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ORIGINAL ARTICLES.

I.—ON THE GEOLOGY OF CENTRAL SUMATRA.¹

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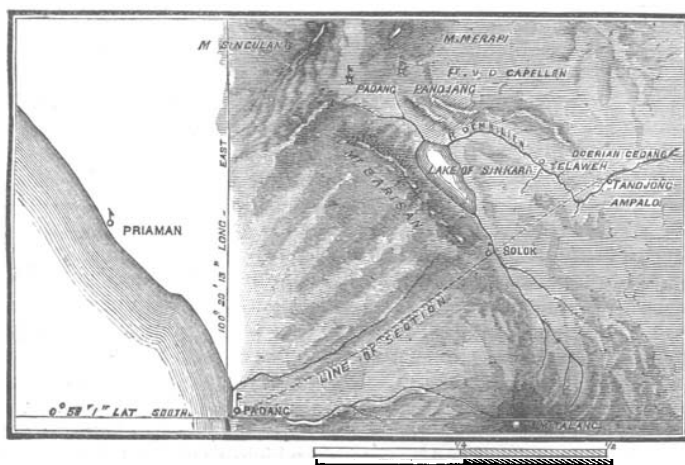
Superintendent of the Geological Survey of Sumatra.

THE fossils, which will be described hereafter by Dr. Günther F.R.S., Prof. T. Rupert Jones, F.R.S., H. Woodward, F.R.S. and H. B. Brady, F.R.S., were found in the years 1873 and 1874 partly in rocks of the “Padangsche Bovenlanden” (Highlands of Padang), Government of the West Coast of Sumatra, and partly in marls and limestones of the Island of Nias.

In order to show the position of the fossiliferous rocks to each other, and to the plutonic and volcanic rocks which accompany them I offer the following brief sketch of the geology of some parts of Sumatra, as far as it is known from the investigations of our Survey.

I.—*Highlands of Padang* (Government of the West Coast of Sumatra). See Map, Fig. 1, and Section, Fig. 2.

FIG. I. MAP OF A PORTION OF CENTRAL SUMATRA.



Scale 1 : 1,400,000.

Degrees of the Equator.

¹ This Memoir on the Geology of a part of Sumatra, including notes on Borneo and Java, by HERR R. D. M. VERBEEK, Superintendent of the Geological Survey of Sumatra, is introductory to a series of palæontological papers, descriptive of Fossils from the West Coast of Sumatra, to be published with Illustrations, in the GEOLOGICAL MAGAZINE, by the authority and with the assistance of the Dutch-Indian Government.—Editor.

1. The oldest rocks of this part of Sumatra are *granites*, *granite-syenites*, and *syenites*, in several modifications. There are granites which contain only felspar, quartz, and mica; but a great part of them contain also amphibole. The syenites contain, beside orthoclase and amphibole, almost always quartz and some mica; but the granites have more quartz than the syenites. A great part of the rocks of this group may be best called "syenite-granite," or "granite-syenite," as they stand in composition between granite and syenite. There seems to be no difference in the age of these rocks, as there are syenites which regularly pass into granites. The felspar of the granites and syenites is partly orthoclase, partly plagioclase, which shows its triclinic nature by the fine varicolored laminated structure, when examined under the microscope with polarized light. The quartz contains always a great number of "fluid-cavities."

2. Next in order follow sedimentary rocks, which are probably of either *Carboniferous* or *Permian* age, as they contain *Fusulinae*, which are only met with in rocks belonging to the Carboniferous and Permian periods. Both Professor T. Rupert Jones and Professor H. B. Geinitz, to whom I submitted some of these fossils, determined them as *Fusulinae*; but the Encrinital stems which occur in our *Fusulina*-limestone have, as Professor Geinitz informed me, a younger appearance, reminding him of the Triassic *Encrinurus Cassianus*, Laube.

This oldest sedimentary formation of Sumatra can be divided into two parts. The lower portion consists of clay-slates, with auriferous quartz-veins, marl-slates, and siliceous schists; the upper part consists only of limestone, with some small beds of schists. This limestone contains the *Fusulinae*; but these fossils also occur in some limestone beds which are found between the schists of the lower part. The schists and the limestones are conformable one with another. They are widely spread all over Sumatra, and form great mountain-ranges in the Highlands; and are often accompanied by greenstones, which will be described hereafter.

