Geology. — *"On the Geological position of the Oil-fields of the Dutch East-Indies."* By Prof. G. A. F. MOLENGRAAFF.

(Communicated at the meeting of June 26, 1920).

Experience has taught that the majority of the large oil-fields have originated in long enduring geosynclines, where these are marginal areas of sedimentation along the coasts of continents. [1]) In those geosynclinal belts, which are characterized by a long continued subsidence of the soil, the organic matter in the sediments, i.e. the remains of animal and vegetable organisms may, as the subsidence of the soil proceeds, successively be covered by layers of fine sediments. Thus, being shut off from water and air these organic remains may escape from destruction by oxydation. They may then be accumulated to a considerable thickness. As long as in such a geosynclinal coastal belt, subsidence prevails over sedimentation, the area remains covered by the sea; if, however, sedimentation gets the better of subsidence, the area may become land.

In the first case petroleum or allied hydrocarbons may be ultimately formed in the subsiding area; in the second case coal or allied substances may finally be found. A slow and gradual subsidence, the area meanwhile remaining all the time either low land or shallow sea, affords the most suitable conditions for the accumulation of such fossil fuels. Through the shifting of the equilibrium between the processes of subsidence of the soil and sedimentation, as well as through epirogenetic movements of land and sea relative to each other, every geosynclinal area may during its long life be land at one time and sea at another. Thus in the same geosyncline an accumulation of coal may take place at one time, and of petroleum at another; consequently in one and the same geosyncline coalbeds

[1]) Among the recent publications bearing on this subject the following deserve special attention: M. R. DALY, Geosynclines and petroliferous deposits. Trans. Amer. Inst. of Min. Eng. LVII, p. 1054, 1918 and the discussion on it, ibid. p. 1065. W. F. JONES, The relation of oil-pools to ancient shorelines. Econ. Geol. XV, p. 81, 1920 and the discussion on it, ibid p. 350.

and oilbeds may [1]) occur alternately from the surface downward.

Broadly speaking the filling in such a geosyncline may be said to begin, as a rule, with the deposition of marine sediments with a monotonous microfauna, later and only when these sediments have attained a considerable thickness, they are overlaid by deposits of brackish-water, of fresh-water and perhaps by terrestrian deposits which will or will not alternate one with the other and possibly also with marine deposits.

Experience has also taught that in such marginal geosynclines during their long life folds may originate more or less parallel to the shore-line of the continent and at some distance from the shore. These folds may cause one or more rows of islands or a more or less continuous strip of land to emerge from the sea. Not seldom in such a case the folding process is attended with volcanic activity. The result may be that the portion of the geosyncline immediately bordering the continental shore, gets separated from the deeper ocean by a row of islands or a more continuous strip of land consisting of a system of one or more folded mountain-chains, which may even shut the inner portion of the geosyncline off completely, thus converting it perhaps into a freshwater lake for some time. It is evident that then the materials for sedimentation will be transported to the geosynclinal receptacle from two quarters, viz. from the continent and from the strip of land or mountain-range newly emerged from the sea, whereas prior to the folding the geosynclinal belt received its sediments from one side only, viz. from the pre-existing continent. In the case of violent volcanic action in the said strip of land, volcanic material will perhaps from that moment play a prominent part among the sediments which continue to accumulate in the geosyncline.

Finally experience has also taught that the geosyncline, which tends to get filled up completely, now that it has become narrower and receives sediments from two sides, mostly undergoes itself gentle folding. It is well known that this folding brings about a position of the strata, which is of prime importance for the working of oil-fields.

