14. *On the CORALLIFEROUS SERIES of SIND, and its Connexion with the last UPHEAVAL of the HIMALAYAS.* By Prof. P. MARTIN DUNCAN, M.B. Lond., F.R.S., F.L.S., &c. (Read February 2, 1881.)

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I. *Introduction &c.*

A MEMOIR by Grant, illustrated by Sowerby, which appeared in the 'Transactions' of the Geological Society (series 2, vol. v. 1837), first brought the countries west and east of the Indus under the notice of European geologists. Fossils from Sind, Baluchistan, and Cutch were therein described; and the types were presented to the Society. But it is to Mr. Vicary that science owes the first attempt at a complete description of the geology of Sind*. Written in 1847, the fossils which should have illustrated his paper, and some others collected by Lieut. Blagrove in Cutch, were handed over to MM. d'Archiac and Jules Haime for examination and publication. Their fine work, the 'Description des Animaux Fossiles du groupe Nummulitique de l'Inde,' was published in 1852. They only recognized one geological horizon, the Nummulitic, although Grant had expressed an opinion that there was more than one fossiliferous series. Messrs. Cook and Carter added to the knowledge of the Baluchistan area in 1860†; and the last-named naturalist felt it necessary to give a Miocene age to some fossils which Sowerby had figured for Grant. On the other hand, MM. d'Archiac and Jules Haime severely criticised M. d'Orbigny for stating that some of their Sindian species were of Falunian age, and decided against Dr. Carter's grouping of some of the marine Tertiary beds as Miocene‡.

In 1863 Mr. Henry M. Jenkins, F.G.S., at that time Assistant-Secretary of this Society, and myself were endeavouring to learn something about Tertiary deposits situated as remotely as possible from European types.

A collection of Mollusca and Corals from Java had been sent to the Society by M. de Groot; and we proceeded to examine them; and in order to determine the affinities of some, which seemed to be of younger age than the Nummulitic, it became necessary to study the work of MM. d'Archiac and Haime on India and to examine their types.

We found that there was a species in Java which my friend called

* Quart. Journ. Geol. Soc. 1847, vol. iii. p. 334.

† Cook, Trans. Med. Phys. Soc. Bombay, vol. vi. pp. 1-45; Carter, Journ. Bombay Royal Asiatic Society, vol. vi. p. 184.

‡ See Carter, Geol. Papers on Western India, pp. 628-776, and the general *résumé* in their work already noticed.

Vicarya callosa, and that it was closely allied (the distinctions being only of ornament) to *Vicarya Verneulii*, D'Arch., from Sind.

This *Vicarya* of Java was associated with species which are closely allied to those of the Miocene of Western and Eastern Europe.

A Coral (*Heliastrea Herklotzi*, Dunc.) from Java resembled the Miocene *Heliastrea*s more than those of the Eocene*.

Following up the subject carefully, I examined all the collections submitted to MM. d'Archiac and Jules Haime; and to my surprise I found that they had neglected many specimens which had not only a Miocene but even a Pliocene facies. The identity of some species with members of the West-Indian Miocene Coral-fauna was tolerably evident; and whilst admitting the similarity of the mineral condition of all the fossils, I divided the genera into those which elsewhere are found in Eocene, Miocene, and Pliocene formations.

During the following year† I examined and described twenty-six species of Corals from Sind, from unknown geological horizons near Karachi. Some had been previously described by D'Archiac and Haime; but the bulk had not. The evidence of the existence of three Tertiary deposits instead of one seemed overwhelming.

Subsequently the Geological Surveyors of India, Mr. W. T. Blanford, F.R.S., and Mr. Fedden, made an elaborate survey of Upper and Lower Sind, and Messrs. Wynne and Fedden of Cutch.

In the last-mentioned district fossils were found which proved the equivalency of the deposits with those of Sind, and that there was a higher Tertiary horizon than the Nummulitic.

The Corals collected in Sind by the Survey, under the superintendence of Messrs. Blanford and Fedden, and carefully marked with figures denoting their geological horizons, were sent to me by Mr. Medlicott, F.R.S., the present Superintendent of the Survey, so that they might be described in a volume of the 'Palæontologia Indica.'

But simple description was not all the requirement of the Survey and myself. Certain questions of great importance had arisen in the geology of India; and it was probable that the determination of the age of the coralliferous strata would assist in deciding the ages of the Himalayan upheaval, of the Siválik deposits, and of certain olive shales underlying a trap at the base of the Nummulitic series—questions which had been attempted and had been answered by Messrs. Medlicott, Blanford, and Lydekker, and which required some confirmatory evidence.

There was another reason why I should be honoured by the Geological Survey of India asking me to undertake the description of their splendid collection of fossil Corals from Sind. In my Presidential Address for the year 1878 I criticised the opinions of my friends Messrs. Medlicott and Blanford regarding the age of the Himalayas, and inferred that their decision regarding the Post-pliocene date of the so-called Nerbudda fauna, was influenced by the discovery of a human implement in the containing deposit.

They took the very philosophical course of affording me the means of converting myself to their opinions.

* Quart. Journ. Geol. Soc. vol. xx. p. 45.

† Ann. & Mag. Nat. Hist., April 1864 (Fossil Corals from Sind).

The description of the Corals has been published in a volume of the 'Palæontologia Indica;' and although the evidence regarding a Pliocene marine fauna failed, there is no doubt about the former existence of Lower and Middle Tertiary coralliferous deposits in Sind.

II. *The Stratigraphical Position of the Series and of the Ossiiferous Manchhar Deposits.*

The detailed description of the geology of Western Sind is to be found in the Memoirs of the Geological Survey of India, vol. xvii. part 1 (1879), by W. T. Blanford, F.R.S. &c., Deputy Superintendent of the Geological Survey of India; and it is therefore only necessary to explain those parts of it which relate to the general succession of the stratigraphical series and the position of the strata yielding Corals.

The mountain-ranges west of the Indus run nearly north and south, in irregular parallel series. The longest range, the Khirthar, is slightly curved, the concavity being to the east; and it extends from slightly south of 26° N. lat. to close to 28° N. lat. The Laki range, more to the east, is nearly coincident with the sixty-eighth parallel of east longitude, and extends from the Indus north of 26° N. lat. to nearly a degree to the south. Other minor but nearly north-and-south ranges occur; and the whole were comprised by M.M. d'Archiac and Haime under the title of the Hala range (a name unknown to the natives).