3. *Quartz-porphyrries* are probably younger than the schist- and limestone-formation; some quartz-porphyrries, at least, inclose fragments of schists; but it is not yet proved that *all* the quartz-porphyrries of the Highlands are of the same age.

These rocks always show, when examined with the microscope, an amorphous and so-called "felsitic" matrix, which is not resolved by the highest magnifying powers into crystalline grains. In this paste are imbedded crystals and grains of quartz (with many "fluid-cavities"), crystals of felspar (orthoclase and some oligoclase), and some fragmentary, green, dichroitic crystals, which belong to amphibole.

4. *Greenstones*. These rocks, as stated above, are often associated with the older schists and limestones, which are dislocated and heaved up by them, in such a manner that portions of those rocks lie sometimes as islands upon the greenstones. The age of these rocks is not exactly known, but it is sufficiently proved that their eruption took place *before* the Tertiary Period, and that they consequently are not to be confounded with the greenstone-trachytes of Hungary. The Sumatran greenstones are pyroxenic rocks, partly diabases, partly

pyroxene-porphyrries. They have a dark-coloured matrix, in which are imbedded crystals of faint-white plagioclase, green pyroxene, and magnetite. The magnetic iron-ore shows partly octahedral forms and large crystals; and it occurs copiously in excessively small grains throughout the matrix, which is coloured dark by it; and it is also found inclosed in the crystals of pyroxene. The crystals and grains of magnetite, even in the thinnest microscopical slices, are always opaque.

5. *The Tertiary deposits*, which follow next, are to be sub-divided into four groups.

- a. *Breccias, conglomerates, arkoses* (sandstones, derived from decomposed syenite, granite, and quartz-porphry), and *marl-slates*; the last contain remains of Fishes and Plants. This lower part of the Tertiary formation is called the *Breccia-stage*, or *Breccia-group*. The thickness differs greatly at various localities.
- b. *Sandstones, with clays and coals*. Some Fishes and Plants. The thickness of this portion, called the Sandstone-group, varies from 300 to 500 mètres.
- c. *Marl-sandstones*. Shells, etc. The thickness of this group is at least 500 mètres, and at some places probably much more.
- d. *Limestone*, with Corals, Shells, etc., and abounding with *Orbitoides*. The thickness is 120 mètres.

5 a. The *breccias* and *conglomerates* contain fragments of the several older rocks,—syenite, granite, quartz-porphry, Fusulina-limestone, schists, etc.

The *arkose* is a sandstone whose substances have been derived from syenite, and partly also from quartz-porphry; the beds of coarsest grain contain balls of hard syenite; the beds of finer grain alternate with beds of the most remarkable rock of this group, namely, the marl-slate.

These marl-slates have proved to be fossiliferous at several localities on the Rivers *Sipang*,¹ *Malakoetan*, *Sangkaréwang*, *Loera Gedang*, and in the neighbourhood of the village of Telaweh; they contain Fishes and Plants. Between the marl-slates occur very thin beds of hard shale; and it is remarkable that the Fishes are always imbedded at the bottom of the marl-slates. It is thus probable that the Fishes lived in the water which deposited the shales, but that the great quantity of lime contained in the water which deposited the marl-slates was unfavourable to their existence.

The marl-slate was deposited in the neighbourhood of the old coasts as a littoral deposit, and received the land Plants from the coast.

5 b. The sandstones of this group are composed of quartz-grains cemented by an argillaceous paste. The colour is yellowish or brown. This is the Sumatran Coal-formation. The beds of coal vary in number and thickness at different localities; and they are generally near the base of the series. The *Oembilien Coal-field* contains about 200 millions of tons (1 ton=1000 kilograms). In the northern part of this coal-field, seven or eight coal-seams are known; in the southern portion, the so-called Soengei-Doerian Coal-field, there are only three

¹ The pronunciation of the Dutch vowels is the same as in German, except the *oe*, which is the German *ü*; thus the Dutch *a* is pronounced as the English *a* in *are*, the *e* as the *e* in *latter*, the *é* as *a* in *male*, the *i* as *e* in *he*, and the *oe* as *oo* in *good*.