The outlines of the geological history of the largest and best known oil-fields of the world are similar to those described just now. Among the numerous instances only two, the oil-fields of Pennsyl-

[1]) Particular stress must be laid on the word "may", because it is possible that during the development of a geosyncline the conditions for the origin and accumulation of coal, of petroleum or of both are never quite fulfilled; in that case the geosyncline will remain sterile.

vania and those of Argentina, may be mentioned: in the Pennsylvanian geosyncline, which has originated as a belt marginal to the then North-American continent (the archaean Canadian shield built out southward), the sedimentation, as well as the folding of the Appalachians (Appellachia), which separated the inner portion of the geosyncline from the Ocean to the south-east, reached its maximum of intensity in Pennsylvanian time, and closed in Permian time; the oil-fields in the Andine portion of Argentina are marginal to the ancient South-American continent, which, in geological structure, exhibits striking similarity to South-Africa and the so-called Gondwana-land. The sedimentation in that geosyncline occurred in Jurassic and in Cretaceous time, while the folding which was attended by intense volcanic activity and gave rise to the Andes, terminated in Tertiary time. As a third instance the oil-fields of Venezuela may be quoted. As soon as one considers this mode of development of an oil-field to be the typical one, such a field must show the following features (see fig. 1):

1. a geosynclinal coastal belt G (fig. 1), being the depository of the sediments in which the hydrocarbons originate. The position of this belt will indicate in a rough way the original shore-line of

2. the continental area L, from which the terrigenous material is derived, which gradually has been accumulated in the marginal geosyncline. This area may also be called the ancient continental area or the primary area of denudation, because it existed already as a landmass before the geosyncline had originated.

3. the sea or ocean S, which, reckoning from the continent, lies on the other side of the geosyncline.

In the geosynclinal belt one can distinguish:

a. The portion near the land G_1 consisting of sediments deposited in a shallow sea or on a low land. These deposits consist preponderantly of terrigenous materials (limestones are rare) and contain coal-, or oil-beds or both. They are folded generally not very strongly during the last period of the orogenetic phase, which terminated a long era in the still longer life of the geosyncline.

b. The portion G_2 more remote from the land in which the sediments, for a great part marls and limestones, were deposited farther away from the shore of the continent than in the portion G_1. Generally this portion has been folded in a period of the orogenetic phase prior to the folding of the portion G_1. In that case the anticlinal parts of the folds had already emerged from the sea as rows of islands or more or less continuous strips of land or may be as lofty folded mountain-chains, whilst in G_1 the subsidence

of the soil and the sedimentation was still in progress. The belt G_2 generally has been upheaved, folded and compressed to a stronger degree than the belt G_1.

The folding of the belt G_2 is not seldom accompanied by volcanic activity causing the sediments in this area to be for the greater part composed of volcanic material. This area G_2 might, in contradistinction to L, also be called the secondary area of denudation.