The following is the list of geological formations in Western Sind, and which are to be recognized in one or other of the mountain-ranges* :—

Group.	Subdivisions.	Approximate Thickness.	Age.	Remarks.
ALLUVIAL		feet. ?	Post-Tertiary.	
MANCHHAR... {	Upper	5000	Pliocene	Unfossiliferous.
	Lower.....	3000-5000 ...	Old Pliocene or Upper Miocene.	Vertebrate remains.
GĀJ		1000-1500 ...	Miocene	Coralliferous; no Nummulites.
NARI	Upper	4000-6000 }		Unfossiliferous.
	Lower.....	100-1500 }	Oligocene. {	Coralliferous, with <i>Nummulites garan-</i> <i>sensis</i> .
KHIRTHAR ... {	Upper	500-3000 ...	Nummulitic	Nummulitic lime- stone.
	Lower.....	6000?		Unfossiliferous.
RANIKOT.....		2000	Lower Nummu- litic.	Fossiliferous. Corals and Nummu- lites.
TRAP		40-90	Deccan Trap.	
	<i>Cardita Beau-</i> <i>monti</i> beds.	350-450	Transition beds ...	Fossiliferous.
CRETACEOUS . {	Sandstones ...	700	Cretaceous.	Horizon not deter- mined.
	Limestones with Hip- purites.	320.		

* From the Memoir by Blanford, p. 32, slightly modified.

Explanatory Sections.—In the Laki range, south-west of Amri on the Indus, are dark-coloured hills which contrast with the cliffs of grey and white Nummulitic limestone behind them. A section close to the hill called Barraha is given by W. T. Blanford, F.R.S.; and it shows that the range consists of three parallel ridges (see fig. 1, p. 194).

The outer, to the east, is composed of Tertiary rocks, while the intermediate one consists of Cretaceous beds faulted to the eastward against the Lower Eocene strata, and dipping under them to the westward.

This section shows the normal sequence of the groups of strata from the Cretaceous to the Khirthar inclusive. Above the Nummulitic limestone of this last group the Nari and Gáj series are wanting, and the Manchhar succeeds*.

On the Gáj river, in the Khirthar range, W. T. Blanford remarks that a thickness of at least 25,000 feet of strata is exposed (see fig. 2, p. 194). The succession from west to east is:—unfossiliferous strata, probably of Cretaceous age, followed by Khirthar strata (the Ranikot series, the lowest Eocene, being absent); then the lower and upper Nari series come in, and are followed by the Gáj and the Manchhar deposits.

The lowest coralliferous deposits occur in the soft olive shales and sandstones with volcanic ash, belonging to the *Cardita Beaumonti* series below the trap. The accompanying remains are those of Amphicoelian Crocodilia and Echinodermata; and the deposit was neither a reef-structure nor a deep-water one.

The lower part of the Ranikot series, resting immediately on the trap, consists of soft sandstones, shales, clays with gypsum and lignite, and pyritous shale. A few fragments of bones and some dicotyledonous leaves occur. These freshwater strata are succeeded by highly fossiliferous marine limestones, often brown in colour, interstratified with sandstones, shales, clays, and ferruginous bands.

Nummulites appear for the first time, and there is a grand development of Corals, Echinodermata, Gasteropoda, and Cephalopoda. It was not a very deep-water formation. Erosion of the surface of the Ranikot strata occurred before the deposition of the next series.

The Khirthar series includes in its highest portion a massive, pale or dark grey, hard, compact Nummulitic limestone whose extreme thickness is 3000 feet. It thins out to the south-west, and disappears within a distance of twenty-five miles of its greatest development. Other Nummulitic limestone-beds are found, which may be lower in the series; and they and the main group are represented elsewhere by shaly limestones and sandstones with calcareous bands. In some districts flint occurs in a limestone with *Alveolinae*. The lower members of the series are often wanting, and are well represented by shales, marls, and sandstones and where these are present: unconformity with the underlying Ranikot beds is not seen; but where they are absent the Nummulitic limestone (as in the Laki range) rests unconformably. The compact limestone is of course

* Memoirs Geol. Survey of India, vol. xvii. pt. 1, p. 131.

Fig. 1.—Section through *Barrah Hill*. (Scale, 1 inch to 2500 feet.)

a, Manchhar strata, rest on pale clays of Khirthar age, with *Nummulites Leymeriei*, and then on Khirthar Nummulitic limestone, *b*, the beds dipping to the west. This limestone forms the eastern ridge. West of the ridge is some low ground, in which the upper members of the Kanikot group, *c*, crop out, also with a reversed dip. They end abruptly against a cliff of white and grey limestone, the boundary being a fault. This limestone, *g*, forms the base of the Barrah Hill, and contains Hippurites. A great thickness of sandstones, *f*, forms the top of the dark-coloured hills. On the top of the hills is a bed containing oysters and fragments of apparently reptilian bones. West of the hills are olive shales with *Cardita Beaumonti*, *c*. The trap, *d*, follows, and then the Kanikot group, *e*, which is of great thickness, and the Khirthar limestone, *b*.

Fig. 2.—General diagrammatic Section of *Khirthar Range*, on the north bank of the *Gaj River*. (After Blanford, half size.)

highly fossiliferous; but it has not yielded very good specimens of Corals. The indications of a fringing-reef-building fauna, or a bank of coral, are distinct; but the species when compared with their modern analogues do not indicate a great reef-development. Amongst other fossils, Lamellibranchiata prevail, and the Echini are numerous; but the Nummulites and Orbitolites, *Alveolina*, and *Patellinae* are the most important organic remains. Amongst the Nummulites there are *N. Ramondi*, *N. biaritzensis*, *N. Beaumonti*, *N. granulosus*, and *N. Leymeriei*.

The Nari series rests conformably on the Khirthars; and there is occasionally an apparent passage from the Khirthar limestone into a yellow or brown rock of the Nari group. There is, however, a biological break; for the Nummulites of the upper group are characteristic, and differ from those of the lower. The Khirthar forms are not found, and *Nummulites garansensis* appears with *Orbitoides papyracea*, in the Nari series. The rock is a limestone with intercalations of sandstones and shales. As a rule, shales, fine sandstones, and occasional bands of limestone form the base of the Nari group, and pass upwards into coarse, massive, thick-bedded sandstones, attaining a thickness of from 4000 to 5000 feet on the eastern flank of the Khirthar range.