seams, but these are of considerable thickness. The section of this series in the neighbourhood of the village of Soengei-Doerian, from bottom to top, is:—

										Thickness in Mètres.
Sandstones and clays	...	...	...	...	...	...	...	...	...	50 (more or less).
First (lowest) coal-seam	...	...	...	...	...	...	...	...	...	6
Sandstones and clays	...	...	...	...	...	...	...	...	...	20
Second (middle) coal-seam	...	...	...	...	...	...	...	...	...	2
Carbonaceous shale, with fossil remains	...	...	...	...	...	...	...	...	...	$\frac{1}{2}$
Sandstones and clays	...	...	...	...	...	...	...	...	...	15
Third (upper) coal-seam	...	...	...	...	...	...	...	...	...	2
Sandstones and conglomerates	...	...	...	...	...	...	...	...	...	250 (more or less).
Total thickness of the series										350 (more or less).

Total of coal 10

The coal from the Oembilien coal-field is the best in the Netherland Colonies; and indeed, although of Tertiary age, is among the very best coals known. The composition, according to the analysis by Dr. Vlaanderen, at Batavia, is:—

$$\begin{aligned}
 C &= 76.80 \\
 H &= 5.80 \\
 O + (N) &= 12.76 \\
 S &= 0.45 \\
 H_2O &= 3.49 \\
 Ash &= 0.70
 \end{aligned}$$

100.00

The theoretical evaporating power, according to this composition, $A=7500$.

It is a black, shining, lustrous, and compact coal. As the Soengei-Doerian seams are very regular, they are under very favourable circumstances for working.

The clays are found immediately beneath the coal-seams. The second (middle) coal-seam is covered by a carbonaceous shale, half a metre thick, which is remarkable for its fossil remains,—spines and teeth of Fishes. The sandstones contain no fossils; the coal and the clays only a very small number of fossil Plants.

5 c. In the marl-sandstone series, although of considerable thickness, there are only found some small *Operculinæ* and little Fish-teeth, in the neighbourhood of the village of Moara-Bodi, and some fragments of Shells, belonging to *Ostrea*, *Pecten*, etc., which prove that the marl-sandstone is a salt-water deposit.

5 d. The upper part of the Tertiary deposits, which are known in the Sumatran Highlands, is a limestone offering a great variety of fossils,—Corals, Echinids, Gasteropods, and Conchifers, mostly as casts, and a great many specimens of an *Orbitoides*.

These four groups of strata generally succeed one another conformably, but in some localities there is a fault between 5b and 5c. The lower series, 5a and 5b, rest unconformably on the Limestone with *Fusulinæ*.

The preliminary determination of some fossils from these beds, for which I am very much indebted to Prof. T. Rupert Jones, Yorktown, Surrey; Prof. H. B. Geinitz, Dresden; and Prof. O. Heer,

Zürich; showed that the four series or groups 5a, 5b, 5c, and 5d, belong to the Tertiary, and probably all to the Eocene period.

Among the Fishes from 5a Prof. Geinitz determined *Fistularia Koenigi*, Agass., which occurs in the Eocene schists of Glarus (Switzerland); some other Fishes strongly resemble *Osm. (Sard.) Sardinoides*, v. d. Marck) *microcephalus*, Münt., and *Osm. (Sard.) Monasterii*, from the "Plattenkalke" of Sendenhorst, Westphalia, which are of Senonian age (described and figured by v. d. Marck in "Palæontographica," vol. xi. pl. 6, and Agassiz, "Poissons fossiles," vol. v. pl. 60d).

The fossil Plants from 5a have a more Miocene than Eocene character. Some have already been described and figured by Prof. O. Heer in the "Abhandlungen der schweizerischen paläontologischen Gesellschaft," vol. i. 1874. According to Prof. Geinitz, there are some Echinids from 5d nearly related to *Prenaster Alpinus*, Desor (Desor, "Synopsis des Echinides fossiles," 1858, p. 401, and W. A. Ooster, "Petrifications remarquables des Alpes Suisses; les Echinodermes," p. 112), and to *Periaster subglobosus*, Desor (*op. cit.* p. 385) and W. A. Ooster (*op. cit.* p. 109), both from Eocene or Nummulitic rocks of Switzerland. It is therefore highly probable that 5d belongs to the Eocene period. As 5d is the upper part of all these sedimentary deposits, the formations 5c, 5b, 5a, must be of Eocene age too. It is not at all probable that 5a belongs to the Upper Cretaceous (Senonian) formation, firstly, because the Senonian character of some Fishes from 5a is easily explained, the Marl-slates being the oldest of all our Eocene deposits, and the fossils from the Senonian "Plattenkalke" of Sendenhorst, although older, having a strong resemblance to those from Eocene rocks of other parts of Europe; secondly, because rocks of Cretaceous age are wanting in the Highlands of Sumatra; thirdly, because the Marl-slates at the top of the series become sandy, and pass into the coal-bearing sandstones of 5b, which are most probably of Tertiary age; fourthly, because the fossil Plants from 5a have a Tertiary, and even more of a Miocene than Eocene, character.

