4. Contributions to the Geology and Morphology of Siam.

By

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(Plate I.)

Contents.

Introduction.

This journey in upper Siam, the geological results of which here are presented, was made principally for prospecting purposes, and therefore scientific research could only be prosecuted from time to time. But, as the regions I had to pass through were still but little known geologically, it was my intention from the beginning to try to make observations as far as possible from the scientific point of view too.

The journey into the interior of Siam was begun in the new year of 1912, and the return to Bangkok was accomplished in the May of the

same year. An account of the journey itself will be given in another paper; here it will suffice to refer to the maps attached. It may be mentioned that the total length of the journey, railway journeys excepted, was about 2,000 km., mainly through the northern parts of the country. Thus I crossed the patch — blank on almost all geological maps — representing the land between the Mekong with the French occupations in the east and the drainage area of the Saluen with the British colonies in the west. The Malay peninsula, partially Siamese, is better known, and is, as far as I know, the chief district surveyed by Departement of Mines of Bangkok, as it is nowadays the only mining district of the country.

It is hardly necessary to explain that from such a journey as mine no complete geological maps can result, nor even good summaries with positive general conclusions, as the country is larger than Great Britain, and practically no earlier geological researches have been undertaken. The few contributions to a geological map wich are the result of my journey thus are far from being sufficient. Moreover, my route was not selected in order to get as many geological data as possible, and it was passed over rather hastily. But as materials that may later be of use these observations may be considered worthy of publication. Besides, some comparisons with the surrounding tracts can be made. The igneous rocks, occupying a considerable area, and some of them of a certain interest, will also be briefly described, as well as some occurrences of minerals. With regard to the ore deposits, however, it may be admitted that neither time nor money permitted of any very close examinations being made. With regard to the tectonics dip and strike are almost the only contributions that can be obtained on such a journey, and they are given in the following pages. Finally some notes are added upon the morphological features of the country and their history.

Every geologist, who has travalled in similar wet tropical regions knows how seldom solid rock is exposed, a circumstance always resulting in difficulties, but especially when great areas are rapidly crossed. Therefore, often only loose boulders can be studied in order to get an idea of the geology. In such cases I have naturally paid attention to such boulders only as can not have been transported from any distance, e. g. by means of rivers, down mountain slopes etc. As will be shown in the following pages it is especially in the case of the often quite local igneous rocks that I have had only loose boulders to refer to, thus the nature of their mode of occurrence will be more or less questionable. In reality the exposures of solid rock are so infrequent that they seldom afford any further information, and as the zones of contact do not resist erosion well, they could hardly ever be studied. However, I collected a great many samples of rocks and minerals, but as small in size as possible, for they had to be transported for months over rough tracks by the dozen carriers composing my caravan.

The dense vegetation is in every respect a severe obstacle and seldom permits of any prospect over the landscape. To this is to be added the haze which prevails especially in the dry season, and sometimes quite hides mountains only a few kilometers away.

During the whole journey only a few fossils were found, which was certainly due to their scarcity, the older formations, moreover, being strongly metamorphosed. The presence of fossil-bearing, easily recognized layers of identified age would have been most important for linking up the scanty observations. But as it was, the thickness of the formations and their limits could be only very vaguely estimated, but some indications were afforded by information that was available about the neighbouring French and British territories, which are better surveyed.

The existing maps of Siam are rather unsatisfactory, and the scale is only 1 : 2,000,000. The names on the last and most complete edition[1] are written in Siamese characters and therefore difficult to read, in certain regions the lack of exactnass and completeness is very obvious. A French edition[2] on the same scale is to some extent more complete and more clearly printed, but in some respects it is even worse, especially with reference to the topography.[3] As it was printed in Latin characters, I generally used the same, and it may therefore be referred to in connection with the following pages. The place-names, however, are generally in this paper written differently, as the French language is very little suited for rendering the pronounciation.

Abbreviations. In the following pages some abbreviations are used, in addition to those in general use. They are abbreviations of some Siamese words, one or other of which occurs in nearly every place-name:

B. = Ban, means village,
Ch. = Chieng, » town (in northern Siam only),
M. = Muang, » bigger village, town,
N. = Nam, » water, river etc.

Geological investigations along the authors route.

The Korat railway.

See map, fig. 1.

This railway from Bangkok, viâ Aythia, to Korat runs through an alluvial plain to Pak Preo, where the first outposts of the Don Pia Fai

[1] An official Siamese map, published in Bangkok 1911.

[2] Indo-Chine. Carte de la mission Pavie. Edition complétée par le Ct FRIQUEGNON en 1902. Paris 1909.

