A section of the mountain ranges of North-western Siam

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Objekttyp: **Article**

Zeitschrift: **Eclogae Geologicae Helvetiae**

Band (Jahr): **32 (1939)**

Heft 1

PDF erstellt am: **24.04.2024**

Persistenter Link: https://doi.org/10.5169/seals-159915

ECLOGAE GEOLOGICAE HELVETIAE

Vol. 32, N° 1. — Juni 1939.

A Section of the Mountain Ranges of North-western Siam.

By **Arnold Heim**, Palembang, and **Hans Hirschi**, Erlen.

With 1 plate (I) and 5 textfigures.

Introduction.

The observations of this report were made by the authors on two crossings of the main mountain ranges of Further India, following the trail along the International telephone line from Raheng to Mesod (Maesohd on our text-figure 1, or Mesauk), in the months of April and May 1935. The traverse of about 80 kilometers was made in both directions, on foot, in four days.

Our thanks are due to the Siamese Government who consented to the publication of this scientific paper. It may be of some value, since, the geographer Professor WILHELM CREDNER excepted, no geologist ever crossed the country between the Me Ping and Me Moi (boundary river to Burma).

Only three geological papers are related to this region. COTTER[1]) described the Oil shales west of Mesod on the Burmese side, HÖGBOM[2]) in a valuable contribution to the geology of Siam gives maps and sections along the Me Ping river down as far as Raheng, and CREDNER[3]) in his most interesting book illustrates especially the morphology and some tectonic lines of the area. Unfortunately this book was accessible to us only after our return to Europe.

Maps and Survey.

The only topographic map is the " International Map 1 : 1000000, sheet Jiengmai ", printed and published by the Royal Survey Department, Bangkok. For details this map is useless. The telephone poles along the trail are marked by kilometers. Although on many older poles the numbers were obliterated, the remaining ones were of great help in sketching the cross section. The distances were reduced in proportion to the projecting direction in places where the direction of these poles do not coincide with the general direction of the cross section. Thus the numbers of kilometers as indicated on the section do not always correspond to equal intervals.

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[1]) G. P. COTTER, The Oil shales of Eastern Amherst, Burma. Rec. Geol. Survey, India, Vol. LV, 1924.

[2]) B. HÖGBOM, Contributions to the Geology and Morphology of Siam. Bull. geol. Inst. Upsala, Vol. XII, 1913.

[3]) WILHELM CREDNER, Siam. Eine Landeskunde auf Grund eigener Forschungen, 1935.

Topographical Features.

According to the map 1 : 1000000 there are three main mountain ranges at the latitude between 16 and 17° which together form the back bone of " Further India ". Their direction coincides with the geological strike, namely NNW to

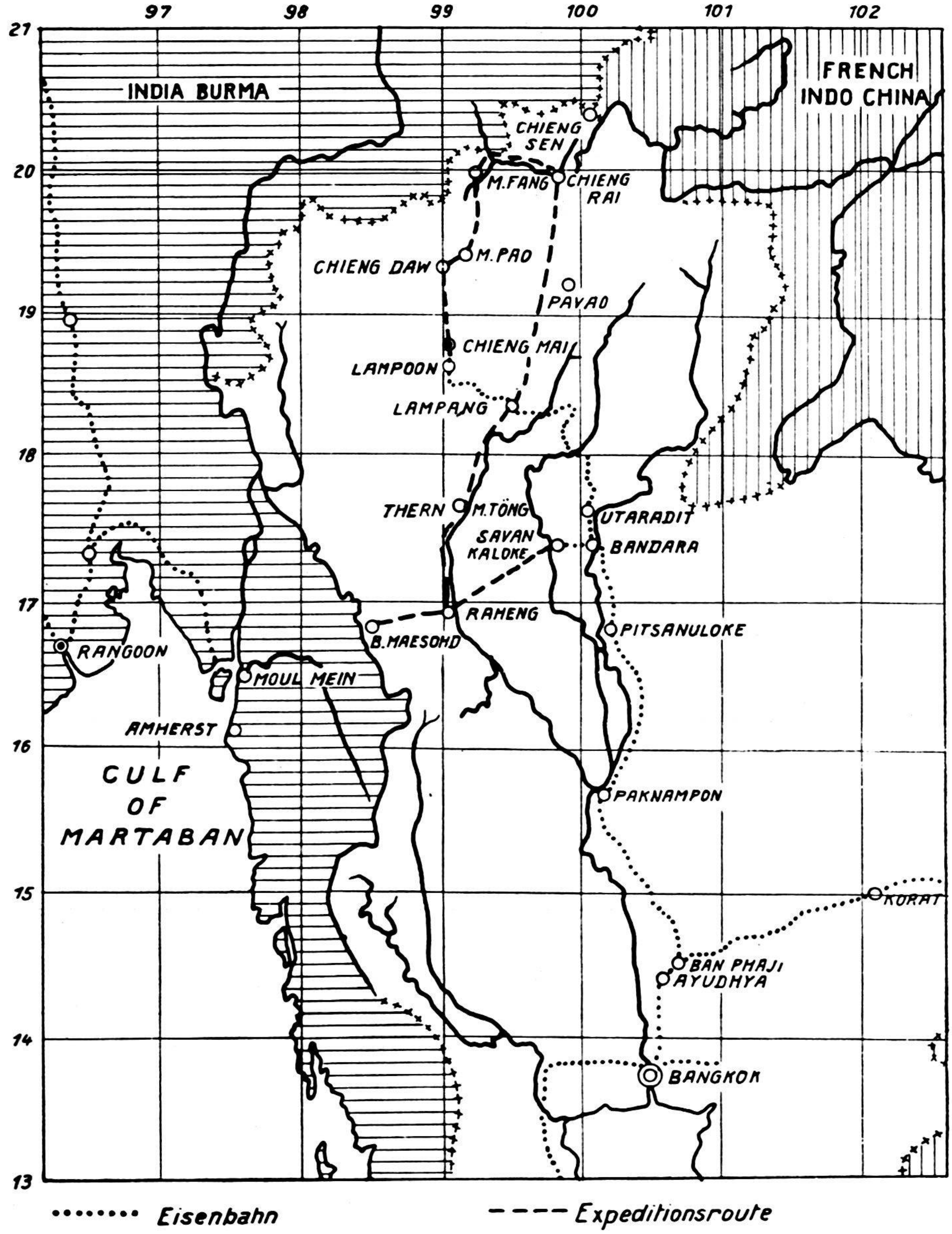

Fig. 1. *Sketch map of North Siam.*
1 : 6 000 000.

