

ON THE SUPPOSED UPPER PALEOZOIC UNCONFORMITY IN NORTH SUMATRA

by

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Introduction

In UMBROVE'S "Geological History of the East Indies", published in 1938 in the *Bulletin of the American Association of Petroleum Geologists*, we find on page 7 the following remarks about the possible existence of an Upper Paleozoic unconformity in North Sumatra:

"According to ZWIERZICKY (1929) the Triassic near Prapat on Lake Toba (Sumatra) rests unconformably on phyllites, which he considers to be Upper Paleozoic. As this is the only angular unconformity of the sort that has been established with certainty in the entire western part of the Archipelago, we shall — until this important question has been definitely settled by field research — have to consider two possibilities: either a local, more recently developed structural discordance, or a real unconformity caused by transgression. In the latter case we would meet with an Upper Paleozoic folding (and transgressive Triassic) in the Area of Lake Toba. On the other supposition, we should have a conformable sequence from Paleozoic to Upper Triassic in Western Sumatra and Malaya".

In the descriptive notes of plates 1—8 in the second edition of *The Pulse of the Earth*, UMBROVE (1947) again mentions on page 332 the possibility of such an unconformity when he writes: "A Variscian unconformity has also been observed in Sumatra near Lake Toba".

These are the only, presently known, recent informations about the possible occurrence of an Upper Paleozoic unconformity in the Western part of Indonesia. From other parts of Sumatra, viz. the Padang Highlands, a conformable position of the Triassic on the Paleozoic has been reported by MUSPER (1929). Perhaps there are some disconformities but no angular unconformities have been reported so far (KATILI, 1953; S. SIGFT, 1953).

In case there would be indications for an angular unconformity we would have to extend the sphere of influence of the upper Paleozoic orogenesis further towards the West than is accepted by most authors on this subject. For that reason it is of interest, particularly in connection with the modern thoughts of a zonal structural pattern for these parts of SE Asia, as proposed and accepted by STILLE (1945), VAN BEMMELEN (1949), and the author (1954), to trace what is known about the geology of the area east of Lake Toba and North of Prapat and to add a few notes based on some recent investigations in this particular area. This may give us a clearer picture about this supposed occurrence of an upper Paleozoic unconformity.

Former investigations

Geologists who occupied themselves with fieldwork in the area from which this unconformity has been reported are: W. VOLZ (1899, 1907, 1909), W. C. KLEIN (1917) and J. ZWIERZICKY (1919, 1925).

VOLZ' conclusions are not particularly based on results of geological fieldwork in the area of Lake Toba, but in a region immediately southeast of this lake, in the upper basin of the Kualu River. Based on field evidence, VOLZ (1899) concludes that a thick series of darkgray, thin-banded, upper Carboniferous limestones is unconformably overlain by an upper Triassic, fossiliferous, 600—800 meters thick series of sediments which consists of variegated slaty clays (200 m) at the base and a thick sandstone complex (500 m) on the top. The age of these limestones is not based on paleontological evidence, but VOLZ compares these limestones with the upper Carboniferous gray limestones on the West-coast of Sumatra. The sandstones are at the base rather soft and clayey and become more quartzitic towards the top. At irregular intervals they include streaks of a gray clay which are in the upper part unfossiliferous and rich in silica. The lower clays, however, are very fossiliferous. From the clays, south of Pangunjungan, several *Daonella* and *Halobia* species were determined, of which 4 are new species and 3 are known from the Alps, which give these deposits a definite upper Triassic age. VOLZ considers these layers as an equivalent of the Raibler of the Alps, they are deposited in a Mediterranean Tethys.

We may also conclude from the occurrence of so much sandstone and a calcareous facies further to the West (Toba Area) that the coast of the land area was lying further East which would be in accordance with STILLE's and VAN BEMMELEN's opinion about the appearance of a young Paleozoic land-mass, covering the larger part of Malaya and the easternmost part of Sumatra (STILLE 1945, fig. 5, VAN BEMMELEN, 1949, p. 362).

The intercalations of more or less thick clay-layers in the sandstone show that the coastline was not always at the same place, but was shifted from time to time.

Recording to VOLZ a pre-Carboniferous age has to be ascribed to the earlier folding and granitisation of North Sumatra because very frequently he found the Permo-Carboniferous limestones in immediate contact with granites or gneisses and in those cases the slates had been eroded.

KLEIN (1917) reports from the immediate environments of Prapat, on the eastern shore of Lake Toba, pre-Tertiary rocks which are represented by slates, quartzites and a boss of an intrusive granitic rock, surrounded by a rim of hornfels and by limestones near the villages Panahatan and Sibaganding (fig. 1).

THE OLD SLATES are not very well exposed but they build up a rather extensive area and reach till great heights. They construct nearly the complete Marhalatuk ridge until Bangundelok and a fairly weathered Tertiary conglomeratic sandstone overlies these slates on the southern side of this ridge with a distinct unconformity. This unconformity can very well be observed from Prapat. The trail which leads from Sait Dolok on the lake toward Dk. Marhalatuk passes through these slates upon which lie the limestones of the Dk. Sigualan. A little to the east of Panahatan slates are found in the core of a limestone fold, possibly with a conformable contact. Also the southern slopes of the Dk. Sisae-Sae are built up of slates, as soon as the tuffs, in which the Prapat valley has been carved out, cease.