A local break occurs to the south, and the Upper Nari beds rest unconformably on the denuded edges of the Lower Nari brown limestones; and still further south, fifty miles east of Karachi, there is a well-marked distinction between the upper members of the group with *Orbitoides papyracea* and the lower with *Nummulites garansensis*; and in one locality the upper member overlaps the lower, and rests on Khirthar limestone.

To the east of the Laki range the Nari beds are wanting, and the Manchhar series rests unconformably on the Khirthar, with some pebble-beds of the Gáj series intervening. But to the west of the range the Nari and the Gáj series are found in their normal sequence; and towards the coast the exact distinction which can be drawn elsewhere, stratigraphically and petrologically, between the Tertiary series is not possible: this is mainly due to the disappearance of the limestone element of the Khirthar and Nari series, and to the prevalence of sandstones and shales. The fossils, however, distinguish the groups; but the horizons of the zones of Nummulites and Orbitoides vary, being higher or lower in their proper series according to locality.

The upper sandstones of the Nari group have not yielded marine fossils, and in Upper Sind they contain the remains of plants.

The Nummulites become fewer in their species at the base of the Nari group, and cease to be found in the lower beds of the succeeding series, the Gáj.

The Gáj group, with a base of highly fossiliferous limestones and calcareous beds, more or less shaly and stratified, overlies the softer shales and sandstones of the Nari series. The development of the calcareous series is great; but it is subordinate to an arenaceous element. The sandstones are intercalated with clays with gypsum;

and shales and bands of limestone, highly coralliferous, are very constant.

The Gáj series rests conformably on the Nari series; although there is a mineralogical break, the passage is so gradual that calcareous bands of the Gáj series are found interstratified with the uppermost Nari sandstone. The Gáj series overlaps the Nari to the south and rests on the Khirthars, and is wanting in Lower Sind to the eastward of the Laki range.

North-east of Karáchi the series is highly developed, and massive limestones occur; they reach as far as the coast.

The uppermost beds of the Gáj series are variegated clays and grey sandstones, which form a passage into the everlying Manchhar strata, and contain species of *Ostrea*, *Corbula*, *Arca*, *Scalaria*, *Buccinum*, and *Turritella*. A crab of the genus *Typilobus* and the *Vicarya Verneulii* already noticed have also been found there. The oyster is like *Ostrea multicosata*. The Echinoderms are of the genera *Maretia*, *Meoma*, *Breytia*, *Clypeaster*, &c. The Corals found, principally associated with the limestone-beds, are very different in their aspect from those of the underlying Nari group. They belong for the most part to reef-building genera, and some are represented in modern reefs by allied species, which grow in the surf and in the most exposed parts. The rest were dwellers in quiet water. Great masses of the coral limestone consist of *Stephanocenia maxima* in casts, and the presence of the genera *Madrepora*, *Haliastrea*, and *Porites* is very significant of shallow-water conditions.

Resting on the Gáj strata is the Manchhar group; and where the Gáj beds are wanting, and even where the Nari series is deficient, this upper group rests on the Khirthars.

Of great thickness (10,000 feet on the flanks of the Khirthar range) the Manchhar series is divisible into an upper and a lower group. In the lower group much grey sandstone, soft and fine-grained, and composed of quartz with some felspar and hornblende, is found; and red sandstones and conglomeratic beds exist towards the base, as well as red, brown, and grey clays. The conglomerates do not contain pebbles of older Tertiary rocks; but cream-coloured clay, soft sandstone, quartzite, and micaceous shale are found in them. The conglomerates near the base are ossiferous; and the vertebrate remains are teeth or bones more or less rolled. There is no satisfactory distinction to be made on the Gáj river between the estuarine beds at the top of the Gáj series and the lowest beds of the Manchhar; and osseous remains have been found in the upper Gáj series.

The upper part of the Manchhars has a conglomerate in it with stones derived from the older tertiaries; below it are red, brown, or buff sandstones, with some clays; and there are no fossils.

Although usually conformable to the Gáj series, in places the Manchhars rest on the older rocks; and there are proofs of the Gáj strata having been greatly denuded before the deposition of the Manchhars.

In the Laki range the Manchhars have an ossiferous conglom-

merate near the base. In the Vero plain, running southward along the eastern side of the Laki range, south of Ranikot, large fragments of silicified wood are common, and some trunks of trees are upwards of 30 feet in length and 10 in girth. In the south, near Karáchi, the Manchhars pass into Gáj strata, and marine fossils are associated with the lowest beds.

The general conformity of this great tertiary series is evident—although local unconformities occur, and there is evidence in favour of there having been some disturbance of the older rocks before the deposition of the Lower Manchhar group. The subsidence which took place during the deposition of these thick shallow-water deposits was vast; and there were occasional slight upheavals. The final epoch of the mountain-formation occurred after the deposition of the Manchhars. The strike of the chains is in the main north and south; and the thrust came from the west to the east, and from east to west.

The date of the grand mountain-formation is subsequent to the deposition of the sedimentary strata forming the Upper Manchhars.

III. *General Results of the Study of the Corals of the Series.*

The Corals of the strata with *Cardita Beaumonti* below the trap are shallow-water forms; and their development indicates conditions unfavourable to vigorous coral-growth. There was no reef. The species are new; and there are no characteristic Cretaceous or Eocene forms present. The *Smilotrochi* and the *Rhabdophyllæ* are Secondary genera; but the first-named had species in the European Tertiaries, and may be represented in the shallow seas of the present day. The *Caryophyllæ* of the deposit have four cycles of septa only; and this gives them somewhat an ancient look; and the *Litharceæ* would pass either as a Cretaceous or as an Eocene form.

The fauna as a whole is deficient in characteristic forms, and may be considered transitional.

It has been stated by the Geological Surveyors that the trap resembles the Deccan and Malwa trap; and the position of that vast outburst is anterior to the Nummulitic age, and subsequent to some Cretaceous strata in Western Central India. Certainly there are no Nummulites in the sands and shales which contain the fossils; and these are the remains of a Cretaceous crustacean.

The Corals of the Ranikot group are numerous in genera and species; and the fauna is remarkable for the number of simple forms. It contains, and for the predominance of the family Fungidæ.