Reprod. from Schweiz. Min. & Petr. Mitt. XVIII, 1938, p. 481.

NW. The ranges of the Siamese side (called Tung Tshai) are separated by the wide valley of the Ramau, while the interval of the second to the third main range consists of the large flood plain of Mesod along the Me Moi. The topographical subdivisions from ENE to WSW are illustrated in the cross section. In regard to the drainage, the most remarkable fact is that the main rivers of Further India are directed towards S and SE, while the Me Moi, a tributary to the Salween following the synclinal boundary valley, flows in the opposite direction towards NW. The same is the case of its confluent Me Ramau. The mountain ranges are covered with jungle. The lower parts are characterized by leaf-shudding trees and thorn brush (monsun dry forest) while the higher parts exposed to the sea breeze are covered with evergreen tropical jungle, with luxuriant bamboos, climbing and epiphytic plants. The dense vegetation all over the country is a serious obstacle to the geologist and considerably impeded our observations.

Local geological description.

The different divisions shown in the geological section I to XI of figure 2 will be discussed from E to W beginning at Raheng.

Division I. The Peneplain of Raheng.

The flat country all around Raheng belongs only partly to the great alluvial plain which extends down to the sea. Although practically level, granitic to dioritic rocks comes to the surface over a vast area. This can best be seen along the motor road which crosses the plain or peneplain East of Raheng for more than 25 kilometers. Rounded blocks of igneous rocks weathered out in situ are found all along in the low, only slightly undulating country, covered with open and ugly jungle (monsun dry forest). There are some hills looking like islands and even high mountains, not shown on the map 1 : 1000000, projecting out of the plain. Some of them North of Raheng, East of the Me Ping, were visited by us; they generally consist of highly acid granite[4]). Raheng lies on very strongly folded and pressed schists intruded North of Raheng by large masses of granite.

Division II. Km 1 to 8.

After crossing 3 kilometers of rice fields, the first exposed rock is a fresh looking amphibole-diorite; at km 4 from Raheng more diorite is exposed; at km 5,1 appear dykes of granite-aplite; at km 5,7 decomposed diorite to gabbrodiorite; at km 6 fine granulated diorite with quartz-amphibole-biotite-diorite; at km 6,3 mostly contactmetamorphic rocks (quartzite, hornfels, schists, etc.); at km 6,5 amphibole-biotite-diorite, quartzveins, dioritic dykes; at km 7 monzonite; at km 8 mylonitic granite, sericitic schists, fine crystalline marble, black phyllite, vertical or dipping to ENE.

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[4]) About a more detailed description of the crystalline rocks see Schweiz. Min. Petr. Mitt. Bd XIX, 1939.

Division III. Km 8 to 13.

Permo-carboniferous and older.

At km 8,1 limestone-marble; at km 8,4 highly compressed polygenic conglomerates, very similar to the Verrucano in Switzerland, forming together with the following sedimentary rocks the first higher hills with their rounded heads on both sides of the trail; at km 9 highly dynamometamorphic, granitic looking arcosic sandstone; at km 10 phyllitic conglomerate with pressed red limestone beds, dipping to WSW; at km 11 phyllites; at km 12 pressed and crumbled phyllitic polygenic conglomerate and greenish, sericitic slates of an unique aspect: pebbles up to 10 cm diameter being flattened out to paperlike sheets, followed as far as km 13 by red to pink formation of fine stratified limy sandstone, limestone with green and redbrown veins, phyllite, quartzite and marbles with diopside, plagioclase, microline, further granitegneiss with porphyritic structure by large orthoclase, highly compressed and stretched (fig. 3), further marble, pegmatites, orthogneiss, marbles (ophicalcite) with contactminerals. The direction of stretching is that of the general strike: NNW.

Division IV. Km 13 to 19.

The syncline of Jondam. Trias.

Between km 13 and 14, the river is crossed. Some houses of the natives with banana gardens follow on an alluvial plain which covers the contact of the gneissic nucleus with the following sedimentary syncline: A crystalline limestone of about 20 meters thickness seems to form the basal layer. Thereupon follows a series of partly very coarse conglomerate, with sandstone of about 200 meters or more. Some big blocks of limestone on the trail may derive from intercalations. The dip is 30° and more towards W. The basal formations apparently belong to the Triassic. Indeed, above them follows the easily recognizable sedimentary formation of the country: a series of nonmetamorphic red clay shale or marl with sandstone, containing numerous thin nodulous limestone beds or kidneys of dense limestone. It is the same formation that forms the basal division of the Red Formation of Muang Fang in northernmost Siam, where it overlies the granite. The upper part of the Red Formation, of 500 meters at the least, is chiefly made up of red sandstone with conglomeratic layers. North of the Jondam police station the volcano-shaped cone with its top-flat of horizontal stratification represents the axis of the Jondam syncline. The axis of the syncline is directed to N 30° W. The strata of the eastern limb traversed on the plateau E of Jondam station, dip to SE and nearly S, apparently caused by an axial pitch of the syncline of 10—20° towards SSE. After crossing the river and passing the houses of Jondam, the western limb of the syncline of 45 to 65° dip towards NE is traversed. The lower subdivision of the Red Formation characterized by its sandstones with limestone nodules is about 200 meters thick. So far, the West-side of Jondam syncline is formed of the same stratigraphical succession as its eastern limb. But instead of coming now again to the basal conglomerates and to the massive limestone, a new sedimentary series of 1½ km or more is traversed. The predominating facies of the vertically erected strata is a non-metamorphic greenish clay-shale with thin layers of a more or less silicified sandstone. On account of laterite, the outcrops are partly obliterated and the succession cannot be established. The age of this shaly formation,