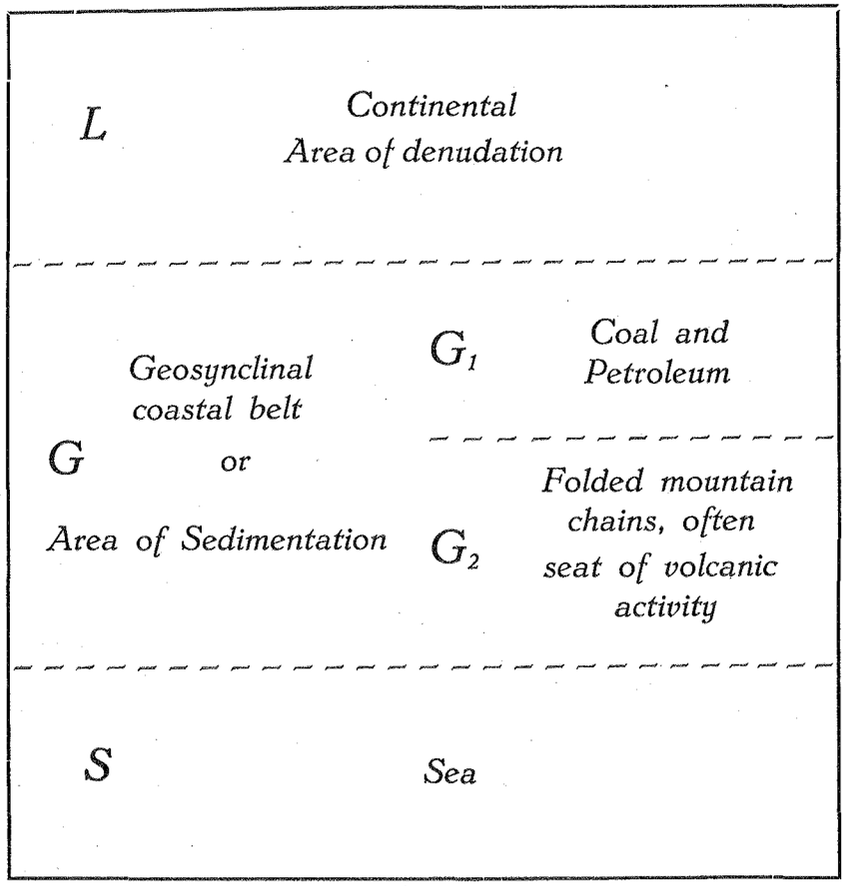

Fig. 1.

Our object in writing this paper is to discuss how far the position of the oil-fields of the Dutch East-Indies, fits in with the scheme sketched above.

The location of these oil-fields is marked on the accompanying sketchmap [1]) (Fig. 2). They are situated along the north-east coast of Sumatra, along the north coast of Java and along the east coast of Borneo. The sediments of which those oil-fields consist, have been deposited in the geosynclines in Tertiary, especially in Neogene time.

[1]) In compiling this sketchmap two authorities on the Australasian oil-fields KLEIN and RUTTEN kindly have procured me some valuable data.

There is in the Dutch East-Indies another oil-field of little importance in the island of Ceram, which probably dates from Mesozoic time. Its age, however, has not been quite proved. Another oil-field again, genetically closely connected with the Tertiary terranes mentioned above, is found in the East-Indian Archipelago outside of the Dutch possessions. It is the Tertiary oil-field situated in British North-Borneo and Serawak along the coast of the China Sea.

These latter territories will here be left out of consideration.

I. *East-Borneo.*

The geosynclinal belt G lies at the east coast of Borneo, along the strait of Macassar.