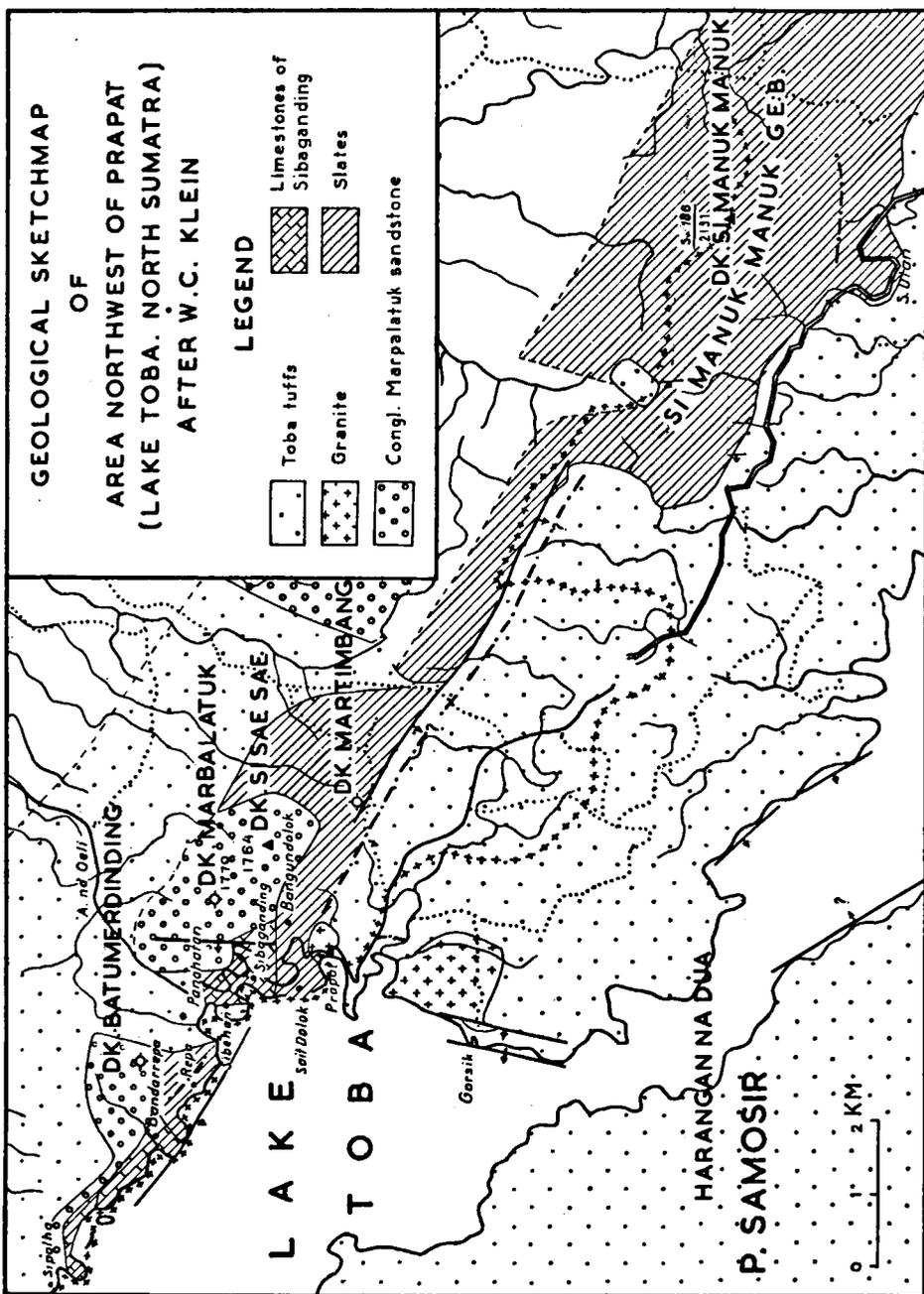


Fig. 1.

West of Panahatan, KLEIN found below the village of Repa an extensive slate complex which reaches to a height of over 1200 meters and which is again unconformably overlain by the Tertiary sandstone of Batu Merdinding. At Banderrepa he found limestone upon these slates. Southeast of Prapat KLEIN reports from the Si Manu-Manuk ridge, from the Nongnonganasu Pass till the Asahan River, besides slates, also phyllites and more or less conglomeratic graywackes. Triassic limestones and Tertiary sandstones seem to fail completely and KLEIN concludes that the ridge from Dk. Sipolding towards the SE is mainly built up of graywackes and phyllites and on his map (fig. 1) these formations are included into the old slates.

The limestones of Panahatan and Sibaganding form over a considerable distance the imposing eastern shore of Lake Toba North of Prapat. The thickness of the moderately to steeply dipping limestones was estimated at 250—300 m by KLEIN, who distinguishes an upper portion of mostly pale blue, generally unstratified limestones with numerous narrow veins of calcite, and a lower portion of dark coloured limestones, which is characterized by intercalations of black flint, with thicknesses varying between 5 and 10 cm.

Northeast of Sibaganding the limestone contains numerous fossils but they are so firmly grown together with the rock that it is impossible to collect any determinable specimen.

KLEIN reports from a place where the Toba-road runs southward and suddenly bends westward in the direction of Panahatan (approx. Km 168), a locality in which the limestone, apparently in a conformable position, lies upon the slates. In the slates some fossils were collected by HAGERUP which were at first determined as the Carboniferous *Aviculopecten papyraceous*.

Rocks with a typical granitic structure are reported by KLEIN from several localities immediately north of Prapat (hornblende granitites according to KLEIN, quartz-diorite-porphyrite according to SCHÜRSMANN, 1930), where they are found till in the vicinity of Bangun Dolok.

They have penetrated into the slates and are surrounded by a rim of hornfels.

Consulting ZWIERZICKY's publications in connection with this supposed unconformity we find that he expresses himself rather vaguely in favour of such an unconformity in the explanatory note to Folio I (North Sumatra) of the General Geological map of Indonesia 1:1.000.000 (1919) in which he writes: "Because the Mesozoic areas in North Sumatra, as far as has been investigated, were folded in the same way as the Permo-Carboniferous, we must accept a late Mesozoic diastrophism, perhaps upper Jurassic (late Cimmerian) or Cretaceous (Lamaric), though also an earlier epoch of compression may, on account of the regional metamorphism of the slates (phyllites) of the Permo-Carboniferous, which is absent in the Triassic shales, not belong to the impossibilities".