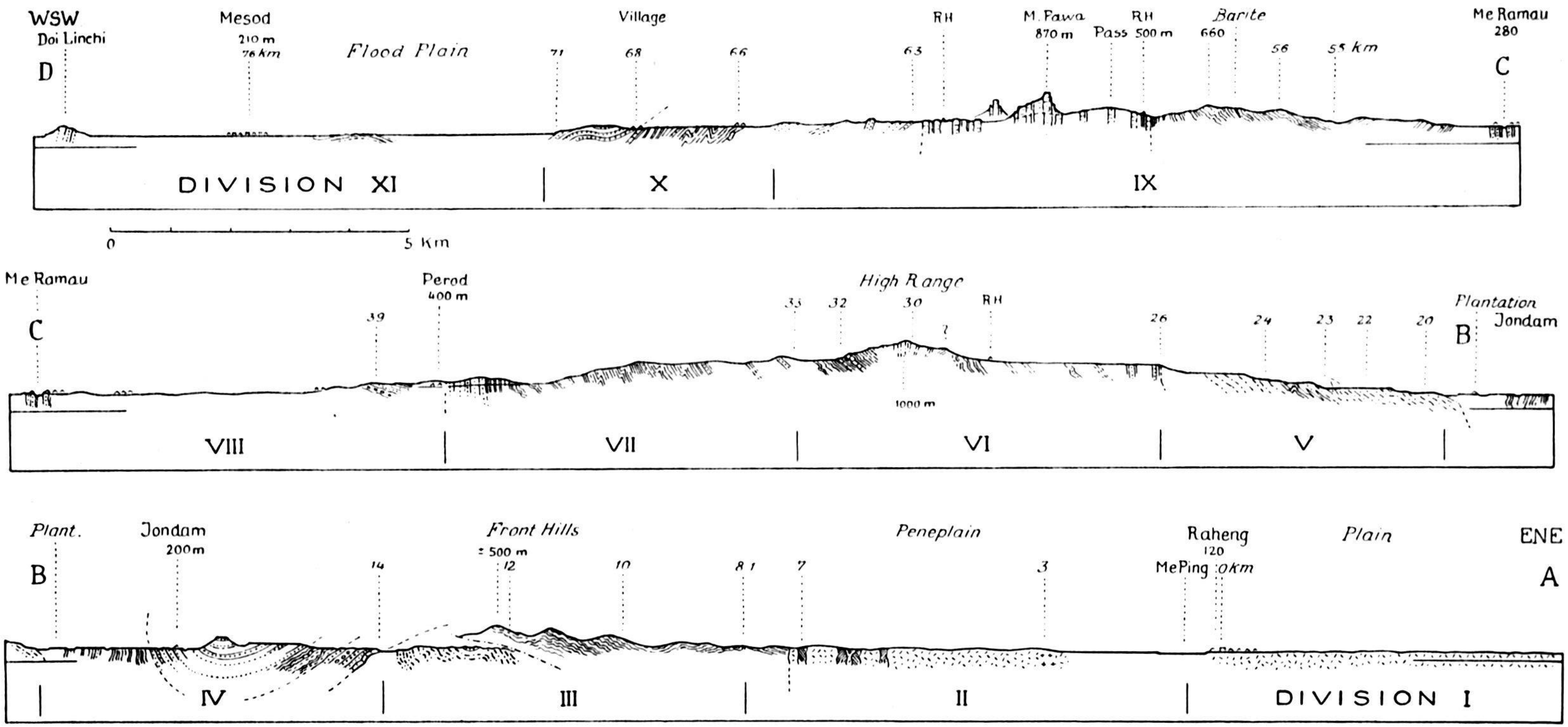

Fig. 2. *Geological Section from Raheng to Mesod.*

1 : 125 000.

however, is indirectly determined: Along the road from Lampang to Chieng Rai (northern Siam) in a sandy layer of the same formation some Pelecypods were found by us and identified as typical *Daonella* proving a middle to upper Triassic age[5]). The Red Formation of Siam, on account of its superposition on the " Permo-Carboniferous " limestone of the Me Ping Gorge, 120 km NW of Raheng was regarded as Triassic by Högbom (l. c. p. 99). The fossil plants found in Indo-China rather suggest a Rhetic or Liassic age. In conclusion we can say that the Syncline of Jondam is formed of a Triassic series. The upper Triassic to Liassic Red Formation forms the upper part of both limbs, while the underlying series are unequally in facies: opposite to the conglomeratic basal layers and massive limestone of the East side is the fine grained shaly marine facies of the West side.

Division V. Km 19 to 26.

The first high range.

After passing a small alluvial flat with banana plantations we come to the slope of the first high range. In a creek greenish shale with calcarous layers of vertical position is present (Triassic). Nearby, a contactmetamorphic rock is exposed. Then we come to an important series of injected paragneisses and mica-schists similar to those between km 12 and 14. Between km 19 and 20 we recognize again the augengneissic granite of km 12, with its stretched feldspar, the schistosity dipping towards NE. At km 21: platy fine grained paragneiss (psammitegneiss) with granitic and pegmatitic dykes and veins. The direction of stretching coincides to the northwestern strike. At km 22 to 26 are exposed: platy injection-gneiss, dipping 30—70° towards NE; fine grained quartzite and quartz-phyllite, psammite-gneiss and mica-schist with compressed pegmatite-dykes; contactmetamorphic limestone, the marble containing diopside, feldspar, garnet, muscovite, titanite, amphibole, tourmaline. All these rocks are intensely compressed into zigzag-folds, although still generally dipping towards NE (fig. 3). Then follows paragneiss, interbedded with mica-schist, phyllite and numerous dykes or veins of pegmatite with tourmaline and aplite dipping 30 to 60° towards NE, alternating with zones of augengneiss of granitic and partly aplitic or quartzporphyry origine. This metamorphic series from km 22—26 thus is originally a sedimentary series (sandstone, clayshale, limestone) injected, and transformed by contact- and dynamometamorphism. Longitudinal stretching is shown at numerous places. The greater part of the compression seems to be older than the pegmatite, which also shows signs of intense compression. The actual contact between the different rock formations must partly be attributed to tectonical movements.

Division VI. Km 26 to 33.

Apart from km 25, the outcrops are poor and scarce. At km 26, vertical quartzite and shale of NW strike is exposed showing intense longitudinal stretching. Quartz-phyllite of western dip characterizes the following long level piece of the side valley. It seems to pass over to the little metamorphic series which forms the crest of the high range: gray sandstone and sandy shale or phyllite.

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[5]) Kindly determined by Prof. Dr. J. Wanner, Bonn.