The Eocene formation of Sumatra is thus represented in four groups, or *étages*. That of Borneo, according to my investigations, is only represented in three groups. The lowest of these latter contains the coals; the middle part consists of marls, with some few Nummulites (*Nummulina Pengaronensis*, Verb.) and many specimens of *Orbitoides discus*, Rütim.); the upper part is a nummulitic limestone with millions of Nummulites and some Orbitoides.

Perhaps the coal-bearing sandstones of Borneo are the equivalent of the Sumatran coal-bearing formation 5b; the Borneo marls, the equivalent of the marl-sandstones 5c; and the nummulitic limestone of Borneo may be the equivalent of the limestone with Orbitoides 5d; in which case the equivalent of the marl-slates with Fishes would be wanting in Borneo. But as there is a very great difference between the Eocene fossils from Borneo and those from Sumatra, this can only be proved by a careful comparison of the fossils. Those which I gathered at Borneo will soon be described by Dr. O. Böttger, Frankfurt-on-the-Maine: Dr. von Fritsch. Halle: and Dr. Gevler. Frank-

fort-on-the-Maine; and the memoirs will appear in the "Palæontographica." (See two memoirs of mine, on the geology of the South-eastern part of Borneo, in the "Jaarboek voor het Mynwezen in Nederlandisch Oost-Indië," Amsterdam, 1874 and 1875. I have formerly described the Nummulites of the Borneo limestone in the "Neues Jahrbuch für Mineralogie, etc., 1871, pages 1-14, pl. i. ii. iii.)

The coal-bearing sandstones of the south coast of Bantam, in Java (not those in the interior of Bantam, which are younger), according to Mr. F. Junghuhn's description (Junghuhn's "Java," etc., German translation, Leipzig, 1852, part iii. pages 163-179), are covered first by marl-stones and clays, and next by limestone, which contains Nummulites more to the east, on the River Kaso (Junghuhn, "Java," part iii. pages 64, 87, and 203); and Prof. von Hochstetter confirms the occurrence of these fossils in the limestone to which the cavern of Linggo-Manik belongs ("Novara-Reise; Geologie," ii. page 146).

It seems to me highly probable that these three series of rocks of Java are the equivalent of the rocks of Borneo described above; and that thus the coals of Java and Borneo, and perhaps those of Sumatra too, belong to the same part of the Eocene period. In order to avoid errors, I must state here that in several parts of the Archipelago coal-beds are also found in rocks which are younger than Eocene; but these coals belong to the brown coal, and are always much inferior in quality to the black Eocene coals. These brown coals are found, 1. in the interior of Bantam (Java), in the neighbourhood of the village of Bodjong-Manik; 2. in the neighbourhood of Doesson-Caroe, in Laïs and Kataoen (Benkoelen, Sumatra), and Palembang (Sumatra); and 3. in the marls of the Island of Nias.

6. The *Trachytic rocks* of Sumatra are all younger than the Eocene period; they are of middle and late Tertiary age (Miocene and Pliocene); and it seems that this is the case in Borneo and Java also.

There are two different groups of trachytic rocks; the one, probably the older of the two, composes mountains and mountain-ranges, without craters, and having no connexion with volcanos; the other comprises the trachytic rocks belonging to the volcanos, those giants of Sumatra and Java, which are often more than 10,000 feet high.

The trachytes of the first class, found in Sumatra in the immediate neighbourhood of Padang and Sibogha, and at several other localities, are oligoclase-trachytes, the so-called *andesites* (Zirkel); they contain no sanidine, but exclusively a triclinic feldspar, either with amphibole (and now and then some quartz and mica), or with pyroxene.

