although no Paleozoic rocks have been identified in Jamaica, the inference appears warranted that Jamaica itself dates back to late Paleozoic, as it has been shown by Sapper that the west end of the tectonic features represented in Mosquito and Rosalind Banks and Jamaica already existed in late Paleozoic time. The Cuban and Jamaican trends meet in Haiti and continue through Porto Rico to the Virgin Islands,

<sup>1</sup> Schuchert, Charles, Paleogeography of North America, Geol. Soc. America Bull., vol. 20, pp. 427-606, pls. 46-101, 1910.

<sup>2</sup> Willis, Bailey, Paleogeographic maps, in Outlines of geologic history with special reference to North America, pp. 306, Chicago, 1910.

while St. Croix, which is closely related in its geologic features to the Virgins, was probably at one time a member of that group and has been separated from them by faulting of comparatively late geologic date. There is no direct evidence of the existence at this time of any of the Caribbean Islands, but certain relations suggest that at least parts of the Caribbean Arc may be old. St. Croix stands on the western end of a ridge between 600 and 700 fathoms deep, on the eastern end of which is St. Christopher. This ridge extends northward to the St. Martin Plateau, eastward to Antigua and Barbuda, and southward from the latter islands through Guadeloupe, St. Lucia, and the Grenadines to South America. These relations suggest that the eastern perimeter of the Caribbean Basin may have been outlined in late Paleozoic time.

From the preceding statement it is evident that the principal tectonic lines of the perimeters of the Gulf of Mexico and Caribbean Sea existed at the close of the Paleozoic. The northern, western, and southern boundaries had been outlined and the major transverse trends had also been formed, the more northern through Oaxaca and Chiapas, including the northward trending Coxcomb Mountains of British Honduras; the more southern through Honduras and Nicaragua. The first may have connected along the axis of the Coxcomb Mountains with Cuba and thence Haiti; the second probably connected with Jamaica, Haiti, Porto Rico, and the Virgin Islands, and there are vague suggestions that the Caribbean Arc also existed. As the positive and negative areas so early outlined dominated the tectonic development during later geologic time, the subsequent history consists in tracing the modification of these old features.

#### TRIASSIC, JURASSIC, AND CRETACEOUS.

It seems necessary to infer diastrophic movements previous to or during Jurassic and Cretaceous time, for there was no connection between the Atlantic and Pacific oceans across Central America during these periods, with the possible exception of certain connections during Jurassic and upper Triassic (Karnic) time, as shown in the table on page 612. During Triassic and Jurassic time the eastern part of the North American continent, except areas of Triassic in Mexico and several Central American States and areas of Jurassic in Mexico and trans-Pecos Texas, was emerged probably to the limits of the present Continental Shelf, while the western end of Cuba was submerged. The eastern end of Cuba apparently was a land area and may have been joined to the southeastern United States. During upper Cretaceous time there was extensive submergence throughout the West Indies and Central America, but the Lower Cretaceous, as represented in Mexico and Texas, is not known in them, except in Honduras. As the Jurassic and Cretaceous faunas are Atlantic in their facies,



the Atlantic Ocean must have had access to these oceanic basins during a part if not all of these periods.

According to Hill, vulcanism existed prior to later Mesozoic in Guatemala, Oaxaca, Jamaica, and the Andes, and perhaps in Cuba and Haiti, as well as in the Cordilleras of North America. Probably there was vulcanism in Porto Rico, the Virgin Islands, St. Croix, St. Martin, St. Bartholomew, and Antigua. In the two last mentioned islands there are volcanic rocks older than Eocene sediments.

At the close of the Cretaceous there was general emergence of the Coastal Plain, an event probably due to diastrophism and a resultant of Laramide mountain making.

#### EOCENE AND OLIGOCENE.

The West Indian islands, because no old Eocene sediments are known in any of them except Trinidad, which is South American in its relations, are supposed to have stood above sea level at that time. In Cuba and Jamaica there are Upper Cretaceous and late Eocene sediments without the intervention of early Eocene deposits.