Just beyond the crest at km 30,2 a layer of marble is interbedded with the phyllite. Coming to the western slope, we find at km 32 the following succession from above: phyllite, stretched, decaying to fibres; bluish black limestone, 40 to 50 meters thick, dipping towards ENE showing intense stretching in the strike N 35° W (fig. 5); white elongated spatches of corals (the tectonical striation showing an axial pitch of 10—30° towards SSE); shale or phyllite, 100—200 meters, deeply weathered; dark limestone 20—30 m, dipping 20—40° towards ENE, little recristallized although intensely stretched in the direction of strike, bluish phyllitic shale with sandstone layers, about 500 meters. This series is apparently reversed, and is supposed to be of Permo-Carboniferous age.

Fig. 3. *Intensely folded limestone from the eastern slope of the High Range.*

Division VII. Km 33 to 38.

Between km 33 and 34, another series seems to begin with 20 meters of sandstone dipping 40° to East, apparently interbedded with greenish shale. All along the ridge which is followed by the trail, such greenish none-metamorphic shales have been noted. Partly, they are of conchoidal fracture and strikingly resemble the Triassic shale of Jondam. Where the new trail descends in zigzag and reaches the level of the creek, good exposures of siliceous shale and thin bedded quartzite are found, with steep dips towards ENE or vertical, with a strike to N 30° W. They again are typical in facies for middle Triassic. This conception is confirmed by the Red Formation, of which sandstone and conglomerate are exposed on the steep slope of the old trail right above the village of Perod (Palod). The western slope of the First High Range thus seems to correspond to the reversed limb of a great anticline, formed of the Permo-Triassic series with a huge development of middle Triassic shale. The corresponding core would be represented by the paragneiss series on the eastern slope.

Division VIII. Km 38 to 51.

The Ramau Valley.

From village Perod (Rest Hut at km 38) to the village Me Ramau (km 51) a broad valley of 6 to 7 km is obliquely crossed, drained by Me Ramau, the largest river between Raheng and Mesod. Outside of the steep slope of the Red Formation follow smaller round hills. The first exposure is made of variegated clay. Then follows coarse conglomerate with greenish pebbles derived from the Triassic shale formation. The dip is 10—30° towards East. Without having a proof, we regarded this formation as younger Tertiary. After km 40 no more exposures were found until Me Ramau, where in the village of the same name big black rocks of massive quartzite are encountered. This quartzite recalls in every respect that which we found in Northern Siam of the Permo--Carboniferous series. The dip is vertical, the strike N to NNW, the thickness about 200 meters as far as exposed in the village. Numerous horizontal striations of friction can be seen on the bedding planes of the quartzite, demonstrating tectonical movements.

Division IX. Km 51 to 65.

Similar to the first range, this ridge is not built up of hard formations, but of shale with thin sandstone beds of deep weathering. At first the dips are 60—80° towards NNW. After km 55 the black shale, although warped in the detail, dips uniformably towards ENE at an average angle of 20—25°, conformably to the slope. Nearly at the summit on the crest at km 56,4, at an elevation of 600 to 650 meters we met a large white exposure of Barite dipping 60—65° towards East. Its structure is coarsely cristalline, the single crystals reaching the size of one inch and more. The maximum thickness is about 20 meters. Towards N and S the Barite pintches and fingers out in the sandy shale in which it has been deposited by hydrothermal processes. Already further down the slope (km 55) loose fragments of Barite had been found from smaller veins in sandy shale. Descending the steep slope on shale with layers of micaceous sandstone of a steep easterly dip, we reach the saddle between km 58 and 59, at about 500 m altitude, where the first reef of limestone is exposed. Then, as already observed from the top of the first range (about 23 km in a straight line) the picturesque peaks of Mount Pawa (870 m) and its rugged neighbour abruptly project out of the evergreen tropical jungle. They consist of massive limestone. The position is vertical, with a normal strike of N 15—20° W.

The width of the limestone zone across the strike is 4 km. But there is not one compact mass of limestone. At the saddle, just below a Rest Hut, the first cavernous and zoogenous reef is about 20 m thick; then follows about 150 m of vertical shale (Rest Hut), followed by an other limestone reef. A thick cover of terra rossa hinders further observation. At km 60 only follows the main body of massive gray limestone, forming the Pawa peak. Its thickness is 800 m at least and possibly more than twice that much. No determinable fossils were found. The trail passes on the North Side of Mount Pawa, where another peak with vertical limestone walls can be seen through the jungle immediately to the North of the trail. At the second Rest Hut (Westside of Pawa) and 400 m beyond the limestone reefs are siliceous limestones interbedded with vertical layers of silex. After this immense series of limestone extending from about km 62,5 to 65,5 we are crossing the quartzite of the same type as that of Meramau. The first layer on the trail dips 40° towards W 10° S. The contact with the limestone is not exposed. A tremendous thunderstorm made detailed observations impossible. At km 64, an intercalation of shale is crossed.

Division X. Km 65 to 71.

The first formation of this division is one that we did not encounter in any other part of Siam. It is reached at km 66 and begins with hard layers of fine grained, sandy limestone (Kieselkalk) dipping towards W 20° N. In contrast to the poor outcrops of the quartzite, nearly uninterrupted exposures are met along the trail or in the creek until a small village at km 68. Summarizing the local observations this "new" formation may be described as follows: Gray, dense, impure limestone of conchoidal fracture, well bedded and intercalated with marls; the limestone beds are usually 0,2—1 m thick, generally dipping 30—60° towards WSW, with local folding. No fossils were found. The general appearence and the microscopic study however do not leave any doubt that it is a marine succession. The age of this marly limestone formation of the western foothills of Pawa could not be directly determined. In spite of much attention only traces of shells were found. Possibly, the ammonites cited by COTTER from the Burmese side derive from this limestone. This would explain his surprise of finding Triassic fossils in the limestone which usually is regarded as Paleozoic. Indeed, two limestone formations of different facies and stratigraphical position must be distinguished. The older one forms the Pawa Peaks, the younger one is weathered down to lower hills. From the village km 68 to km 71 at the border of the great valley plain, few outcrops were found. The low hilly region is covered with pleistocene conglomerate. Below it, green and red sandstone and arcose in a flat position was found. The last outcrop is a quartzitic bed of sandstone at km 71 dipping towards W 30° S. Apparently these sandstones belong to the Red Formation. The stratigraphic position of the marly limestone thus is the same as that of the *Daonella* in as much as both underlie the Red Formation. This is another reason to attribute the marly limestone to the Triassic.