The compound Corals of the family Astræidæ, which so largely enter and have entered into the composition of reefs, are but feebly represented; and the few species which have been described did not aggregate to form massive limestones, but were seated on small flat circular epithecate bases. Fine as were many of the growths, yet it was a stunted Coral-fauna; and the shape of the majority of the forms would rather indicate that they lived in still water, and not in the rush of the waves. Certainly the Corals were beyond the

rolling or scouring action of the sea; for any such movement would have displaced most of them.

As a generic assemblage, the Ranikot Corals are Eocene in facies; and of the twenty-seven genera three are new, and one is known in the Miocene of the West Indies. Out of fifty species seven are identical with European Eocene types, which are not found, however, as a whole, on one geological horizon in Europe. Some of them are found in the Lower Eocene; and the others are to be noticed in the deposits of San Giovanni Ilarione and of the Oberburg, in Styria, and in the higher horizon of Castel Gomberto. These forms are located in one series in Sind, and at the bottom of the Nummulitic group. Five species are closely allied to European forms out of the same great vertical series; and about seven others have a distinctly European facies. These 19 species give the Eocene character to the fauna.

The most distinctive genera are *Stylocœnia*, *Plocophyllia*, *Stephanophyllia*, *Stephanocœnia*, *Pironastrœa*, *Reussastrœa*, *Cyclolites*, and *Litharœa*. It is remarkable that five well-marked species of the genus *Turbinoseris* (nobis) should have lived on the Indian area; they are allied to those of the Eocene of St. Bartholomew in the West Indies.* The genus is Lower Cretaceous in England; and, under another name, it has lately been introduced into the Nattheim oolitic Coral-fauna.

The presence of a species of *Stylina* and of *Thamnastrœa* recalls the Jurassic and Cretaceous ages: the first is found also in the next or Khirthar series of deposits; and the last probably lived longer in the southern seas. Only one genus, *Placocyathus*, is a Miocene type; and its distribution is West-Indian.

There is one very remarkable species, *Stylocœnia maxima*, nobis, in the Ranikot group; and it is so called from the great size of the intercalicular projections, which are little monticules in the British *Stylocœnia emarciata*, Lamk. sp. The breadth of the circular base of the coral is $3\frac{1}{4}$ inches; and it is $1\frac{8}{10}$ inch in height centrally. A concentric epitheca is on the base; and the upper surface is a mass of calices, and tall columns between them, some reaching $\frac{4}{10}$ inch in height. The minute columns in the British species are proved by the examination of these gigantic growths to be stunted or aborted calices. Some of the processes of *Stylocœnia maxima* have a perfect calice on the top, and the costæ come down the side; others have ill-developed calices, and a mere representation of a columella and septa. It is a common form, and is characteristic of the Ranikot series; its nearest ally is *Stylocœnia macrostyla*, Reuss, which is associated with *Nummulites planulatus* and *Cerithium giganteum* in the district of San Giovanni Ilarione.

Young specimens, of course, greatly resemble the European *Stylocœnia emarciata* of Bracklesham age.

Two other species of *Stylocœnia* are very common: one, *S. Vicaryi*, was described by D'Archiac and Haime; and the other is new. It has a large circular epithecate base; and the calices are large.

Astroœnia, that very widely distributed genus, whose range, ver-

* P. M. Duncan, *Quart. Journ. Geol. Soc.* vol. xxix. p. 554.

tical and horizontal, is enormous, has several species in the Ranikot group; and *Astrocenia ramosa*, Sowerby, a Cretaceous type from the Turonian of Gosau, found also in the Eocene of St. Bartholomew in the West Indies, is present in Sind, and has the usual tuberoso branchlets so characteristic of the form.

Large solitary Corals of the genus *Montlivaltia* abound, and also a characteristic series of simple forms which I have had the opportunity of naming after Mr. Fedden, to whom the geology of Sind owes so much. The genus *Feddenia* had its young forms growing on small shells, which, with the growth of the base of the Coral, were enclosed, and the Coral became free. This is not an unusual habit in some two or three species of Corals of another family, now living; and an elongate base is produced. One of the results of this change of condition was that the costæ did not radiate upwards from the peduncle, as is seen in the larger forms, but from the whole length of the enclosing base. Another peculiarity is that the epitheca is like a broken mosaic.

There are three well-marked species of this genus; and one has two good varieties in the Ranikot series. It is near *Montlivaltia* as a genus; and, admitting the great variability of all simple or solitary Corals, it is very possible that the unusual method of early growth may have produced correlative changes in the general shape and septal arrangement. The genus was restricted to this Lower Eocene horizon. Amongst the great series of Fungidæ found in the Ranikot group there are two European forms of *Cyclolites*; and the other seven species of the genus are well differentiated.

Finally, the genus *Stephanophyllia*, amongst the Eupsammineæ, ought to be represented, to give the full early Tertiary facies to the Cyclolitic assemblage. *Stephanophyllia indica*, from Jhirk, in the Ranikot group, maintains the character of the genus for beauty, and is an exquisite gem. Its affinities are rather with the Cretaceous species; and it differs but slightly from *S. Bowerbanki* of the Lower Chalk in its main characters, and from *S. discoides* of the London Clay more decidedly. Like most of the Ranikot corals, the individuals of the new species began life by settling down on a Nummulite; this formed the permanent base of the coral; and the usual radiating costal arrangement of *Stephanophyllia* either does not exist or cannot be seen for the Nummulite.

Khirthar Series.—Sixteen species of Corals were found in this series; but ten of them were taken from beds so high up that it is not satisfactorily proved whether they are at the top of the Khirthars, or form the base of the Nari group, next in vertical succession. By separating these ten species, an indubitable Lower-Khirthar fauna is decided to have existed: its biological conditions were unfavourable to vigorous coral-growth; and there were no littoral or reef-building forms. From the analogy of recent forms, which are identical generically with those of the Khirthar series, or whose shape resembles that of the ancient species, a sea-floor at the depth of from 20 to 200 fathoms or more would be indicated.

The species belong to the genera *Trochocyathus*, *Leptocyathus*, *Stylophora*, *Montivaltia*, *Calamophyllia*, and *Astrocenia*. The *Trochocyathus* is one of the discoid group, and the *Leptocyathus* is of course a low flat Coral. The *Stylophora* is a minute Coral; and so is the *Astrocenia*. But the *Montivaltia* is a finely grown form; and so is the *Calamophyllia*. Of these, *Stylophora contorta*, Leymerie, has also been found in the Eocene of the West Indies and at La Palarea in Europe; and *Astrocenia numisma*, DeFrance, sp., is a Nummulitic form at Gap, in the district of Nice. This little assemblage is thus clearly of Eocene age. No distinction can be made between this and the preceding deposit, as regards age, from the Corals.