In this same explanatory note ZWIERZICKY describes from the area North of Prapat the occurrence of gray, brownish gray, and black clays and shales which are rather similar in appearance to old-Tertiary shales. These are in fact the same layers which have been shown as slates on KLEIN's map (1917). ZWIERZICKY collected some fossils from the same locality as the Danish botanist HAGERUP but he identified the upper-Triassic pelecypod species *Halobia* and *Daonella* and an ammonite (presumably a *Clionites* sp.) in the Prapat fauna, so that KLEIN's preliminary diagnosis does not seem to be correct. ZWIERZICKY's age determination meets further evidence in the earlier discovery of upper-Tri-

assic fossils by VOLZ in the region of the Kualu River, southeast of Lake Toba.

On the other hand ZWIERZICKY emphasizes the occurrence of such an unconformity in his discussion of the Triassic in "Verbeeks Gedenkboek" (1925). The eastern shores of Lake Toba are, close to Prapat, built up of a series of upper-Triassic darkbrown to black, claystones and shales and platy limestones. This sequence possibly forms a direct continuation of the Triassic deposits in the area of the Kualu River further southeast and lies unconformably upon Permo-Carboniferous phyllitic slates. They are transgressively overlain by Paleogene conglomerates and conglomeratic sandstones.

In his final conclusions he particularly mentions the fact that in Ceram, Buru and Borneo the upper-Triassic deposits are lying unconformably upon crystalline schists and in Sumatra upon the Carboniferous.

In the notes accompanying a "Geotectonic Map of Indonesia" (1929), however, ZWIERZICKY again comes to an opposed conclusion. From the present available geological information we may conclude rather definitely that there is no striking unconformity between the Paleozoic and the Mesozoic in the Indonesian Archipelago, on which orogenic activity between both eras may be accepted. Until now only stratigraphic gaps between the Permo-Carboniferous and the Upper-Triassic have been accepted, and nobody has ever reported (! author) a real unconformity. The scarcity in conglomerates in the Paleozoic and Mesozoic Areas of Sumatra, as well, is a fact which rather points to a conformable position between the different formations.

We may add here that UMBGROVE's supposition is almost exclusively based on information obtained from ZWIERZICKY's publications, which are, as we see rather contradictory regarding this unconformity.

WESTERVELD (1947), finally, summarizes in his publication "On the origin of the acid volcanic rocks around Lake Toba" the evidence concerning the pre-tertiary formations in the area around the Lake as follows (p. 13): "It may be said that the majority of the sedimentary part consists of slates, whereas quartzites, graywackes and conglomerates occupy a second place, and are followed in third order of importance by limestones. The rocks are strongly folded and cleaved; the slates are cut by quartz veins and the occasional limestones by veinlets of calcite. There are no definite indications pointing to the existence of planes of unconformity in this series as has been suggested by VOLZ (1907, p. 665; 1899, p. 24—25, 61), who accepted periods of strong folding, each followed by a transgression, before and after the deposition) of the "Carboniferous" limestones and quartzites of the Van Heutz Mts. and the Kualu region. In the Kualu region and near Prapat, however, the limestone beds proved to be almost certainly of upper-Triassic age, and to form normal intercalations in the slates and quartzite series".

Recent investigations

Returning to Medan from the Padang Highlands, after a visit to Mrs. J. KATLI and JOHANNAS who are carrying out some geological mapping for their thesis in that district, I had the opportunity to spend a few days at Lake Toba to study the section along the eastern shores of this lake (fig. 2).

Since KLEIN's preliminary work the Toba-road has been completed and along this road a good upper-Triassic section is now exposed. Proceeding from Sualan, close to the contact of the diorite with the sediments, to the North we pass through a regular sequence of upper-Triassic deposits all showing a regular southwest dip, with angles varying from 80 to 35 degrees, and