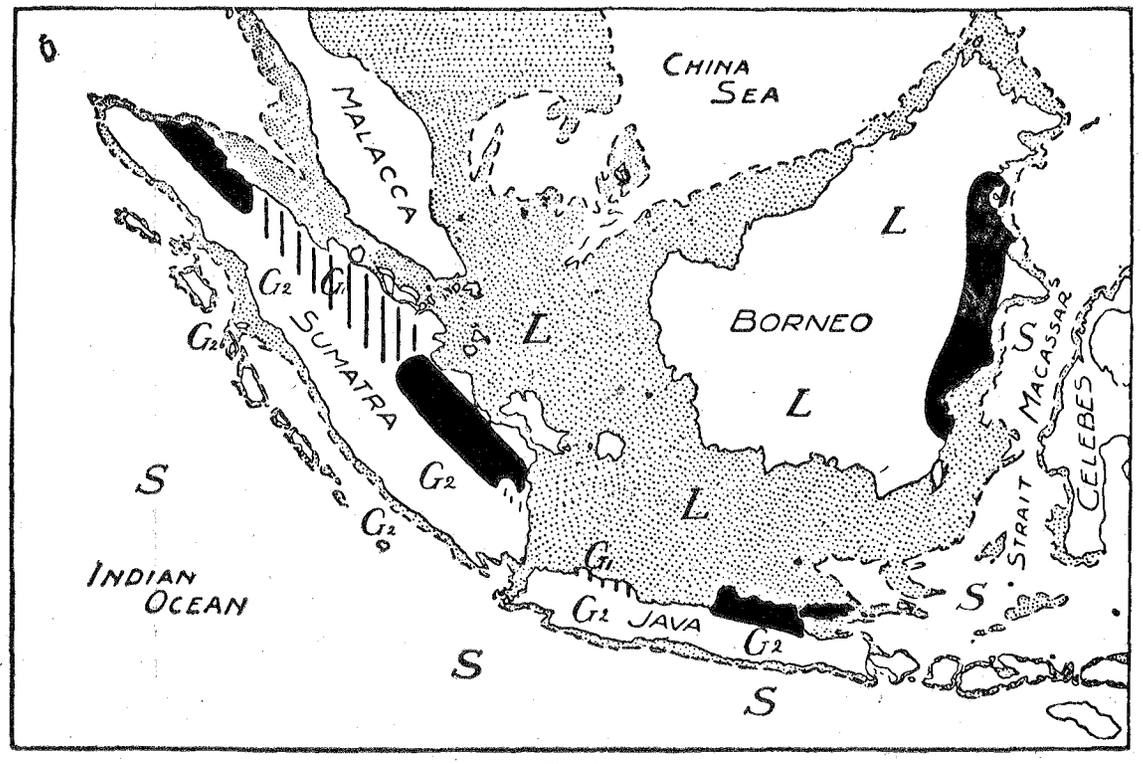

Fig. 2.

Black vertical lining: Neogene geosynclinal deposits, in which the occurrence of petroleum has not yet been established.

Solid black: Oilfields in Neogene geosynclinal deposits.

Dots: The dotted area represents the Sunda shelf; together with Malacca, Sumatra, Java and Borneo it indicates the largest extension of the Sunda Land in Pleistocene time.

The continental or primary area of denudation L is Borneo, the sea S is the Strait of Macassar, and between these two the Tertiary geosynclinal belt G is located, which has now been folded and converted into land for the greater part. The belts G_1 and G_2 gradually pass one into the other. The seaward strip G_2 is richer in limestones than G_1, which lies more landward, as has been shown by RUTTEN. In G_2 no volcanic action has taken place. According to RUTTEN the deposits in the Tertiary geosyncline of East-Borneo attain a thickness of about 5500 m. and comprise the entire Miocene, perhaps even a part of the Oligocene, and the Pliocene. Beds of lignite as well as beds of petroleum occur in this geosyncline. RUTTEN, from the differences in facies of the deposits, and before him VERBEEK concluded that the N.S.-shoreline of Kutei existed already in the Old-Miocene, and that at that time the Strait of Macassar had already been formed as a more or less deep trough. The oil-field of East-Borneo thus has been developed in a geosyncline, which lay between Borneo, a part of Sunda Land being the denudation-area from which it derived its sediments, and Macassar Strait being the adjoining oceanic area. This conception is accepted only provisionally, and some stress may be laid on the point that the geological position of Celebes relative to this geosyncline and to the Strait of Maccassar is not explained by it.

II. *Sumatra and Java.*

The geosynclinal belt G, to which the present oil-fields are confined (see map fig. 2) lies along the north-east and the eastcoast of Sumatra and the north coast of Java, bordering the Java Sea, the South China Sea and Malacca Strait. It is of Tertiary, Neogene age and the belt G_1, which contains petroleum and lignite in many places, is now slightly folded and the major portion has become land. Towards the ocean follows the adjoining belt G_2, which had already been folded and converted into a mountain-chain, whilst subsidence still continued in the portion G_1 of the geosyncline, and the process of sedimentation was still in progress there. The mountains of Sumatra, which I will designate here by the collective name of Barissan Mountains, represent one geanticline, and the row of the Mentawei-islands and others west of Sumatra represent another geanticline in these folded mountain-chains. More to the west follows the sea S, in this case the Indian Ocean. In the belt G_2 intense and prolonged volcanic activity has taken place in Sumatra as well as in Java; this activity commenced as early as the Old-Miocene. In the Miocene already volcanoes rose, presumably as a row of islands above the sea-level, for from that time andesitic material is found in the geosynclinal deposits of the belt G_1. But, where has one to look for the primary area of denudation L from which these geo-

synclinal troughs of Sumatra partly, and of Java entirely have derived the non-volcanic material now found deposited in them?

Where, in other words, is to be found the continental area L, to whose shores these geosynclines were marginal?

This continental area L lay to the north-eastward; it is the neogene Sunda Land, the greater part of which had been overflowed by the sea after the close of the ice-age. The part of Sunda Land which is now submerged is indicated by the dotted area in the sketch map Fig. 2, the contours of which have been derived from the present isobath of 40 fathoms. The dotted portion, however, does not represent its extent in Neogene time, but the largest extent which it reached only in Pleistocene time.