Now the ten species, the horizon of which may be of Upper Khirthar or Lower Nari age, belong to genera whose morphology indicates the presence of totally different physical conditions from those which environed the stunted, simple, and the few large Corals of the lower horizon. They were shallow-water and reef-building forms; and the genera are *Stylina*, *Latimœandra*, *Hydnophora*, *Favia*, *Isastrœa*, *Pterastrœa*, *Plesiastœa*, and *Porites*. There is not a simple Coral amongst them; and the facies is singularly mixed, old and new, Mesozoic and Cainozoic genera existing together.

The species *Hydnophora maliriensis*, nobis, is allied to *H. venusta*, Catullo, of the European Nummulitic. *Porites Pellegrinii*, D'Achiardi, is found in Europe at San Giovanni Ilarione; and *Porites indicus*, nobis, is allied to a species from Crosara, Oberburg. The distinctness of this fauna from that of the Ranikot group is evident enough; but it is still Nummulitic in facies and character.

The Nari Series.—From the remarks already made upon the localities of some of the presumed Khirthar Corals, it is as well to admit that some upheaval took place at the close of that period, and produced fringing-reef-building or bank conditions. But they did not prevail throughout the accumulation of the whole of the Nari series; and it is somewhat remarkable that no species passes up from the reef-building horizon into that of the Nari proper.

The genera of the Nari group above the base, indicate rather vigorous coral-growth, and both deep- and shallow-water conditions. The genera *Trochocyathus*, *Trochomilia*, *Montivaltia*, *Cycloseris*, and *Cyclolites* are the simple forms; and the vigorous compound forms are included in the genera *Dasyphyllia*, *Rhabdophyllia*, *Lepetoria*, *Mœandrina*, and *Prionastrœa*.

The *Trochocyathi* of the Nari series are remarkable for having commenced their growth in a discoid shape. Some retained that shape; but one in particular, *Trochocyathus nariensis*, nobis, grew upwards from its disk-shaped base in a perfect cylinder, reaching 2 inches in height.

Trochocyathus cyclolitoïdes, Ed. & H., is a widely distributed European Eocene coral, and is found in the Nari series of Sind.

Stylophora pulcherrima, D'Achiardi, from the Eocene of Friuli, *Trochomilia varicosa*, Reuss, from Crosara, *Stylocenia taurinensis*, Ed. & H., from European Eocene and Miocene strata, and *Cycloseris*

Perezi, Ed. & H., from the Nummulitic of Nice, are also amongst the Nari corals. Hence, out of the twenty species of fossil Corals in the Nari series, one is found at a higher horizon, and one fourth of the number are found in the Upper Nummulitic and Oligocene deposits of Europe.

Taking the Ranikot, Khirthar, and Nari Coral-faunas as a whole, there are 76 species of Corals in them and several varieties; and of these 16 are identical with European forms which are found in strata yielding Nummulites to the top of the Oligocene. There are also eight species in the Sind series, closely allied to those of the European fauna; and whilst some species are common to the West-Indian Eocene, an important genus is also common to both localities. The absence of species passing up from one series to another is very remarkable.

The Gáj Series.—This series of strata contains a large number of Corals in bands; but although most of the forms are massive and compound, and suited for reef-building, the majority are pedunculate instead of covering a large surface and incrusting. Some are very massive; and the presence of species of *Madrepora*, an essentially reef-building genus, with *Porites*, *Agaricia*, *Echinopora*, *Prionastræa*, *Plesiastrea*, *Brachyphyllia*, *Leptoria*, and *Dasyphyllia* would indicate, at the present time, very active shallow-water coral-growth. The majority of the Gáj genera still flourish; and most of those which are extinct had the structures requisite for reef-building. The Astræidæ as a family preponderate, and simple Corals are rare, in the collection. But although the facies of the Gáj coral-fauna is very recent, and there are very few extinct genera, still the modern Coral-fauna of the Eastern and Red Seas is not represented by a single species. Two species are identical with Miocene West-Indian forms; and one is found in the Nari series.

It is interesting to find the West-Indian Miocene and recent genus *Antillia* represented. Nevertheless the evidence afforded by the Corals is in favour of a mid-tertiary age being given to the 41 species from Gáj.

In the communication to the 'Annals and Magazine of Natural History' (1864, vol. xiii.) I described several species of fossil Corals from unknown geological horizons in Sind; and it is not difficult, with the lists of the genera and species which have been collected by the Geological Survey of India, to decide whence the majority came. Thus *Oculina halensis*, nobis, *Antillia dentata*, nobis, *Antillia ponderosa*, Ed. & H., *Cladocora haimiei*, nobis, *Hydnophora rudis*, *H. plana*, *H. hemisphærica*, nobis, point, with *Cyathoseris valmondoisiaca*, Ed. & H., and *Agaricia agaricites*, Ed. & H., to a late Miocene horizon. They were picked up in the neighbourhood of Karáchi, and doubtless came from the highest beds of the Gáj series.

Finally, many specimens of Isidinæ have been found in the Gáj series; and some of them closely resemble modern forms. No Nummulites occur in the Gáj series; and the Zoantharian evidence indicates a Miocene age, and not an early one.

The Sindian formations, including the transitional beds with *Cardita Beaumonti* beneath the trap, and the Gáj series at the top, contain 136 species of Corals and many varieties. Of these, 9 belong to the transitional series, and 56 to strata in which Nummulites exist in profusion. The Nari series, with few species of Nummulites and with *N. garansensis*, a European type characteristic of the Upper Nummulitic or Oligocene, contains 20 species. The Miocene strata of Gáj contain 41 species. I omit from these numbers all species from doubtful localities. Thus, as only one species transgresses, there are five Coral-faunas; and if the separation I have proposed at the base of the Nari series is right, there are six in the same area, included in a prodigious depth of sedimentary strata. The study of the Corals does not indicate that there was ever a sea there with a depth of many hundred fathoms; on the contrary, shallow-water conditions (within 20 fathoms) usually prevailed during the slow oscillation of the area, in which subsidence on the whole predominated.