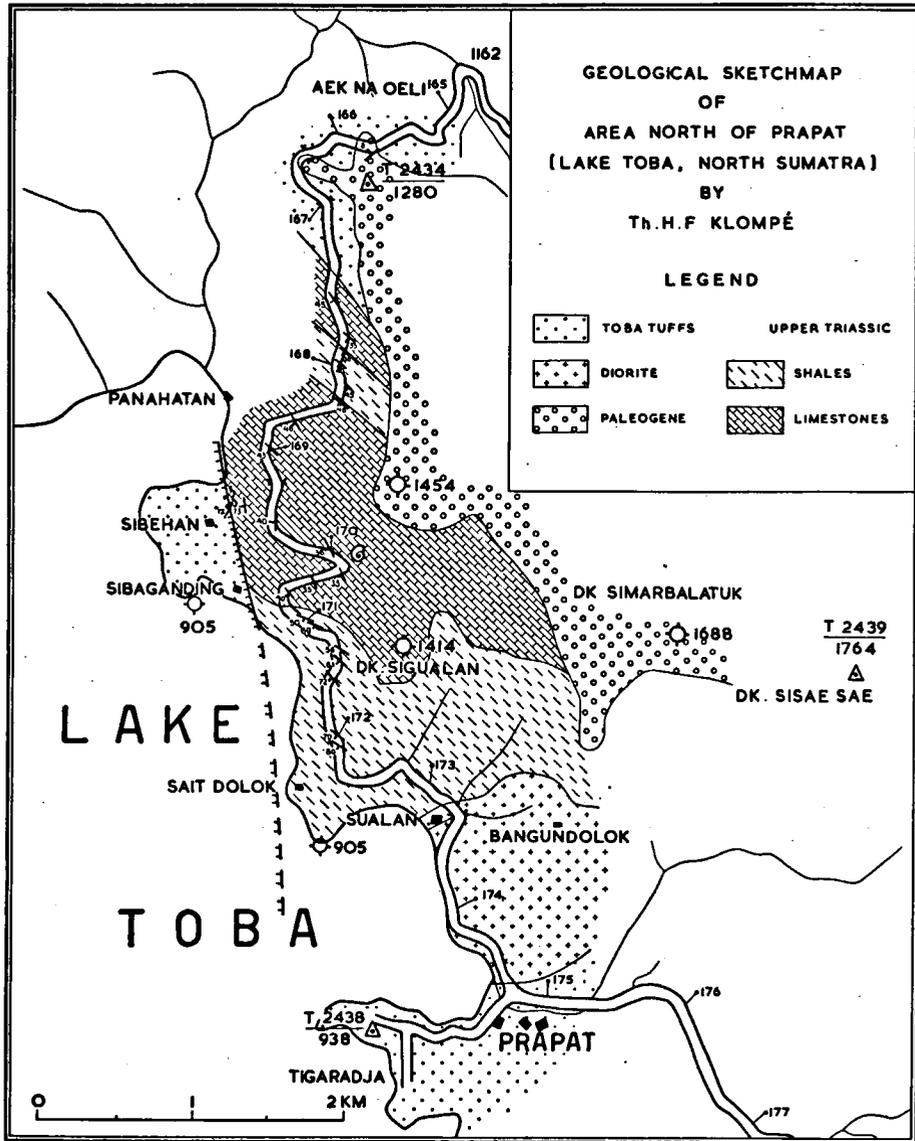


Fig. 2.

in all places showing a distinct steepening up of the dip towards the lake. The diorites we pass along this road before we reach this sequence, form the rounded mountain slopes immediately north of Prapat. This diorite becomes much finer in grain and darker in colour towards the rim of hornfels which separates them from the upper-Triassic sequence. The hornfels are dense and hard rocks and are only locally developed in thin banks.

From these hornfels we pass into the first shale series of the exposed upper-Triassic sequence. Close to the shore of the lake this series has a rather steep dip (70° — 80°) to the southwest which decreases, however, gradually to 50° towards the contact with the first limestone. This first shale series consists out of approximately 300 meters of partly hard and brittle, partly soft and nodular shales which are yellowish to grayish-brown in colour. The yellowish types show darkgray to black stains. These shales sometimes look very similar to old Neogene shales and were mapped as slates by KLEIN and as shales by ZWIERSZICKY. Indeed, these deposits are frequently very strongly silicified and rather hard, but in general the whole series has the appearance and character of shales and certainly not of slates.

Often the bedding is fairly irregular so that no reliable dips can be taken, but in other places the shales are well bedded or banked and alternating with sandy layers, about 30 centimeters thick.

Below these shales occurs the first limestone which is well exposed along the Toba-road and approximately 300 meters thick. These limestones show likewise a regular dip to the southwest which is becoming steeper west of the main road towards the Sibehan promontory.

The limestone does not show a reverse-dip as indicated on KLEIN's map but can with the normal southwest dip, be followed up to the following shale series. These massive limestones are lightgray in colour, and are rich in secondary calcite veins. Locally large blocks of white calcite crystals and fragments of a calcite-limestones-breccia with a yellowish-brown, calcareous cement, were found. The limestones are partly recrystallized and become darkgray in colour towards the base, while the number of calcite veins decreases considerably.

Along the sharp bend in the road, East of Sibaganding, the limestone-banks are very intensively folded and crumpled so that variations in dip and also local reverses could be measured, but the general direction of the dip remains SW. In certain places e. g. in the small valley past the tunnel shortly before kilometer 170 this limestone is rather fossiliferous but it was impossible to collect any determinable material from this locality. Some of the large blocks were entirely covered with the shells and casts of a Brachiopod which as far as its habitus concerns looks very much like a *Rhynchonella*. Beside these indeterminable Brachiopods some fragments of Crinoids and a few small Foraminifera were found. With the exception of a single *Globigerina* sp. no further determination could be done. Below these limestones occur at KM 168.2 again shales which are well bedded so that dip and strike could be measured in several places. These are the same as in the shales and limestones of the upper part of the sequence. These shales are darkgray to darkbrown in colour, and look very similar to those of the upper part of the series. Also here they are locally silicified and show a phyllitic glance, they become than much harder and we may describe these as slaty shales. They are alternating with 20—30 centimeters thick yellowish, fine grained hard sandstones which show some white streaks.

This part of the series reaches a thickness of about 60 meters. Finally

these shales are conformably underlain by another limestone of which approximately 90 meters are exposed in this section. These limestones are dark-gray in colour and occur in banks 40—75 cm. thick with no or only few calcite veins but with thin bands and nodules of black chert. Where these chertbands become numerous the limestones are platy and strongly silicified.

Further north along the road these limestones are covered by Toba tuffs which can, with the exception of a few minor outcrops in Tertiary conglomerates and sandstones, be traced till Aek na Oeli and beyond. These few minor outcrops in the Tertiary along the road form part of a very well developed series of Paleogene deposits which are, with a distinct transgressive unconformity, overlying the upper Triassic shales and limestones, just described. According to KLEIN's map they are well developed further to the Northwest in the Dk. Batumerdinding and further Southeast in the Dk. Marbalatuk and Dk. Si Sae-Sae.

These deposits consist of conglomerates, conglomeratic sandstones and sandstones with in some places some thin claybeds, which are responsible for the occurrence of several springs in this area.

Generally these conglomerates and sandstones are not well cemented and weather very easily. Their unconformable position is clearly demonstrated by their almost horizontal position and the strike of the beds (N 230° E 8° NW) and can very well be seen from Prapat, where the moderately steep NW—SE striking upper Triassic limestone and shales are covered by this series of horizontal Paleogene beds of the Dk. Mabalatuk and Dk. Si Sae-Sae.