During later Eocene (Ludian) and middle and upper Oligocene (Rupelian and Aquitanian) time there was extensive submergence in the West Indies and interoceanic connection through a number of straits across Central America. There may have been interoceanic connection during lower Oligocene (Lattorfian) time, but this is not established. The maximum submergence was in middle Oligocene (Rupelian) time. Vulcanism was widespread in Central America and the Antilles during Eocene and probably also during earlier Oligocene time. The line of the great Mexican volcanoes had its inception at the close of the Cretaceous, near the beginning of the Tertiary, according to Felix and Lenk.

In Jamaica, Cuba, St. Bartholomew, and Antigua the later Eocene age of some of the volcanic rocks is established. There was between the upper Eocene and the middle Oligocene deposition periods great deformation in the Antilles. The folding in the principal mountains of Jamaica, the Sierra Maestra of Cuba, and apparently those of Haiti, Porto Rico, the Virgin Islands, and St. Croix appears to have taken place at this time. Diastrophism seems also to have been active in Chiapas, Tabasco, Petén, Guatemala, Nicaragua, Costa Rica, and Panama.

#### MIOCENE.

During older Miocene (Burdigalian) time apparently there was in places connection between the Atlantic and Pacific oceans, as is shown by deposits of this age containing fossils of Atlantic affinities on the Pacific coast of Costa Rica<sup>1</sup> and Nicaragua, and perhaps at

<sup>1</sup> Romanes, J., Geology of a part of Costa Rica, Geol. Soc. London Quart. Journ., vol. 68, pp. 124, 125, 1912.



other places, but such connections seemingly were restricted, not of wide extent as in upper Eocene and Oligocene time.

As no upper Miocene has yet been identified in the West Indies this is supposed to have been a period of high uplift which terminated the connection between the Atlantic and Pacific oceans. The middle and upper Oligocene and lower Miocene sediments of Mexico, Panama, Cuba, Haiti, Jamaica, Porto Rico, Anguilla, and Antigua, although deformed by tilting and faulting are not intensely folded, as are the older sediments. According to Hill, "in mid-Tertiary time granitoid intrusions were pushed upward into the sediments of the Great Antilles, the Caribbean, Costa Rican, and Panamic regions." The information I obtained in Antigua and St. Bartholomew accords with this opinion.

That there was at some place interoceanic connection subsequent to lower Miocene (Burdigalian) time is suggested, if not actually proven, by the presence on Carrizo Creek, Imperial County, California, of a coral fauna of post-Miocene Atlantic affinities.<sup>1</sup>

Roy S. Dickerson<sup>2</sup> in the paper cited below says regarding my conclusion that the coral fauna of Carrizo Creek is of probably Pliocene age: "His [Vaughan's] conclusions concerning the Pliocene age of these beds rests upon the infirm basis of comparison with a Pliocene coral fauna of Florida," and "All the coral genera except one occur in the Bowden or associated horizons." The last statement is correct in the restricted sense in which I use Bowden and its related zones, and the first is correct in that I compared the fauna from Carrizo Creek with that from the Pliocene Caloosahatchee marl of Florida; but Doctor Dickerson evidently did not comprehend the entire basis for my opinion. The following eight genera, now extinct in the Atlantic Ocean but present in the Pacific, occur in the Bowden marl and related zones, that is in Miss Maury's Santo Domingan section and the La Cruz marl of Cuba, but are not known from Carrizo Creek or from the Caloosahatchee marl:

<i>Placocyathus.</i>	<i>Antillia.</i>
<i>Placotrochus.</i>	<i>Syzygophyllia.</i>
<i>Stylophora.</i>	<i>Pavona.</i> <sup>3</sup>
<i>Pocillopora.</i>	<i>Goniopora.</i>

Neither the coral fauna of Carrizo Creek nor that of the Caloosahatchee marl, as at present known, contains any of the coral genera distinctive of the Bowden and related zones. These distinctive

<sup>1</sup> Vaughan, T. W., The reef-coral fauna of Carrizo Creek, Imperial County, California, etc., U. S. Geol. Survey Prof. Paper 98, pp. 355-386, pls. 92-102, 1917.

<sup>2</sup> Ancient Panama Canals, California Acad. Sci. Proc., vol. 7, pp. 197-205, 1917 (date printed with title July 30, 1917, received by me on Oct. 16, 1917).

<sup>3</sup> Added from Miss Maury's Santo Domingan collections.

genera became extinct in the Atlantic during upper Miocene time, according to the present information, but, they persist in the Indo-Pacific region. It, therefore, seems that the fauna of Carrizo Creek migrated to the head of the Gulf of California after the extinction of these forms.