IV. *The Equivalence of the Manchhar Strata of Sind and the Siválík Group of the Himalayas.*

The Geological Survey of Sind by Blanford and Fedden has proved that in some places the Manchhar strata succeed transgressively to the Gáj series, whilst in others there has been erosion of the marine deposit before the deposition of the freshwater one, or else the lower group is absent. Bones of *Rhinoceros sivalensis* have been found in the uppermost Gáj strata. There is no doubt that the greater part of the coralliferous strata of the Gáj series accumulated in shallow water, and yet beyond the reach of the wash-down of a coast-line. But the lower Manchhars were deposited in shallow water within the scope of terrestrial denudation. There must have been considerable general changes in the physical conditions of the area: and they persisted; for coral life has never since prevailed there. The first change probably was one of slight general upheaval; and subsequently a slow and progressive subsidence occurred, during which the vast vertical development (8000 to 10,000 feet at least) of the lower and upper Manchhars accumulated.

Conglomerates, coloured sandstones (grey, green, and red in tint), and clays, are the prevailing deposits on the inner flanks of the vast mountain-system which surrounds Peninsular India, from Sind to Burma inclusive. Made up of stone brought down by the rivers of the extra-peninsular mountain-system, before it became of very great height, and when its breadth was probably much greater than it is now, these deposits are to be traced to the north of Sind in the Suleiman Mountains, in the Salt range, covering much of the surface of the Northern Punjab, and then, forming part of the sub-Himalayan range, as far east as the Brahmapootra. Similar deposits are found, in diminished thickness, in the Assam range; and they became important in the Burmese territories. The Sindian succession of the strata is the normal one; and it extended to a certain distance northwards; moreover it is exemplified in the Burmese

area. But in the great central area of the Himalayas proper there was no marine Miocene. No marine beds, the equivalents of the Gáj series of Sind and Burma, underlie the Siválík deposits in the Sub-Himalayas.

There was open sea during the Nummulitic age where the great semicircle of extra-peninsular mountains now exists; and marine conditions persisted on the west and east during the Miocene period; but a post-Nummulitic upheaval developed a land-surface and hill-tracts from Kashmir to Assam.

This upheaval commenced before, but culminated after, the close of the Eocene age; and a considerable thickness of purple sandstones, red clays, and grey and purple sandstones containing plants accumulated in the swamps on the plains of that age, near the mountains on the edge of the Nummulitic sea-floor.

These plant-bearing strata and the underlying Nummulite-bearing strata have a minimum thickness of 2000 feet, and they form the Sirmúr series of Indian geologists.

This series underlies unconformably the vast freshwater sedimentary formation comprising the Náhun and Siválík strata, which attain a thickness of about 15,000 feet, and, except where buried beneath recent deposits in one locality, extend, with a varying development, along the south of the great mountain mass, and are found on one of the great tablelands to the north of the Central Himalayan axis. The lower, or Náhun unfossiliferous, series consists mainly of grey lignitiferous sandstones. On it the upper, or fossiliferous Siválíks, accumulated as sandstones and clays; and on the top of all are conglomerates. A great fauna is represented in all parts of the Siválík deposits above the Náhun beds.

From the lie of these sedimentary strata, it may be very reasonably inferred that the Náhun and Siválík deposits are the equivalents of the Lower and Upper Manchhars of Sind; and the inference may be extended to the Upper Tertiaries of Burma. There is an outlier of this series and of its lower member in the Gulf of Cambay or Perim Island.

In attempting to establish exact parallelism between the Sindian and the Himalayan deposits called Manchhar and Siválík, it must be noticed that the vertical development of the last-named rocks is the greatest, and that whilst the lowest beds of the Sindian series are fossiliferous, those of the Náhun beds of the Siválíks are not*. On the other hand, osseous remains are found throughout the Siválíks proper (above the Náhun beds), but not in the Upper Manchhars in a recognizable form.

The Manchhar and Siválík series have been upheaved, uptilted, and in the last instance greatly contorted. Both series were the youngest implicated in the great orographical development; and although they are on different lines of strike, they were affected during the same geological period.

The denudation of their exposed edges has been great. Both are

* Possibly the ossiferous deposit at Kushálghar, near Attock, is of Náhun age. See further on.

covered in some places with high-level gravels; and the Siválíks of the great tableland of Hundes underlie deposits referable to the glacial period, whose effects were not felt so far south as Sind.

In considering the palæontology of these deposit it may be stated that the osseous remains are found on several horizons.

First, the Rhinoceros-remains which were found included in the Marine Miocene series of Gáj in Sind, lead to the inference of the existence of neighbouring contemporaneous land-surfaces and shallow seas—that is to say, of Miocene land washed by a Miocene sea. The Rhinoceros, according to Mr. W. T. Blanford, F.R.S., is *Rhinoceros sivalensis*.

Secondly, the fragmentary bones and teeth found in the conglomerate near the base of the Lower Manchhar formation in Sind accumulated later on than the Gáj series.

The following is the list of the vertebrate remains which were collected by Mr. Fedden, and named by him and Mr. Lydekker in the publications of the Geological Survey of India:—

Amphicyon palæindicus.	Anthracotherium silistrense.
Dinotherium pentapotamia.	Hyopotomus palæindicus.
—— indicum.	Hyotherium sindiense.
——, sp. nov.	Dorcatherium majus.
Mastodon perimensis.	—— minus.
—— latidens.	
—— Falconeri.	EDENTATA.
Rhinoceros palæindicus.	Manis sindiensis.
——, sp. near R. deccanensis.	
Acerotherium perimense.	REPTILIA.
Sus hysudricus.	Crocodylus, sp.
Hemimeryx, sp.	Chelonia, sp.
Sivameryx, 2 sp.	Ophidia, sp.
Chalicotherium sivalense.	

The conglomerate containing the bones was composed of the wash-down of the Lower Manchhars themselves.

Thirdly, the fossil bones which have been discovered in considerable quantities in a conglomerate on Perim Island (although their place in the geological series cannot be determined, from the absence of a succession of rocks) appear to have belonged to a fauna allied to that of the Manchhars and to that about to be noticed.

The species which have been determined by Falconer and Lydekker are:—

Dinotherium indicum.	Brahmatherium perimense.
Mastodon latidens.	Camelopardalis sivalensis.
—— perimensis.	Capra perimensis.
—— sivalensis.	Antelope, sp.
Rhinoceros, sp.	Sus hysudricus.
Acerotherium perimense.	

The remains are included in sandstone blocks.