Division XI. The Basin of Mesod.

Within a region about 50 km from SSE to NNW, and a width of about 20 km, the Valley of Mesod, chiefly on the East side of Me Moi boundary river, is filled with younger Tertiary deposits. The boundary river and some creeks excepted, the outcrops are scarce, all of them being bound to the great flood plain. Therefore it is difficult to establish a stratigraphic succession. Only with the help of mapping all the outcrops, and consulting the important paper of COTTER, an approximate idea was obtained. Three subdivisions seem to occur which pass into each-other:

1. Basal sands and conglomerates
2. Oil shale division
3. Hanging marls.

1. The basal sands are gray and micaceous containing plants and boulders.

2. The oil shale division, of about 100 meters thickness, is characterized by foliated, more or less bituminous marls, interbedded with oil shales. The marls are minutely stratified, often showing 10—50 sheets on one centimeter thickness. Each sheet on one side is made of yellowish barren marl, which passes

to the brown bituminous side. It seems that each of these minute strata represents an annual deposit, the brown part representing the winter, the white part the summer season. It would be an interesting task to apply DE GEER's varve-method in order to obtain a true chronology of these deposits. A rough guess leads to several hundred thousand years.

The oil shales have a wood-like appearance and are tough and very difficult to break with the hammer. The weathered surface is a light yellowish brown, while the fresh cut of the good quality oil shale is dark chocolate brown. The smell is distinctly that of crude oil. Even the poor marly shales smell slightly bituminous on the fresh cutting. The best oil shale, according to COTTER, yields about 200 liters of crude oil to the ton. The good layers are scattered, and of different thickness, up to three meters each.

Fossils and Facies. South of the mouth of Huey Meku, on an island in the Me Moi, a nice exposure of minutely stratified shale of bluish to olive and chocolate colour with a slight odour of oil was found, which contains freshwater fossils like molluscs, remains of fish and insects, some of good preservation, Gypsum in fine cristals or fibrous bands is frequent and locally abundant. Underlying these shales are micaceous sandstones with dicotyledone leaves. Apparently from the same horizon, COTTER and ANNANDALE cite freshwater fossils from the Dawna Hills, Tanasserin, of which some are still living in the country.

Gastropods: *Indonaia bonneandi* EYDOUX and the new species *Aerostoma intermedium* and *Cotteri, Vivipara dubiosa* and *gregoriana.*

Fish: *Daunichthys gregorianus.*

Whether the gypsum also could be precipitated in a fresh water basin, or whether we have to admit a slightly brackish condition is questionable.

3. The hanging marls are chiefly made of fine grained, slightly sandy marls of yellowish colour, rarely interbedded with sandstone layers. They are less thin-bedded and frequently making even massive layers up to one meter thick. Partly, they are still somewhat bituminous, with a slight smell of oil.

Tectonical Features. As a whole, the Tertiary of the Mesod Basin overlies the older formations with a strong unconformity, the youngest of them being the Red Sandstones. This unconformity cannot directly be seen, but is deducted from the irregular border of the basin. Southeast of Mesod it is formed of steeply erected marly limestone (Triassic), East of Mesod of the Red Formation (Rhetic-Liassic), northwest of Mesod of the Quartzite and the massive limestone (Permo-Carboniferous?) or of Red Sandstone. The Tertiary of Mesod has been deposited in a lake basin framed and underlain by Mesozoic and Paleozoic formations, which were already steeply erected and denuded. The folding compression was renewed after the deposition of the tertiary sediments, and it is especially the oil shales which illustrate these latest tectonical movements. Being the most resistent rock to weathering, the oil shale, where folded, crop out on the plain. Dips of 10° are usual and such up to 30° frequent. At some places N and NW of Mesod dips over 60° to vertical were seen on local folds with flexures. Probably these strata are warped by the influence of resisting " ilands " of the old formations. Also the irregularities of the basement must have caused the deviations in the strikes and dips of the Tertiary. In some places, however, also regular folds of the normal NNW-strike were found. The best example is the Anticline of Huey Meka luong S of Mesod, made of the oil shales series (NE limb dipping 25°, SW limb 10°). Orographically, almost no traces are left of these disturbances, the erected strata being levelled to the actual flood plain.

The Sedimentary Succession.

As far as we have travelled in Northern and Western Siam, we have met great difficulty in establishing the stratigraphic sequences. This difficulty is caused by the scarcity of continuous outcrops and of contacts, the difficulty of penetrating into the thorny jungle apart from the few trails of the country, the general lack of fossils, and the numerous unconformities and irregularities of deposition since the oldest times. The section we have tried to study in passing rapidly along the trail from Raheng to Mesod illustrates all these difficulties. Nevertheless, we will undertake an essay as follows.

1. Paragneiss and Mica-Schist.

These dynamo- and contactmetamorphic rocks are obviously the oldest ones of the section. We have found them between km 6 and 8, between km 12 and 14 and from km 20 to 26. The oldest part is regarded as being originally an impure sandstone and sandy shale. It has been transformed by dynamo- and contactmetamorphism to fine-grained Paragneiss and Mica-Schist.

2. Conglomeratic Phyllite, Quartzite, Marble.

This formation is represented by the sericitic phyllite with its flattened pebbles, the quartzite and marble with contact minerals. The conglomeratic phyllite resembles very closely to the phyllitic Verrucano of the Swiss Alps, but probably is much older than Permian.

3. Paleozoic (?).

As Paleozoic, and chiefly Carboniferous are tentatively regarded the large bodies of little to none metamorphic phyllites and shales with quartzite in the lower part, forming the first high range from km 26 to 31 and met again on the eastern side of the Pawa Range from km 51 to 65. The thickness is estimated around 2000 meters.