These andesites are widely distributed in the south-east part of Borneo, where they have dislocated the coal-bearing rocks; they are known too in Java.

The rocks composing the volcanos of Sumatra are of various kinds; there are andesites, trachytes with sanidine and oligoclase, trachyte-pitchstones (Trachytepechsteine, with sanidine and without oligoclase), obsidians, and pumice-stones. The volcanos of the Highlands of Padang are named:—the Talang, the Singalang, the Merapi, the Sago, and the Ophir. The Singalang and the Merapi are about

FIG. II. DIAGRAMMATIC SECTION OF SUMATRA FROM PADANG TO DOERIAN GEDANG.

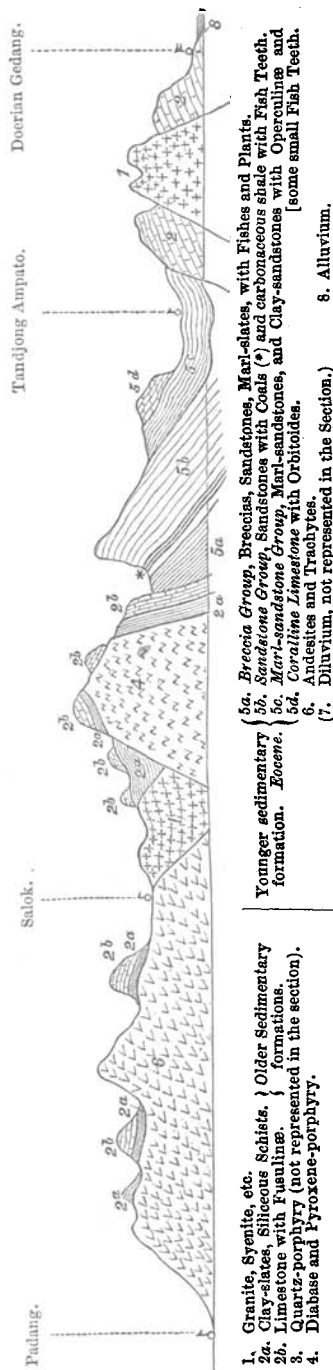
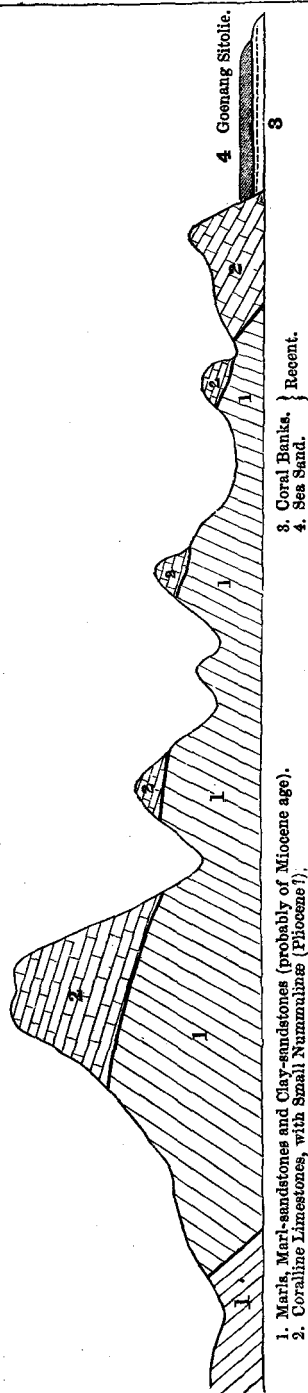


FIG. III. DIAGRAMMATIC SECTION OF THE WESTERN PART OF THE ISLAND OF NIAS.



10,000 feet high; the others are lower, but all the volcanos of Sumatra surpass 6000 feet. The volcanos of Java are described by Mr. Junghuhn in his above-mentioned work.

Borneo contains no volcanos. The mountain Kina-Baloe, in the northern part of Borneo, which was formerly supposed to be a volcano, is composed of a granitic rock.

There are two lakes in the Highlands of Padang which owe their origin to infallings of volcanic ground on a very large scale.