PLIOCENE AND LATER.

Subsequent to the Miocene there have been many oscillations of the West Indian area, and during perhaps Pliocene time there was profound deformation. Zoogeographic data in the opinion of several investigators seem to demand former connection, probably during late Miocene or Pliocene time from Yucatan across Cuba to Haiti, Porto Rico, and the Virgin Islands; from Honduras to Jamaica; and from Anguilla to South America. It also appears that St. Croix was once joined to Anguilla and to the eastern end of the Virgin Islands. There are certain geologically late fault-lines which perhaps date from this time and the severance of the old ridges into the islands we now know may be largely due to movement along them. One of these fault lines forms the northern boundary of the Bartlett Deep, and passes between the east end of Cuba and the west end of Haiti. Another tectonic line which forms the south side of the Bartlett Deep seems to converge toward the former in the Windward Passage. A down-thrown block between these lines has separated Cuba and Haiti and produced the Bartlett Deep. Probably there was also faulting or flexing between Cayman Ridge and the southern shore of Cuba, west of Manzanillo Bay, while either faulting or flexing may have separated Cuba and Yucatan. There is evidence of a downthrown fault block between St. Thomas and St. Croix, the two sides converging toward Anegada Passage. This will account for the deep of over 2,400 fathoms north of St. Croix, and the severance of St. Croix and the St. Martin Plateau group of islands from the Virgin group.

There are three kinds of evidence that bears on the age of this faulting, namely: (1) In eastern Cuba, as the Miocene La Cruz marl is abruptly cut off at the shore line in the vicinity of the Morro at the mouth of Santiago Harbor, the faulting must be subsequent to old or middle Miocene; (2) as the sea along the fault shores has been able since the faulting to cut only narrow benches into the fault planes on the up-thrown side, the faultplanes are physiographically young; (3) the biologic evidence, in the opinion of most of those who have recently considered it, demands land connection in late Tertiary time between Cuba, Santo Domingo, Porto Rico, and thence

to South America. Miller has recently published an important paper on this subject,<sup>1</sup> and states: "With the characters of so many [eight] genera known it becomes possible to gain some idea of the Antillean hystricine fauna."<sup>2</sup> The most noticeable feature of these genera considered as a group is their similarity to the Santa Cruzian and Entrerian rodents which Ameghino and Scott have described and figured. In no instance has the same genus been found in both the West Indies and Argentina or Patagonia; but the Antillean rodents thus far discovered never show such peculiarities that their remains would appear out of place among those of their extinct southern relatives, while as a whole they would at once be recognized as foreign to the present South American fauna."

On the following page of the same paper he says: "So far as can be judged from eight very distinct genera the Antillean hystricine rodents do not present the characters that would be expected in animals derived from South America during any period geologically recent. Neither have they the appearance of an assemblage brought together at different times by migration or chance introduction. On the contrary they suggest direct descent from such a part of the general South American fauna, probably not less ancient than that of the Miocene, as might have been isolated by a splitting off of the archipelago from the mainland. Of later influence from the continent there is no trace."

The mammals furnish more evidence of this kind than I am presenting here, and Barbour and Stejneger, from their study of reptiles, have reached the same conclusions. These conclusions accord with the tectonic history of the region, namely, that in late Tertiary, probably Pliocene time, the West Indian Islands as we know them were produced by block-faulting which broke into pieces a far more extensive land area. Although I greatly respect the scholarship and appreciate the valuable researches of Dr. W. D. Matthew, I am unable to agree with his opinions as to the means of distribution of West Indian mammals and some of the other land vertebrates.

According to Hill, the volcanoes of the Windward Islands date back at least to the Eocene. He says: "After the Miocene, vulcanism became quiescent in the Great Antilles and the Coastal Plain of Texas, but has continued to the present in the four great foci of present activity—southern Mexico, the northern Andes, Central America, and the Windward Islands. In the last two regions mentioned, the greater masses of the present volcanic heights were piled

<sup>1</sup> Miller, Gerrit S., Jr., Bones of mammals from Indian sites in Cuba and Santo Domingo, Smithsonian Misc. Coll., vol. 66, No. 12, 10 pp., 1 pl., 1913.