KLEIN ascribes these sandstones and conglomerates, in which so far no coal layers and coal lenses have been found, an Eocene age.

Along a road branching at KM 166.7 from the main Toba-road and following the eastern shore of the lake to Sipolha, clays and marls rich in *Globigerina* were found on top of these sandstones at KM. 171.9.

The clay contains a sandy-shaly small foraminifera fauna among which *Haplophragmoides* sp., *Cyclammina* sp., *Textularia* sp., *Bathysiphon* sp., *Clavulina* sp., *Ammodiscus* sp., *Tritaxia* sp., *Verneuilina* sp., a. o. were found.

Also a fragment of a macroforam was found which possibly must be ascribed to *Lepidocyclina multilobata*.

The marl is also rich in *Globigerina* (*Globigerina* ooze) among which *Vaginulina* sp. and *Gyroldnia* sp. could be determined. Both the examined samples point to a T e—f. age and must consequently be placed at the base of the lower Miocene. They are typical representatives of the Burdigalian transgression.

Along this same road also several outcrops in nodular clays and brittle shales were found which are similar to those further SE along the Toba-road. KLEIN marks these also as slates on his map but their appearance is so similar to those first described that also these must be included in the upper-Triassic sequence.

I also had the opportunity to study the outcrops of "slates" close to S. Utan, where the road Prapat-Porsea cuts through this formation. In the outcrops close to the road only shales of the same type as those found North of Prapat were found so that possibly this complex of the Si Manuk Manuk mountains or at least a considerable part of it may be built up of upper-Triassic shales.

The shales and limestones of the upper part of the described section

were not found on the Sibehan promontory, which is entirely built up of the typical Toba tuffs.

Proceeding from the Toba-road towards the lake we noticed that in the first shale and limestone the amount of the dip increases considerably in that direction. In several places I also noticed very clearly a gradual steepening up of the dips from 45 to 70, even 80 degrees. Close to the northern inlet a mylonitic limestone zone was found in which the beds were even vertical. These observations on the steep eastern shore of the lake and the whole morphological situation very strongly give the impression that the Sibehan promontory is separated by an approximately N—S running fault from the main land, a fault which might be continued further South where the layers in several places very clearly show a drag in the direction of the lake.

Conclusions

From the former and recent observations we may draw the following conclusions:

- a. The rocks on the eastern shore of Lake Toba, North of Prapat, indicated and described by KLEIN as slates, underlying the limestones, are in fact shales which in that area lie upon and between the upper-Triassic limestones. In some localities these shales are phyllitic in appearance but these are intercalations in the softer and brittle shales. ZWIERZICKY came already to this conclusion and ascribed the shales an upper-Triassic age.
- b. The observed contacts between shales and limestones in this area are conformable contacts; there are no indications, whatsoever, for a Paleozoic-Mesozoic unconformity.
- c. There is a very distinct unconformity between the upper-Triassic sequence and the overlying Tertiary, which is represented by Paleogene conglomerates and sandstones with *Globigerina* clays and marls on the top, representing a Burdigalian transgression.
- d. The steep dips in the upper-Triassic sequence close to the eastern shore of the lake, the occurrence of a mylonitic zone in these limestones east of the Sibehan promontory and the sudden appearance of Toba-tuffs on this promontory are indications for an approximately N—S running fault along this part of the eastern shore of the lake.

The Paleozoic-Mesozoic contact in adjacent areas

It is, of course, no surprise that the faint indications for an upper Paleozoic unconformity in North Sumatra turn out to be incorrect. As well in North as in Central Sumatra there are indications of facial changes in the upper Paleozoic strata which point to oscillating movements in these areas but neither in Central- nor in North-Sumatra there are indications for a stronger diastrophism which may be included into the Variscian orogeny.

Studying the Paleozoic-Mesozoic contact in the adjacent areas we will see that the oscillating movements become stronger towards the East and that we have to go as far East as Thailand to find the results of Variscian diastrophism, caused by the Saalian (Appalachian) orogenetic phase.

Malaya

In SCRIVENOR's "Geology of Malaya" (1931) we find on p. 95 the following remarks on the relationship between the lower Carboniferous and the upper Triassic: "Is there an unconformity between the sedimentary series (lower Carboniferous) and the calcareous series (upper Triassic)? Now, most unfortunately this question cannot be answered satisfactorily because of two factors which make the presence or absence of an unconformity obscure. One of these is the intense folding and faulting that the rocks have undergone. After many years of searching for proof of an unconformity, I have not yet seen any section in the field that can be said to make it certain that an unconformity exists between these two series." On p. 96 SCRIVENOR continues "Field evidence in Malaya does not give us any reason to suppose that there was any long break in rock-deposition between the lower Carboniferous and upper Trias, marking the existence of an old land-surface on the site of the Peninsula at that time, therefore all the intervening rocks — middle and upper Carboniferous, Permian, lower and middle Trias — of the European succession should be represented by Malayan Rocks. We feel on fairly safe ground in saying that during that long period the site of the Malaya Peninsula was a sea of moderate depth, gradually becoming more and more shallow until in Triassic times calcareous rock-building organisms were finely swamped by sediment. The occurrence of Triassic limestones in Sumatra and other islands of the Archipelago points to the sediment having come from land to the east of the present peninsula" (spacing by author).

Further north, in Thailand, the Triassic, in some publications considered as Jurassic, is developed in another way. SCRIVENOR describes the Triassic rocks of the Peninsula as gray and green clayshales. Limestones, which are so characteristic for Sumatra are almost missing, so that the Triassic of the Peninsula possibly represents a transition from the pure terrestrial deposits of the Red Sandstone Formation which is very well developed in Thailand.