The greatest length of the Lake Singkorah is 21,000 mètres, the greatest breadth 7700, the smallest breadth 3350, and the circumference 53,000; the surface is 2.04 square geographical miles. The only channel which carries off the water of this lake is the Oembilien River, which is afterwards called Kwanten, and finally Indragiri, and has its mouth on the east coast of Sumatra. The Lake Manindjoe is 16,600 mètres in length, the greatest breadth is 8000, the least breadth 3650 mètres; the circumference is 48,900 mètres, and the surface 1.81 square geographical miles (1 geogr. mile = $\frac{1}{15}^{\circ}$ of the Equator). The water of this lake is carried off by the Antokkan River, which has its mouth not far from Tikoe on the west coast.

The surface of these two lakes is, in comparison with other lakes in volcanic districts, as for example the "Maare" of the Eifel, very considerable. The surface of the Lake Singkorah is 33 times, and that of the Lake Manindjoe 29 times greater than that of the Lake of Laach (Laacher See) in the Eifel.

7. The *Diluvium* of the Highlands of Padang is a river-deposit; and is chiefly composed of tufaceous conglomerates and sandstones. The beds are always horizontal, and contain many fragments of trachytes. These are two characters by which the Diluvial conglomerates are easily separated from the conglomerates of Eocene age. The Diluvial beds form river-terraces, which attain a height of twenty to thirty mètres above the alluvial deposits.

8. The *Alluvial* river-deposits are for the greater part transformed into rice-fields (sawahs).

In the Section Fig. 2, the western part of Sumatra is represented from Padang, on the west coast, to the village of Doerian-Gedang, near the frontier of the independent districts. The eastern part of Sumatra, from Doerian-Gedang to the east coast, is not given in the Section, as that part is composed only of recent deposits of the Rivers Djambi, Indragiri, and Kampar. With the exception of the quartz-porphry (3) and the diluvium (7), all the above-described rocks are represented in the Section. The four groups of Eocene deposits are generally conformable with each other, but unconformable to the old Fusulina-limestone; but, as was stated above, in some localities there is a fault between 5b and 5c.

II.—*The Island of Nias* (Government of the West Coast of Sumatra). See Fig. 3.

This island is situated westward of Sumatra; its surface is about 70 square geographical miles. It is chiefly composed of marls, clay-

marls, clays, and very fine-grained sandstones, partly of tufaceous nature. It is most probable that the materials of the greater part of these rocks were derived from volcanic rocks, but on the Island of Nias itself no such rocks occur.

The beds of marls, clays, etc., are very much dislocated, and vary much in direction and in dip; they are seldom horizontal. They have a bluish-grey colour; and are probably of Miocene age, according to Dr. O. Böttger, to whom I submitted some of the fossil *Conchifers* and *Gasteropods* from these marls.

In the neighbourhood of Goenoeng-Sitolie, the chief place of the island, and also at some other localities, the marls are covered by an unconformable limestone.

It is remarkable that this limestone, probably (from its discordant position) of late Tertiary age (Pliocene?), contains, besides indistinct fragments of Corals, some small *Nummulinae*. It is a new proof that this genus not only occurs in rocks of Eocene age, but in younger rocks too. The diameter of the *Nummulinae* from the Nias limestone is three millimètres, the thickness 1 to 1½ millim.; they have eight whorls, about 150 chambers, the central chamber is small; their internal structure resembles very much that of the Eocene, *N. Pengaronensis*, Verb., from Borneo, and perhaps they are a small variety of that *Nummulite*.

The position of the different rocks in the neighbourhood of Goeneng-Sitolie is shown in the Section Fig. 3.

For those who feel interest in the Geology of Sumatra, I add a list of the principal geological papers on parts of that Island.