4. Pawa-Limestone.

This vertical calcarous series of 3—4 km thickness begins with a reef of only 20 m bedded in shale. At Mount Pawa the limestone is compact. In vain we have sought for Fusulinids. The rock usually is too much crystallized. Flint layers only have been noticed on the western border. It thus seems that the Pawa Series belongs to one sequence. The facies of the limestone so much resembles that of the limestone in which we have found some Fusulinids in North Siam, that we are inclined to regard it as Permo-Carboniferous. To this type and age probably belongs the small occurrence at km 32. According to observations from the train and to WALLACE LEE[6]), a large series of limestone with great quarries is crossed by the railway not far from the station Bandara Junction. A loose piece found on the tracks proved to be full of perfectly conserved *Fusulinidae*. Prof. CARL O. DUNBAR of the Yale University, New Haven, has been kind enough to examine them. He wrote us on August 21st, 1935, the following:

" We found four species, which are as follows, listed in order of abundance:

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[6]) WALLACE LEE, Reconnaissance Geological Report of the Districts of Payap and Maharashtra, Northern Siam. Published by the State Railways of Siam (s. l. & s. a.).

Neoschwagerina craticulifera (SCHWAGER), Plate I, fig. 1, 3a.
Verbeekina verbeeki (GEINITZ), Pl. I, fig. 2.
Pseudofusulina douvillei (COLANI), Pl. I, fig. 3c.
Sumatrina annae (VOLTZ), Pl. I, fig. 3b.

This is the fauna of the Maokou limestone of South China. HUANG[7]) has recently shown that this is a well-marked faunal horizon widely distributed in South China. It is definitely younger than the Taiyaun fauna of North China and the Uralian of Russia. I think it is certainly younger than the Chihsia limestone of southern China and probably younger than the Artinskian of Russia, though in the absence of the neoschwagerines from Russia, the latter conclusion is based on indirect evidence. In short, the horizon is certainly Permian rather than Carboniferous, and, as I would classify the Permian, it is of Middle Permian age."

5. Quartzite.

The extreme irregularity of the quartzite and its frequent absence suggest a great unconformity. Also the difference of dip between km 62 and 63 points to an unconformity below the quartzite. This formation is widely distributed and of great thickness in North Siam, especially West of Me Fang valley. On our Raheng-Mesod section we have found the quartzite at Meramau, and on the West side of Pawa Range. A further isolated exposure is the eastern hill of Doi Linchi 7 km NW of Mesod. Tentatively, we regard this rock as Permian.

6a. Green Shale Formation.

This formation seems to be the same as that found N of Lampang (North Siam), in which *Daonella* was found. It is regarded as Triassic. It forms the western limb of Jondam Syncline, with a thickness of 1½ km or more. At an enormous thickness of 2—3 km, although badly exposed, the greenish shale is developed between km 33 to 38.

6b. Marly Limestone.

More than 1000 meters of this formation is found along the Eastern border of Mesod Valley, but is unknown anywhere else. It is characterized by a well-bedded repetition of gray dense limestone of conchoidal fracture with marls, and supposed to be also Triassic.

7. Red Formation.

Red and greenish sandstones with clay-shale and conglomerate are widespread all over Siam, Burma, Indo-China and Southern China. The age is supposed to be youngest Triassic to Liassic. The thickness is very variable. It has been found at Jondam between km 13 and 19, and East of Mesod. In its lower part of 200—300 m, characteristic nodular layers and kidneys of limestone occur as a leading horizon, nothing similar having been found in any other formation of Siam.[7a]

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[7]) HUANG, Mem. Geol. Survey China, Ser. A, No. 10.

[7a]) W. LEUPOLD (Berne) examined some small fossils from limestone beds, underlaid by sandstone formation (Red formation?), collected by H. HIRSCHI, about 18 km due South of Mesod, a little North from the place where on both sides of the Me Moi river intensely folded limestone formation rises several hundred meters above the river bed. According to LEUPOLD the fossils indicate the presence of uppermost Jurassic or lower Cretaceous. More about this interesting discovery shall follow in an other paper.

8. Tertiary.

The conglomerate and variegated clay West of Perod excepted, Tertiary sediments were only met in the great Me Moi Valley (Mesod Basin) and in the nearby Htichara Basin (Burma). Upon coarse terrigenous material with boulders and micaceous sandstone followed the most quiet and undisturbed deposit of sapropelitic freshwater marls. The few fossils point to younger Tertiary. These neogene sediments were unconformably deposited upon steeply erected rocks of Mesozoic and Paleozoic age.

9. Quarternary.

High Terrace Conglomerates or boulder beds were found upon the Red Sandstone between km 68 and 70. Very coarse gravel and boulder beds, 20—30 m above the plain can be seen along the Me Moi River SW of Mesod. Some warping in the terrace beds indicate that the tectonical movement has continued into recent time. The greater part of the flood plain of Mesod, Meramau and Raheng is covered with alluvial mud which is cultivated for rice.

The longitudinal Stretching.

As much as we know, special studies or compilations in regard to longitudinal stretching of mountain ranges or folds have not been made yet, except those related to the border of the Helvetic thrust sheets of Switzerland[8]). There, the stretching is easily understood, the arch of the thrustfold being longer than the original extension of the anticlines. In this way, structures have resulted of an anvil shape.

The Ranges of Further India, although clearly autochthonous, show the most striking effects of longitudinal stretching and relative internal displacements. We have found them first in the augengranite-gneiss at km 12 (fig. 4), then again at numerous places in the metamorphic rocks of the first high range as stries of friction in the direction of the strike. It is true that normal striation of friction in the direction of the dip also was observed but more locally and less pronounced. The augen of the gneisses are all directed towards N and NNW. The less compressed igneous rocks seem to be stretched exclusively in the direction of strike. The most extraordinary stretching is presented by the reversed limestone at km 32 (fig. 5). The original dense structure and dark blue colour (of the type of Quintnerkalk in the Helvetic Alps) is little changed, although each strata has slipped on the other, with or without having developed minute calcite films with striation in the direction of the general strike. These stries are not always horizontal, but may be inclined 10—30° towards SSE. Finally, horizontal and little inclined stries of friction have been observed again on the vertical strata of Quartzite at Me Ramau. No such phenomena were found anymore in the Mesozoic or Tertiary formations. It seems that the longitudinal stretching movement was contemperaneous with the intense folding at the end of the Paleozoic era. The many occurrences of the various older rocks in different regions point out that the longitudinal stretching was not of local occurrence

[8]) ARN. HEIM, Die Erscheinungen der Längszerreissung und Abquetschung am nordschweizerischen Alpenrand. Vierteljahrschr. Nat. Ges. Zürich 1906. — Monographie der Churfirsten-Mattstock-Gruppe. Atlas und Vol. IV. Beitr. z. geol. Karte der Schweiz, 1917. — ALB. HEIM, Geologie der Schweiz, Bd. II, 1, 1921, p. 372—413, Taf. XVII.

only, but has effected the old crustal folds of Further India in general. More observations on the subject would be valuable not only for Further India. The longitudinal stretching must not be confounded with a striation through minute microscopical folding. This case has been observed in the Daling Series of the Tista Gorge in the Himalayas. The explanation of the longitudinal stretching of autochthonous mountain ranges is difficult and the problem not yet satisfactorily solved. For the longitudinal differencial movements or shearing in California, an explanation has been given as deducted from a difference in the speed of rotation[9]).