SCRIVENOR's conclusions about a conformable contact between the Paleozoic and Mesozoic and the occurrence of a landmass east of the present Peninsula are confirmed by more recent investigations by RICHARDSON (1939, 1947) and INGHAM (1938), resp. in Kelantan and Pahang, the Raub District, west of Pahang, and Perak. According to RICHARDSON (1947) the occurrence of neritic Permo-Carboniferous deposits in Kelantan and Pahang make it probable that the coastline of the Malayan geosyncline was located north and northwest of that area and near this coast there were important centres of volcanic activity. The products of this activity (Pahang Volcanic Series) were clastic ejectamenta and changed in composition from acid in the beginning to basic at the close of the period. In connection with this VAN BEMMELLEN (1949) believes that the first phase of orogenesis occurred at the end of the Permo-Carboniferous terminating the preceding geosynclinal evolution in the eastern part of the Peninsula by uplift and granitisation. "Thereafter, renewed geosynclinal subsidence caused the transgression of the sea and the deposition of a flysch-like formation of upper-Triassic age. Intercalated polymict conglomerates contain detritus of the Permo-Carboniferous formation (e. g. pebbles of silicious shales with radiolaria, shales, acid eruptive rocks), and also boulders of pre-Triassic granites. In western Malaya the unconformity between both formation is less clear, and locally sedimentation might have continued uninterrupted". From the Raub District, west of Pahang, RICHARDSON (1939),

reports the occurrence of a series of shales and dolomitic limestones with some rare bands of chert which he believes to be of Permo-Carboniferous age. These rocks are overlain by deposits which are known as the arenaceous formation and referred provisionally to the Triassic.

The paucity of fossils in Malaya has made it necessary for geological mapping to be based on the lithological characters of the stratified rocks.

It is therefore the practice that calcareous beds are Carboniferous or Permo-Carboniferous and that arenaceous beds are Triassic.

They are definitely deposits in a shallow sea so that this may point to a shifting of the coast towards the west between the Carboniferous and the Triassic, later on the coastline was shifted again because sedimentation appears to have ceased with the deposition of the arenaceous formation, possibly at the close of the Triassic because post-Rhaetic sediments are unknown.

Prom Perak, still further west, INGHAM (1938) reports the occurrence of limestone, phyllite, schist, shale, quartzite and granite. The limestone is believed to be the oldest formation and forms the southern continuation of the Carboniferous or Permo-Carboniferous limestones of the Kinta-Valley.

Based on these facts it is clear that, with the exception of the easternmost part of the Peninsula there is no evidence for an unconformable contact between the Paleozoic and Mesozoic. Instead of that, there are several indications that the coastline of a landmass east of the Peninsula has been shifted gradually towards the west which points to a steady growth of Southeast Asia in that direction. For distinct results of Variscian diatrophism we have to look further east and northeast and this orogenesis has possibly only slightly touched the eastern part of the Malayan Peninsula. For this reason I have shifted in Malaya STILLE's foldmargin for the Variscian orogeny further to the east (fig. 3).

Langkawi Islands

The stratigraphic sequence of the Langkawi Islands consists, after SCRIVENOR and WILLBOURN (1923), out of the following three groups of rocks:

Quartzite and shale (top).

Limestone with a middle series, 200—1200 feet thick, of shale with a little quartzite.

Quartzite and shale with a few thin beds of siliceous limestone (bottom).

No unconformity has been found between these 3 groups of rocks. That is to say, there is no evidence that when the lowest beds were deposited in shallow water the rocks formed a land surface on which the limestone was deposited later after submergence. This limestone is conformable to the lower quartzites and shales and some evidence has been found that also the upper quartzites and shales are conformable to the limestone. The three groups form a series beginning and ending with shallow water sedimentation with a period in the middle during which deep water conditions prevailed for all but a short time.

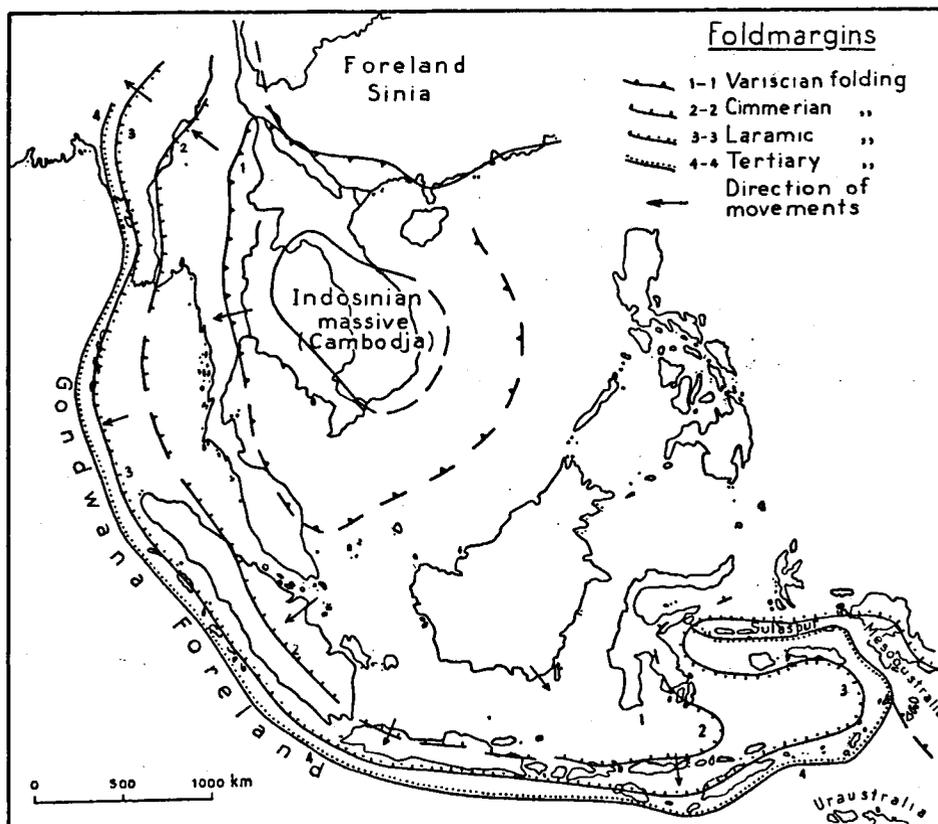
There can be little or no doubt that the limestone is part of the Permo-Carboniferous limestone formation that is found in Sumatra (Kualu area), the Malay Peninsula and Burma.