The same, or a slightly higher, horizon is recognized far away to the north, not, however, by its geological position, but by the fossil remains, in the neighbourhood of Kushálghar, forty miles south of Attock, in the Punjab. The deposit contained, according to Falconer and Lydekker, the following genera and species:—*Dinotherium*

pentapotamia, *Mastodon*, *Listriodon pentapotamia*, *Rhinoceros*, *Merycopotamus*, *Dorcatherium*, *Sanitherium Schlagintweitii*, and *Amphicyon palæindicus*.

It is remarkable that all these horizons should contain *Dinotherium*.

Fourthly, the Siválik clays, sands, and conglomerates above the Náhun series present an assemblage of genera and species second to none in importance, and much grander generally than the existing fauna, which is very slightly represented. A number of genera which had lived in the Miocene elsewhere were associated with genera not known in mid-Tertiary deposits, and which have lasted either into Post-Pliocene or into Recent times. The *Dinotheria* are absent. Omitting the common Miocene genera and stating the others, an African element is noticed, as in the instance of *Pikermi* in Greece. The characteristic genera are *Palæopithecus*, *Macacus*, *Semnopithecus*, *Stegodon*, *Elephas*, *Loxodon*, *Hippopotamus*, *Camelopardalis*, *Camelus*, *Bos*, *Bubalus*, *Bison*, *Cervus*, *Equus*, *Canis*, *Ursus*, *Mellivora*, *Meles*, *Lutra*, *Enhydriodon*, *Tapirus*, *Hystrix*, *Mus*, *Rhizomys*, *Crocodylus*, *Gavialis*, *Varanus*, *Ballia*, and *Emys*.

Moreover many of the freshwater Mollusca are identical with recent forms.

It appears that these wide horizons are separable into an older series, with *Dinotherium*, *Hyotherium*, *Hemimeryx*, *Sivameryx*, *Hyopotamus*, *Anthracotheerium*, *Acerotheerium*, and *Manis*, but without *Elephas* and the later bovines; and into a younger series, in which genera of an African type, such as *Hippopotamus* and *Camelopardalis*, are found, and without the older types.

The first series is in relation with the Lower Manchhars, and the second with the Siválik deposits above the Náhun beds. But the interesting fauna from Kushálghar appears to be probably of Náhun age; and if that should be proved eventually, the succession of two fairly distinct faunas, linked together by some species, will be evident.

Finally, the Post-Pliocene deposits of the Jumna area, and also of the Nerbudda and other peninsular rivers, contain some species of the Siválik horizon.

V. General Considerations regarding the Age of the last Himalayan Upheaval.

It might be supposed, considering the ready manner in which European mammalian faunas are placed in the scale of geological succession, that the contemporaneity of some of them with the Siválik-Manchhar assemblage of vertebrates would be easily determined, and a geological age given for the latter without doubt.

But the critical examination of the positions in which many of the European mammaliferous deposits have been found, indicates that the manner in which the Tertiary deposits have been classified by means of the fossil Mammalia is open to exception.

Two well-known examples of European mammaliferous deposits which resemble, in their succession, the Siválik-Manchhar series are

those of Eppelsheim and Heppenheim and of Pikermi. At Eppelsheim sands in small patches are at the top; and they contain a few specimens of fossil Rodentia, Insectivora, and Carnivora. A conglomerate is beneath, and contains the Dinotherian remains, and also those of Rhinoceros and Mastodon; and all are remanié. At the base of the series there is a clay with freshwater shells; and it rests conformably on a marine limestone; and this is of late Miocene age.

At Pikermi the deposit, the bones from which have been so ably described by Gaudry and commented on by W. T. Blanford, rests on a freshwater stratum of Pliocene age, and a Miocene lacustrine series underlies the whole unconformably.

Now at Sind as at Eppelsheim the underlying marine beds are Upper Miocene in age, and freshwater conditions prevailed subsequently, during which the osseous remains were deposited.

What is the age given to the *Dinotherium*-conglomerate at Eppelsheim? Carl Vogt, influenced apparently by the presence of *Dinotherium*, and regardless of any stratigraphical arguments, and not considering the important changes which had occurred in the area, in the relative level of the land and sea-floor, decided that the overlying freshwater beds are of mid-Tertiary age. But Credner, dealing with the subject more philosophically, and not being so much impressed with the presence of a genus which elsewhere is represented in Pliocene strata as by the evidence of the considerable mutations which had occurred in the physical geography of the district, and which had brought a marine deposit above the original sea-level, places the bone-bearing conglomerates in the Pliocene age. Thus one geologist associates the land and marine elements together, and the other separates them.

The comparison which can be instituted between the Manchhar and Siválik deposits and those at Pikermi is very close; and, according to the ordinary rules of stratigraphy, if the osseous remains at the last-mentioned locality overlies Pliocene deposits, the animals which left their bones could not have been of Miocene age. Yet Prof. W. Boyd Dawkins, in his contributions to this Society, asserts that the Pikermi fauna flourished in the Miocene. Evidently there is a great diversity of opinion regarding the age which should be given to land-surface remains overlying marine strata, freshwater and estuarine deposits intervening. And if this subject is studied it will be found that great discrepancies of opinion have existed in regard to similarly placed deposits in many of the great formations.

About the relative age of some superincumbent terrestrial remains there is no discrepancy of opinion. The Coal-measures are associated with the underlying grits and limestones; and the land remains of the Inferior Oolite are similarly connected in classification with the marine deposits beneath them. When the lateral extension of the strata can be traced, and distant marine equivalents of the overlying series can be proved to contain fossils representative of or identical with those of the underlying series, the land-surface is classified with the formation in which the marine strata are placed. Or when there is

a succession, on the same area, of marine beds over the terrestrial and freshwater series, if the fossils of the upper strata resemble those of the deeply seated marine ones, the whole belongs to one great aspect of nature.

It will be found that there can be no exception made to placing the Woolwich and Reading series out of the formation which includes the white chalk; but the propriety on any grounds of linking the Purbecks on to the marine Portland is open to exception.

Except in instances similar to those of the Carboniferous and Inferior Oolite, and where there is also decided unconformity, the question can only be answered after a careful consideration of the amount and extent of area implicated in the changes in the physical geography which may fairly be assumed to have occurred since the underlying marine deposit was completed. The upheaval of *limited* marine deposits recognizable as belonging to a particular formation, and the accumulation upon them of freshwater deposits and conglomerates, would hardly necessitate the belief in such a change in the aspect of nature as would warrant their classification under two great geological ages. But when the same phenomenon is witnessed over *widely* separated areas, and a conglomerate is followed by some thousands of feet of fluviatile and other freshwater strata (the wreckage of high land close at hand), it becomes certain that the physical change has been wide enough to admit of an alteration in the geological nomenclature.