It appears, thus, that the geosynclines in which the three large oil-fields of the Dutch East-Indies, to wit those of Java, of Sumatra and of Borneo, have originated, during their development were marginal to one and the same continental area of denudation, the Sunda Land. This marginal position is now only noticeable in the Kutei-oilfield, of East-Borneo, because Borneo is the only portion of the former neogene Sunda-continent which still emerges from the sea as a small continental area. In order to understand the original relations between the area of denudation and its marginal geosynclinal belts, we must imagine the now overflowed portion of the neogene Sunda Land, viz. the Java Sea and the South China Sea, to be united again with Borneo, thus forming one continuous land. The assumption is admissible that originally the geosynclinal deposits constituted an entirely or almost entirely uninterrupted belt round the neogene Sunda Land. This is not the case now in the oil-fields hitherto known. The four oilbearing terranes, that of North-Sumatra, that of Djambi-Palembang, that of East-Java and that of East-Borneo are separated by large intervals. In Central-Sumatra, in the gap between the first-mentioned two territories, the geosynclinal deposits are present and petroleum may also occur in them, but, if so, presumably only at a great depth and overlaid by younger, posttertiary mostly volcanic deposits of considerable thickness. The same probability holds for the Lampong districts in the extreme south-east of Sumatra.

There is good reason to expect the occurrence of petroleum in deposits of the neogene geosyncline along the north coast of Java to the west of the peninsula of Japara, i.e. in the gap between the East-Sumatra- and the East-Java-oilfields. Here, however, the petroliferous strata will be overlaid, besides by more recent sediments of unknown thickness, also by the sea to a depth of 50 metres at the utmost.

The rapid improvements in the methods of boring will in the near future probably enable to prove conclusively which portions are still in existence of the deposits of petroleum and lignite which have originated in the far-extending geosynclinal trough marginal to the neogene Sunda-land.

CONCLUSIONS,

1. The three large petroleum-fields of Sumatra, Java and East-Borneo have originated in a similar way in neogene time in geosynclinal belts, marginal to the former Sunda Land, which after the close of the Pleistocene age for the greater part has been overflowed by the sea.

2. It may reasonably be accepted that, along the north-coast of West-Java, oilfields may occur below the surface of the sea overlaid by younger deposits down to a depth not established as yet. These oil-fields are closely connected to and fill the gap between those of East-Sumatra and East-Java.

3. It is improbable that in the eastern part of the East-Indian Archipelago [1]), more especially in the volcanic Lesser Sunda-islands, however much their geological structure may resemble that of Java, neogene lignite- or petroleum-deposits will be found, because one of the conditions for their genesis has not been fulfilled there, namely the presence of a geosynclinal belt of sedimentation, marginal to a continental area of denudation.

4. The opinion, enunciated by VERBEEK [2]) and RUTTEN [3]), that the Strait of Macassar had already been formed as a deep depression in Old-Miocene time, is supported by the way in which the oil-fields occur.

5. The fact that in Neogene time a continuous, or nearly continuous, geosynclinal area (which was folded afterwards) extended in a semicircle along the coast of the continental Sunda Land, makes it doubtful whether HAUG and P. SARASIN are right in considering the East-Indian Archipelago as the area where the Alpine and the circum-Pacific orogenetic systems meet or are interlaced.

This fact rather points to the conclusion, that it would be preferable to distinguish between a circum-Asiatic and an Australo-Pacific orogenetic system as those, which may be surmised to meet or to be interlaced in the East-Indian Archipelago.

1) With the exception of New Guinea and the adjacent islands.

2) R. D. M. VERBEEK, Rapport sur les Moluques. Jaarboek van het Mijnwezen XXXVII, p. 823. Batavia 1908.

3) L. RUTTEN, Modifications of the facies of the Tertiary formations of East Kutei. These proceedings. Vol. XIX, p. 728, 1917.