The shale and quartzite overlying the limestones conformably represent probably also a shallow-water phase. Neither chert nor conglomerate were

seen with these younger shales and quartzites in the Langkawis but it is nevertheless possible that they are equivalent to the Triassic quartzite and shale series of the Peninsula because they have been deposited further from the coast and beyond the main sphere of influence of volcanic activity.

Burma

The predominant rocks of the Mergui Archipelago and the Tavoy District in the southern part of Burma (BROWN-HERON, 1923; RAMA RAU, 1933) are



ZONAL GROWTH OF S.E. - ASIA AFTER STILLE

(slightly modified by Klompé)

Fig. 3.

an assemblage of sedimentaries, highly folded, indurated and granitized, but little metamorphosed, to which OLDHAM has given the name Mergui Series. The position of this series in the geological scale is very doubtful. No fossils have yet been found in it. In the Mergui district this Mergui Series is overlain by a coarse grained and crystalline, fossiliferous limestone.

This limestone is rather tough and compact and the extraction of fossils is difficult. They contain: *Schwagerina*, *Lonsdaleia*, *Lithostroton*, *Polypora*, *Productus sumatrensis*, *Athyris* sp., *Spirifer* sp., *Bellerophon* sp., *Murchisonia* sp.. NOETLING thinks, based on this fossil content, that the age tends to a

Permo-Carboniferous period. There is little doubt that they are unconformable with the underlying Merguis, but the evidence is insufficient to establish this as a definite fact. This Permo-Carboniferous with its light coloured limestones may be considered as a marker horizon for SE Asia and is well developed from Yunnan in the north till in Sumatra. In Burma this limestone reaches its greatest thickness in the Plateau Limestone of the Shan States and stretches from there in eastern direction over Further India till on the coast of the South China Sea.

The folding of the Mergui Series is sharper and more intense than that of the Moulmein limestone, in which it is of a comparatively gentle type. It is quite probable that the first folding preceded the deposition of the Moulmein limestone and that after this folding the whole country was submerged under the ocean during the deposition of the sediments forming the Carboniferous limestones. There followed an upheaval by crustal movements which folded the rocks of the Moulmein and Mergui series and an extensive granitisation took place. The sediments formed from the disintegration and denudation of these granites were deposited in the beds of the Red Sandstone Series. Although direct fossil evidence was not obtained in the Mergui District, RAU thinks that this Red Sandstone Series forms a link in the chain of outcrops extending from the northern Shan States till in Thailand and may probably be of the same age, viz. Jurassic. Based on this the second series of crustal movements may have taken place during the interval between the Carboniferous and the Jurassic and is very likely of the same age as the folding in Malaya.

Thailand

The Permo-Carboniferous limestone (Moulmein lst. and Plateau lst. of Burma) described by CREDNER (1935) and LEE (1927) have been given the name of Rat Buri limestone in the Geological Survey Memoir No. 1 of the Royal Department of Mines, Bangkok, 1953. It is a lightgray crystalline limestone which is widely distributed through Thailand and is believed to be partly of Permian age. The lower part of the limestone contains thin layers of chert carrying fossils of Permian age. At the type locality, Rat Buri, such beds are found lying unconformably on top of the Silurian to early Carboniferous Kanchanaburi Series. In turn the erosional surface of the limestone is capped by Triassic sandstone of the Korat Plateau type, in earlier publications called Gondwana Formation, further indicated as the Korat Series. This series is composed out of a thick deposit of continental sandstone and conglomerate and covers most of eastern Thailand. These conglomerates contain fragments of the older formations so that these must have been exposed at short distances. For this reason we have to accept an orogenetic phase before the deposition of these sandstones. In the extreme southern part of Peninsular Thailand the Korat Series consists of quartzites, phyllites and crumpled black shale. They form the northern extension of beds recently mapped in Malaya as Triassic (INGHAM, 1948).

Such an age seems probable for part of the Korat series which lies above and in contact with the Permian Rat Buri limestone. The fossils found are *Daonella* sp. and *Halobia* sp., they are not very well preserved, but enough of them could be identified to make it certain that they are of Triassic age and probably middle Triassic. Widespread evidence suggests that the Korat Series includes beds of Triassic and Jurassic age but may also include beds

of Permian age. Apparently the lower part of the series has been folded but less intensely than the Kanchanaburi Series in western Thailand.

Thailand and Burma were the site of marine deposition throughout much of Paleozoic time, which culminated in the widespread deposition of the Rat Buri limestone of Carboniferous (?) and Permian age.

Following the deposition of this limestone most of Thailand was elevated and the rocks were regionally metamorphosed by diastrophic movements, approximately concurrent with the Saalian orogeny (UMBROVE, 1947, p. 331—332) which has also been reported from Laos, east of Thailand.

This orogeny seems to have involved most of Thailand, although the older beds are buried in the eastern part of the Korat Plateau. Wherever exposed the Paleozoic beds are moderately to intensely compressed into north-trending folds.

In the eastern part of Thailand, for the first time, there is definite evidence for the occurrence of diastrophic movements belonging to the Saalian phase of the Variscian orogeny.

In general the eastern limits of the belts of orogeny have moved West insofar as the geological history can be brought to light. The Saalian orogeny apparently affected most of Thailand; a Mesozoic orogeny of uncertain age, possibly old and young Cimmerian, affected most of the western half, and the late Tertiary orogeny of the central belts of Burma moderately affected the Tertiary beds along the western frontier.