With regard to Sind, the Lower Manchhars usually rest conformably on the Gáj marine Miocene, and marine, estuarine, and freshwater intercalations exist at their base and before the conglomerate is fully developed. In one locality the Manchhars rest on a greatly denuded surface of Gáj strata.

Upheaval (slow, irregular, and on a very grand scale) occurred subsequently to the deposition of the Gáj series; and a marine tract became estuarine, fluviatile, and a region of wearing of high land. Subsequently the enormous subsidence took place, doubtless almost synchronously with the deposit of the thousands of feet of the Manchhars; and yet the sea never broke in: it was far away.

The area of change was vast; and it appears to be unreasonable to associate all these deposits under one geological formation.

The disassociation of the Manchhar and Gáj series is a necessity; and the nature of the fauna, so singularly allied to that of Pikermi, necessitates its relegation to the early Pliocene time.

In following up this subject it must be remembered that the Siválik strata, the horizon of which is above the Lower Manchhars, have a vast vertical as well as horizontal development, and that osseous remains have been found in them throughout their height. The fauna as a whole has a later facies than that of the Lower Manchhars, and resembles, even in its African element, that of Pikermi.

On the ground of inferred equivalency with the Upper Manchhars, and of faunal alliance with the assemblage at Pikermi, it must be credited that the Siválik strata are of Pliocene age.

There is another argument which has not hitherto been employed and which favours this theory.

The Siválik strata rest on, or are in contact with (along a line of fault), certain plant-bearing strata of the Sirmúr series which are associated with the underlying Nummulite-bearing Eocene rocks of Subáthu.

The nature of the flora, so far as it has been examined, is not very foreign to that of India at the present time; and by the same kind of reasoning which asserts the separation of other terrestrial and underlying marine strata, these beds, called Kasaoli and Dugr'hai, may well be the remains of the Miocene land.

Whence were the vast thicknesses of the sands, clays, and conglomerates of the Manchhar-Siválíks derived? They represent a ruined mountain-chain in bulk; and they are found not only on the flanks of, but also within, the orographical systems of which they form parts.

It appears from the study of the history of the Himalayas by Strachey, Stoliczka, Medlicott, and those Indian Geological Surveyors who have laboured so industriously of late years, that a low mountain-chain existed on the area after the Nummulitic age—the results of a post-Nummulitic earth-movement. It was probably a broad chain, and not a sufficient barrier to prevent the roaming of the animals on and over it in the subsequent geological age. This chain appears to have had an axis of old rocks; and the whole suffered denudation during the age of the Siválik Mammalia. In Hundes Strachey found the great tableland (now at an altitude of from 14,000 to 16,000 feet) to consist of sediments filling up a basin in old rocks to the depth of 3000 feet—sediments which included osseous remains of animals that could not have traversed high and difficult mountain-ground.

Part of the Siválik sediments were formed out of low mountain-ground by fluvial denudation; but to account for the vast development of the rest on the flanks of the present mountain-system, it is necessary to admit that the upheaval, and much of the north-and-south crush of the Himalayas, occurred *pari passu* with the slow accumulation. Elevation and diminution of the breadth of the area progressed; and doubtless much of the great crush which folded and often reversed the flanking strata was final.

The Siválik strata rest on the flanks of the chain and on old rocks within the range; and they were the youngest deposits affected by the mountain-making. Hence the Himalayas, as a grand system, culminated during and subsequently to the collection of these strata, which have been pronounced to be Pliocene in age.

The Siválik deposits in the tableland of Hundes are overlain by relics of the great glacialization of the Himalayas. Hence, before the vast glaciers of the glacial period accumulated, valleys had been worn out and denudation had proceeded. So it is necessary to recognize that the culmination of the movements which developed the height of the Himalayas occurred in preglacial times and during the Pliocene age.

To complete the serial changes, it is to be remembered that a Postglacial fauna was found in the old alluvium of the Jumna, a wash-down of the Himalayas.

With regard to the Upper Manchhars, they were implicated in the great orographical movement, which was contemporaneous throughout the extrapeninsular area of India; and they are of Pliocene age.

The details regarding the succession of strata and of many of their organic remains are to be found in the publications of the Geological Survey of India, and in the communications to this Society by Strachey, Grant, Falconer, and others. The 'Manual of Indian Geology,' by Medlicott and Blanford, an abstract of the labours of the Survey, contains them in a condensed form. I am under great obligations to all those writers, and also to Messrs. Medlicott and Blanford for much unpublished information; and in thus heartily acknowledging my obligations, I am glad to have the opportunity of expressing my assent to their conclusions regarding the age of the Himalayas.

DISCUSSION.

The PRESIDENT remarked on the persistence of Mesozoic types in the Tertiary strata of the Himalayas.

Mr. BLANFORD expressed the obligations of himself and other Indian geologists to Dr. Duncan for his researches on the Corals which they had collected. The base of the series of Sind consists of a limestone containing Hippurites; and above these Cretaceous beds are strata partly unfossiliferous and the representatives of the Deccan traps, the whole being overlain by the Lower Eocene and Nummulitic. This succession is shown both in the Laki and the Khirthar ranges. The Nari or Oligocene group is 5000 or 6000 feet thick; its upper subdivision, which is much thicker than the lower, is of freshwater origin, and contains imperfect plant-remains. This is overlain by the Gáj and Manchhar. The unconformities which occur in the series are purely local. He was gratified to find that Dr. Duncan had arrived at the same conclusion as the Geological Survey of India as to the age of the Siválik beds. He replied to the opinions expressed by Prof. Boyd-Dawkins and Mr. Bose on this subject.

Lieut.-Col. GODWIN-AUSTEN remarked upon the greater contortion of the Nummulitic strata in the Western Himalayas as compared with those of Assam.

The AUTHOR stated, in reply to the President's remarks, that while the *genera* of Corals are remarkably persistent, the *species* are not. He bore testimony to the great value of the volume published by the Geological Survey of India. He doubted the value of the terrestrial Mammalia as fixing the age of the strata overlying the Eocenes.