<sup>2</sup> *Idem.*, p. 3.



up before the Pliocene, and the present craters are merely secondary and expiring phenomena."

The last important shift in position of strand line along the Atlantic coast of the United States and around the shore of the Gulf of Mexico and the Caribbean Sea has been by submergence of land areas, but subsequent to this there has been local emergence, often accompanied by minor tilting or warping.

Except vulcanism, the following table presents a succinct summary of the major events considered in the foregoing remarks. It is the primary intention of the present paper to characterize biologically and to correlate the marine formations of the Canal Zone and the geologically related areas in Central America and the West Indies, and to lay particular stress upon the successive periods of emergence and submergence of the land and the crustal deformation, folding and faulting, concomitant with changes of that kind. Comparison of the table opposite page 594, showing the correlation of the Tertiary formations of Panama, with the following tabular summary, will reveal that the story told by the two tables is essentially identical, the erosion intervals and the marine formations in the correlation table representing respectively the periods of emergence and the periods of submergence in the tabular summary.

TABULAR SUMMARY OF SOME OF THE IMPORTANT EVENTS IN THE GEOLOGIC HISTORY OF THE WEST INDIES AND CENTRAL AMERICA.

Time subdivisions.	Events.
Recent .....	Submergence of land areas probably resulting from deglaciation, except local differential crustal movements in places producing uplift.
Pleistocene .....	Emergence of large areas, probably due to withdrawal of water to form the continental ice sheets; also oscillation of land areas by differential crustal movement.
Pliocene.....	Local moderate submergence, period of cataclysmic faulting breaking up a large land area and forming the Antilles nearly as they are at present. Probably a narrow interoceanic connection that admitted an Atlantic fauna into the present site of the Gulf of California.
Miocene. { upper..... middle and lower.....	{ Extensive emergence of the land joining North and South America through Central America; Greater Antilles joined to each other, and possibly to Central America by bridges from Jamaica to Honduras and from western Cuba to Yucatan, and to South America along the Caribbean arc. All these supposed connections not necessarily contemporaneous. Extensive submergence in the West Indies and around the continental margins; narrow, areally limited interoceanic connections in lower Miocene time, none known in upper Miocene time; land emerging in Central America.
Oligocene. { upper..... middle..... lower.....	Extensive submergence with interoceanic connections. Maximum areal submergence with extensive interoceanic connections. Extensive submergence in Central America and southeastern United States; local emergence in the West Indies. Extensive diastrophism and mountain making by folding.
Eocene. { upper..... middle..... lower.....	Extensive submergence with interoceanic connections. Apparently interoceanic connection across Central America. Emergence of the Greater Antilles and Central America, no known interoceanic connection.



TABULAR SUMMARY OF SOME OF THE IMPORTANT EVENTS IN THE GEOLOGIC HISTORY  
OF THE WEST INDIES AND CENTRAL AMERICA—continued.

Time subdivisions.	Events.
Cretaceous { Upper Lower	Extensive submergence; but without interoceanic connection. Submergence in Mexico and Central America, especially in late Comanche time. Probable emergence in the Greater Antilles; no interoceanic connection.
Jurassic { Upper Middle Lower	Submergence in western Cuba, eastern Mexico, and west Texas without interoceanic connection, except possibly in late Upper Jurassic time. Submergence in southern Mexico (Oaxaca and Guerrero) with possible interoceanic connection. Submergence in southeastern Mexico (Puebla, Vera Cruz, and Hidalgo, possibly also in Guerrero) with possible interoceanic connection. Nonmarine plant-bearing beds in same region and also in Oaxaca. Possibly the latter may be of same age as the supposed Rhaetic plant-bearing beds of Honduras and Nicaragua.
Triassic { Upper (Rhaetic) Upper (Karnic) Middle Lower	Plant-bearing beds in Honduras and Nicaragua, above mentioned, bespeak land conditions in latest Triassic or earliest Jurassic. Submergence in central Mexico (Zacatecas) with probable interoceanic connection. Probable land conditions throughout Mexico and Central America. Probable land conditions throughout Mexico and Central America.
Late Paleozoic.....	Formation of the major tectonic axes of Central America and the initial east and west axes of the Greater Antilles.

<sup>a</sup> Mesozoic history of Central America, Mexico, and the West Indies, by T. W. Stanton.