General conclusion

The summarizing conclusions based on former and recent fieldwork in the area of Lake Toba and a short survey of the Paleozoic-Mesozoic contact in the adjacent areas, make it clear that there are no indications for the occurrence of a Variscian phase of diastrophism in the area, until we reach the eastern part of the Malaya Peninsula, where there are vague indications for stronger movements and the eastern part of Thailand, where there is sufficient evidence for the occurrence of the Saalian phase of the Variscian orogeny. In 1945 STILLE gave in his "Geotektonische Forschungen" a negative answer to the question whether Variscian folding, which is so important on the mainland of Indochina (Cambodian massive), had also influenced parts of the Malayan Archipelago. Studying the regional position of Sumatra it cannot be expected that Variscian diastrophism would have taken place in that part of the area, because we are here in the tectonic continuation of the a-Variscian Burmese area.

References

- BEMMELEN, R. W. VAN, 1949. The geology of Indonesia. Martinus Nyhoff, The Hague.
- BROWN, J. C. and A. M. HERON, 1923. The geology and ore deposits of the Tavoy District. Geol. Surv. India, Mem. Vol. 44, pt. 2, p. 178.
- , G. F., et al., 1953. Geologic reconnaissance of the mineral deposits of Thailand. Royal Department of Mines, Geological Survey Memoir 1, Bangkok (Also Bull. U. S. G. S. No. 984).
- CREDNER, W., 1935. Siam, das Land der Tai, p. 9—63, Stuttgart, J. Engelhorn's Nachr.
- INGHAM, F. T., 1938. The geology of the Neighbourhood of Tapah and Telok Ansan, Perak. Geol. Surv. Dep. F.M.S. Mem. No. 2.
- and others, 1948. Geological maps of Malaya. Federation of Malaya Survey Dept. No. 35, Singapore.
- KATILI, J., 1953. Verslag geologische proefkaartering in de Padangse Bovenlanden. Afdeling Geologie, Universiteit Indonesia, Bandung.
- KLEIN, W. C., 1917. De Oostoever van het Tobameer in Noord Sumatra. Jaarb. Mijnw. in N.I. 1917, Verh. Dl. I.
- KLOMPÉ, TH. H. F., 1954. The structural importance of the Sula Spur (Indonesia). Ind. Journ. f. Nat. Sc. Vol. 110, p. 21.
- LEE, W. M., 1927. Outline of the geology of Siam with reference to petroleum. Bull. Am. Ass. Petr. Geol. Vol. 11, p. 411.
- MUSPER, K. A. F. R., 1929. Beknopt verslag over de uitkomsten van nieuwe geologische onderzoekingen in de Padangsche Bovenlanden. Jaarb. Mijnw. in N.I. 1929, Verhandeligen.
- RAMA RAU, Sethu, 1933. The geology of the Mergui district. Geol. Surv. Ind. Memoir Vol. 55, pt. 1, p. 8.
- RICHARDSON, J. A., 1939. The geology and mineral resources of the neighbourhood of Raub, Pahang, Fed. Malay States, with an account of the geology of the Raub Australian Gold mine. Geol. Surv. Dept. F.M.S. Singapore.
- SCHÜRSMANN, H. M. E., 1930. Geologische notities uit de Bataklanden, Noord-Sumatra. De Mijningenieur, Dl. 11, p. 197, Bandung.
- SCRIVENOR, J. B. and E. S. WILLBOURN, 1923. The geology of the Langkawi Islands. Malayan Branch Royal Asiatic Society, Journ. Vol. I, p. 338—348.
- SCRIVENOR, J. B., 1931. The geology of Malaya. Macmillan and Co., London.
- SIGFF, S., 1953. Verslag proefkaarteringen Padangse Bovenlanden. Afd. Geologie, Universiteit, Indonesia, Bandung.
- STILLE, H. and FR. LOTZE, 1945. Geotektonische Forschungen. Heft 7/8 Gebrüder Borntraeger, Berlin.
- UMBROVE, J. H. F., 1938. Geological history of the East Indies. Bull. Am. Ass. of Petr. Geol. 22, p. 1—70.
- , 1947. The Pulse of the Earth. Sec. Edition, Martinus Nyhoff, The Hague.
- VOLZ, W., 1899. Beiträge zur geologischen Kenntniss von Nord-Sumatra. Zeitschr. d. D. Geol. Ges. 50.
- , 1907. Vorläufiger Bericht über eine Forschungsreise zur Untersuchung des Gebirgsbaues und der Vulkane von Sumatra in den Jahren 1904—1906. Sitzungsber. der K. preuss. Akad. der Wissensch. VI. Sitzungber. vom 7 Febr. 1907.
- , 1909. Zur Geologie von Sumatra. Nord-Sumatra, Bd. I, Die Battakländer.
- WESTERVELD, J., 1947. On the origin of the acid volcanic rocks around Lake Toba, North Sumatra. Verh. Kon. Ned. Ak. v. Wet., Afd. Natuurk. Tweede Sectie, Deel XLIII, No. 1, Amsterdam.
- ZWIERZYCKY, J., 1919. Geologische overzichtskaart v. d. N.I. Archipel. Toelichting bij Blad I (Noord Sumatra). Jaarb. Mijnw. in N.I. 1919, Verh. Dl. I.
- , 1919. Geologische overzichtskaart v. d. N.I. Archipel. Toelichting Blad VII (Tapanuli, Sumatra's Oostkust. Sumatra's Westkust). Jaarb. Mijnw. N.I. 1919, Verh. Dl. I.
- , 1925. Overzicht van de Triasformatie in Nederlandsch-Indië. Gedenkboek Verbeek, Den Haag.
- , 1929. Geotectonic map of the Netherlands East Indies, Scale 1:5,000,000; Jaarb. Mijnw. in N.I. 1929, Verh.