1. *F. Valentijn*. Oud en Nieuw Oost-Indiën, 1724. Sumatra, in vol. v.
2. *William Marsden*. History of Sumatra, 3rd edition. London, 1811.
3. *Malayan Miscellanies*; published at the Sumatran Mission Press, at Bencoolen: vol. ii. (1822) contains accounts of several journeys.
4. *Dr. Jack*. On the Geology of Sumatra. Transactions of the Geol. Society, new series, vol. i. page 397.
5. *Memoir of the Life and Public Services of Sir Thomas Stamford Raffles*. By his Widow. London, 1830. Particularly in the Government of Java, 1811–1816, and of Bencoolen and its dependencies, 1817–1824.
6. *L. Horner*. De Batoe-eilanden. Tijdschrift voor Nederlandsch Indië. Jaargang iii. vol. i. p. 313–371.
7. *L. Horner*. Reizen over Sumatra. Tijdschrift van het Bataviaansch Genootschap, vol. x. pp. 322–373.
8. *S. Müller*. Gezigten van bergen, kraters, kusten en eilanden van Java, Sumatra en straat Sunda. Verhandelingen over de natuurlijke geschiedenis der nederlandsche overzeesche bezittingen, door de leden der Natuurkundige Commissie. Leyden, 1839–1844, pp. 447–469 (with plates).
9. *F. Junghuhn*. Die Battaländer auf Sumatra. Berlin, 1847, 2 vols.
10. *F. Junghuhn*. Java (German translation, Leipzig, 1852), vol. i. pp. 51, 70–72, 75–78, 99–106, with seven sections (topography of Sumatra); vol. ii. pp. 808–816 (volcanos of Sumatra).
11. *Nieuwenhuizen en v. Rosenberg*. Verslag omtrent het eiland Nias. Verhandelingen van het Bataviaansch Genootschap, vol. xxx. 1863, pp. 1–153.
12. *W. H. de Grevé*. Het Oembilienkolenveld in de Padangsche Bovenlanden. 's Gravenhage, 1871.
13. *R. D. M. Verbeek*. In the "Jaarboek voor het Mijnwezen in Nederlandsch Oost-Indië," vol. iii. and iv. 1874 and 1875, the following memoirs:
 - a. Preliminary report on the Island of Nias.

- b.* On the age of the Oembilien Coal-field.
- c.* Geological description of the Oembilien Coal-field.
- d.* On the Geology of the Island of Nias, with several maps and sections.

Fort van der Capellan, West Coast of Sumatra,

March 10th, 1875.

II.—ON THE ORIGIN OF COUMS.

By J. G. GOODCHILD, F.G.S., of H.M. Geological Survey.

IN my paper on Glacial Erosion lately laid before the readers of the *GEOL. MAG.* (pp. 323 and 356), I have endeavoured to prove that the origin of nearly all the more prominent surface characteristics of the rock scenery in the Yorkshire Dale District admits of a simple and complete explanation by the theory of the modification of pre-existing subaerially eroded surfaces by Glacial Erosion. At the same time it was shown that the character of many of the phenomena is entirely opposed to any theory of their origin by means of Subaerial Denudation alone. In the present communication it is proposed to inquire how far this Glacial Erosion theory may be applied to explain the origin of the deep, semicircular recesses that are commonly found in all well-glaciated mountainous districts, and are variously known by the names of Coums, Corries, or Cirques.

The more prominent terraces and scars whose origin was discussed in the paper just referred to seem to occur only where the ice moved in the direction of the valley's length: where the ice flowed to a greater or less degree across the valley, or, in other words, where the ice moved across, instead of along, the outcrops of the beds, these characteristic scars and terraces are either slightly developed, or else are wanting altogether. But whatever the minor inequalities of the slopes of the valleys may be like, it is commonly found that there is a striking resemblance in form between the contours of the surface at any given elevation and the contours for a considerable distance both above and below. Where the side of the valley is convex in contour, the gradations in form are complete between the curves of largest radius near the bottom of the valley, and the more decidedly rounded contours of lesser radius that are found in greatest perfection at the higher parts of the feature. So, too, with the slopes that present concave contours. In these the least regular curves are nearly always found near the base, and the contours gradually become more decidedly concave and of larger radius as the upper limits of the feature are approached; and, as a rule, it is also at the upper limit that the most regular curves occur.

Some of the rock surfaces whose form I have before endeavoured to show must be due to the unequal resistance to mechanical erosion offered by beds of various degrees of hardness graduate, by insensible degrees of form, from surfaces with contours that are nearly straight, through others that are more or less concave, into semicircular recesses that remind one rather of gigantic pot-holes than of anything else. A very beautiful example of this kind occurs at the head of Snaizholme Beck, about a mile to the south of Hawes, in Wensleydale. Others of similar but less perfect form may be found in the neighbourhood.