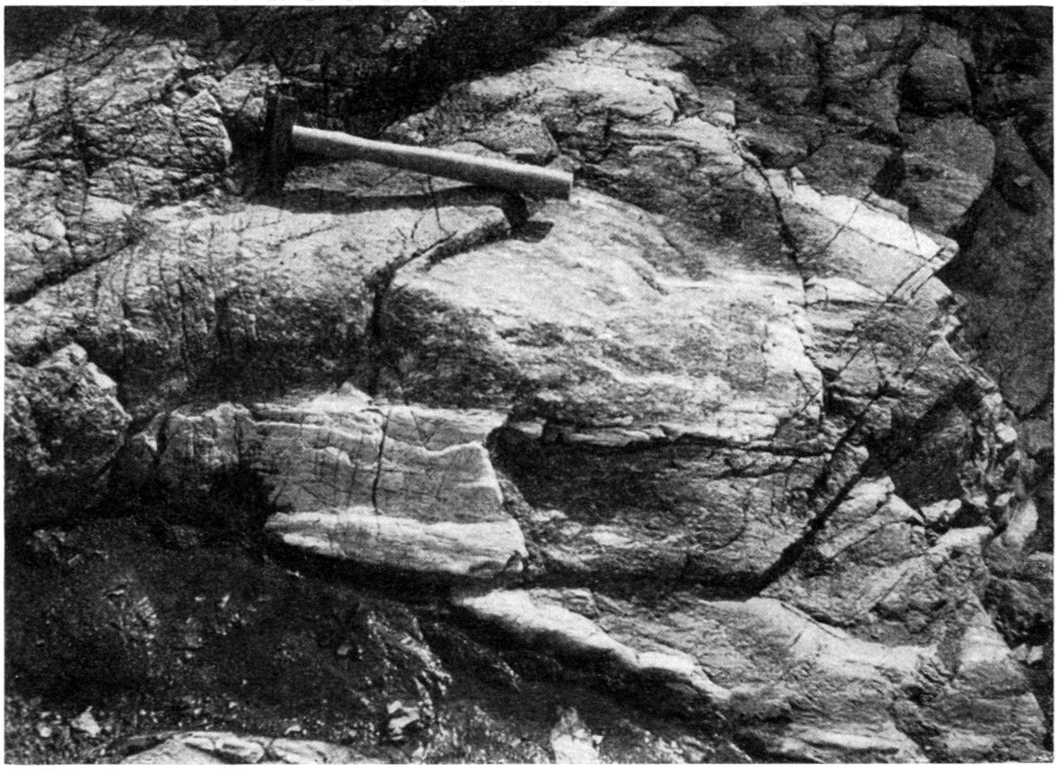

Fig. 4. *Stretched granite-gneiss from the Front Hills* (km 12).

Notes on the Geological History.[10])

Our conclusions in regard to the geological history of the traversed region depend on the interpretation of the stratigraphic succession given above. For that reason, some of our conclusions may need correction by future observations.

1) Oldest mountain-making, gneissification of the former eruptive rocks and sediments, and injection into them, causing contactmetamorphism in addition to the dynamometamorphism.

Unconformity (?).

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[9]) ARNOLD HEIM, Energy Sources of the Earth's Crustal Movements. XVIth Intern.-Geol. Congress 1933, Washington 1936, p. 909—924.

[10]) Compare CREDNER, l. c., p. 19.

2) Accumulation of clay, sand and pebbles with some layers of limestone. Second intense compression by which the conglomerates are transformed into conglomeratic phyllite with squeezed pebbles. Epoch 1 and 2 may be older Paleozoic or Pre-Cambrian.

Unconformity.

3) General subsidence and accumulation of thick bodies of sandy clay and sandstone etc. Carboniferous (?).

4) Irregular deposits of massive marine limestone with and without corals. Permo-*Carboniferous*.

5) Irregular deposition of quartz sand.

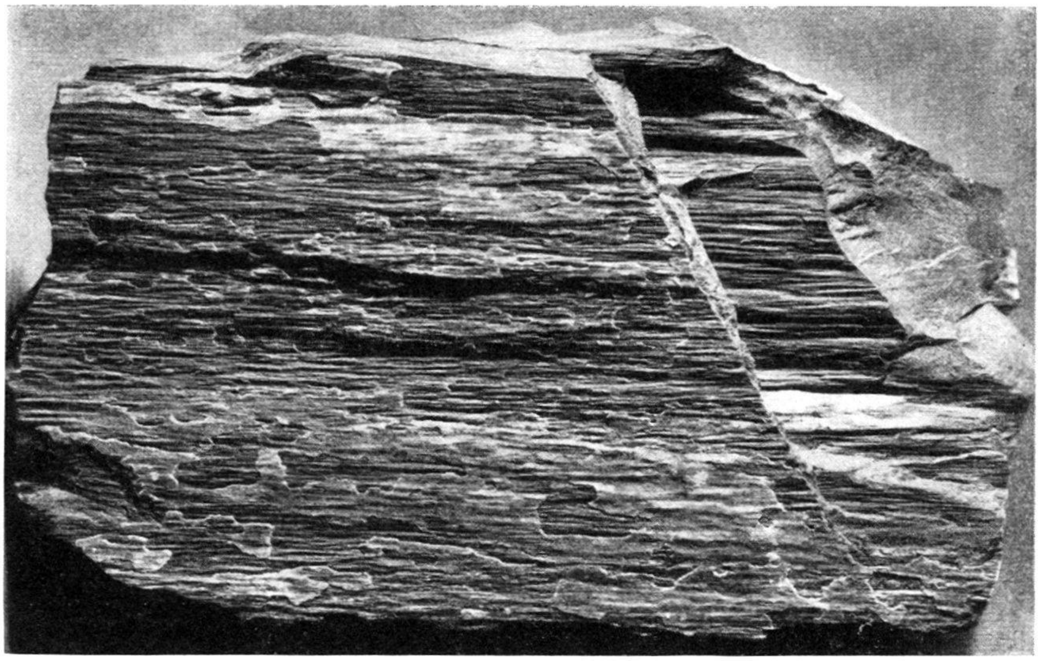

Fig. 5. *Stretched limestone from the western slope of the High Range* (km 32).

6) Great diastrophism, folding in NNW direction.

7) Extensive intrusions of gabbro, diorite, granite. Contactmetamorphism of carboniferous sediments. (These igneous rocks are massive, generally showing no trace of dynamometamorphism.)

8) The great mountain ranges since their erection are subject to intense erosion until middle Triassic time (Basal conglomerate E of Jondam). Unconformity.

9) General subsidence, but still leaving some ranges in the shape of peninsulas and islands in the Daonella Sea. Deposition of greenish clay of unequal thickness (0—3 km). Middle to upper Triassic. Unconformity shown by abrupt termination towards East at Jondam syncline.

10) Renewed erection (folding). Terrestrial deposition of red sandstone, shale and conglomerate in the depressions. Latest Trias to Lias.

11) Post-Triassic intrusion especially of porphyrites.

12) General erosion. Second modelling of the mountain ranges, of which part has been denuded already during the former periods. Great unconformity.

13) Slight subsidence of the western depressions. After deposits of boulder beds and sand follows a quiet sedimentation in fresh water basins during several hundred thousand years characterized by annual varves of bituminous marl with sapropelite (oil shale of Mesod and Htichara basins).

14) Renewed lateral compression, at least in the western region (Mesod). Hardening and warping of the Eogene sediments. Extrusion of basalts. Pliocene to Pleistocene. Unconformity.

15) Local gravel deposits. Continuation of erosion. Formation of the great flood plain of Siam, of the Peneplain of Raheng, of the flood plain of the Mesod basin, where the folds of the Eogene sediments are levelled down. Last tectonical movements recognized by slight deformation of terrace gravels. Quarternary.

Manuscript received November 18, 1938.

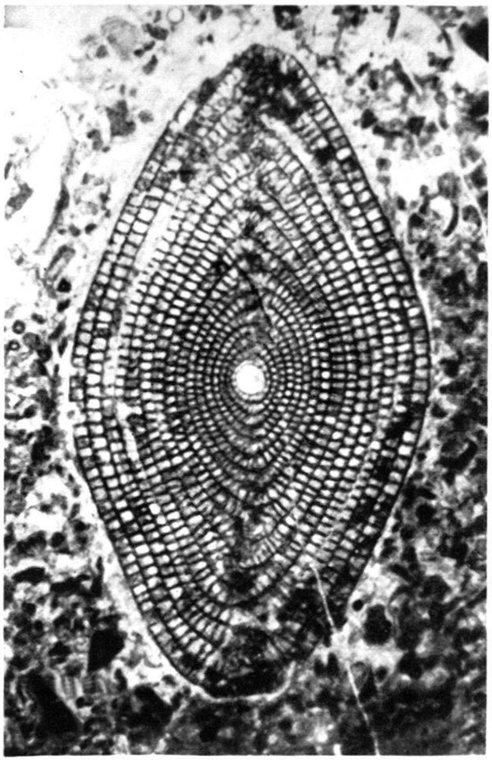

Fig. 1.

Fig. 2.

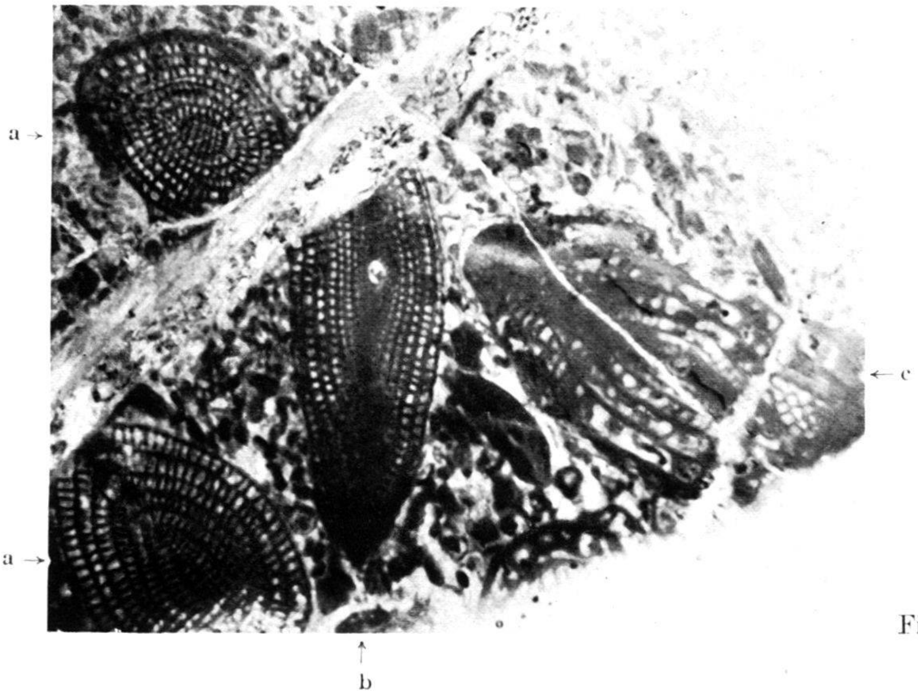

Fig. 3.

Fusulinidae from North-western Siam.

Fig. 1. *Neoschwagerina craticulifera* (SCHWAGER).
Axial section. × 10.

Fig. 2. *Verbeekina verbeeki* (GEINITZ).
Axial section. × 10.

Fig. 3. a *Neoschwagerina craticulifera* (SCHWAGER).
b *Sumatrina annae* (VOLTZ).
c *Pseudofusulina douvillei* (COLANI).
× 10.