[3] It is more complete especially as regards the regions along the watershed between the Mekong and Menam systems. There has been a more or less clearly expressed desire to make this the western boundary of the French colonies. In these better surveyed districts the topography is exceptionally detailed and partly very exaggerated.

(and Don Pia Jen) range are met with. At this station are situated some stone quarries, where a greenish, sometimes brownish porphyrite is worked. Probably this igneous rock occurs as dykes. A short, microscopical description is as follows:

Porphyrite, Pak Preo. Dark greenish or brownish. Groundmass microgranitic with distinguishable felspar stripes. Euhedral phenocrysts of zonal plagioclases (andesine in the centre), often with enclosures of matrix. Other, chloritized phenocrysts occur more sparsely. Somewhat magnetite. —

From here the limestone mountains of Pra Bat are seen to the north, and at Genkoi one crosses the strike of their vertically upraised strata, running N.W.–S.E. or N.N.W.—S.S.E. Not until after Tap Quang has

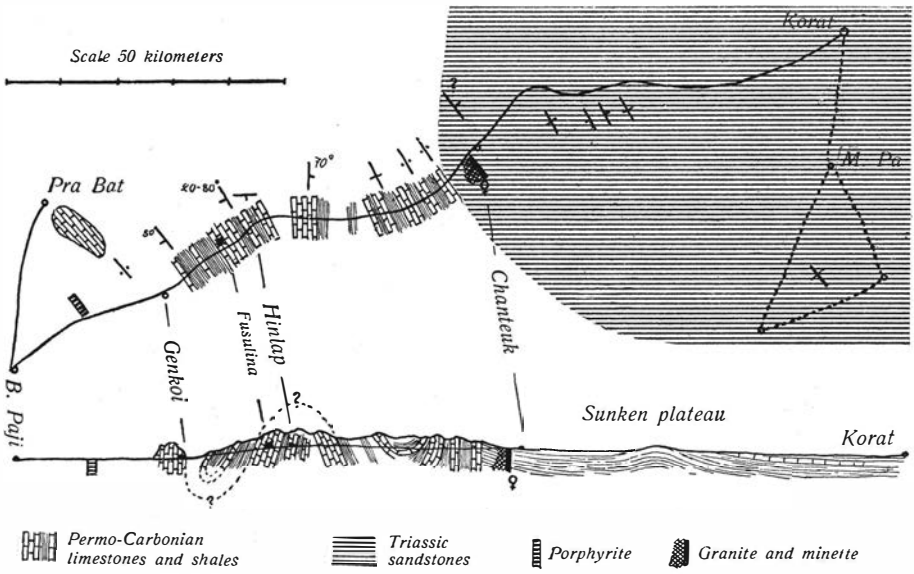

Fig 1. Map and section along the Korat railway.

been passed does the railway actually enter the mountains. In the cuttings upraised beds of marl and slates, intercalated by some limestone banks, are exposed. Towards Hinlap, where some quarries and limeworks are situated, the limestone predominates more and more. In one of the banks — a light-coloured, irregularly coarse-grained limestone, of a half-crystalline appearance — I found, on microscopical examination, Fusulinas together with fragments of Bryozoes and other fossils. This find is not without a certain importance, in a land so poor in fossils as Siam seems to be, and it shows that these mighty limestone series are homologous to those, known from other parts of Further India as being of Permo-Carbonian age.

The limestone is generally grayish and rather compact, and the pressure due to the strong folding has not affected it much, but the shales

and slates, that intercalate the limestone and sometimes attain considerable thickness, have been much more affected, and are often so sqeezed and cracked that the real stratification is obliterated. However, they may be considered to belong to the same Permo-Carbonian formation and are certainly of greater extension than the observations indicate, as they are more covered. At Hinlap a newly discovered valuable galena deposit is said to exist and it is understood that mining operations are being planned by a German company.

Towards Muok Lek similar limestone beds outcrop, showing the same dip as has predominated hitherto, viz. steeply to the W.S.W.—S.W. At this station they still occur, dipping in the opposite direction. Between Muok Lek and Pak Djong limestones and slates are passed, here almost vertically upraised. At a stretch are the slates predomining, the stratification is also locally nearly horizontal. Thereafter the Korat plateau is reached with its reddish sandstone series, containing shales of similar colour or showing more violet shades, as well as thin conglomerate and limestone beds, a formation, which may be said to be of Triassic age, according to investigations in the neighbouring colonies.[1]

These strata seem to be scarcely disturbed by tectonic movements compared to the limestone series, the last outposts of which were still strongly upraised. In some sandstone hills towards Chanteuk a gentle dip to E. appears to exist. Not far from here, however, some cuttings are passed where the layers show a quite horizontal position.

It is of no use to give a detailed report of the observations made along the whole route, and here, as many times in the following pages, it will suffice to refer to the sketch-maps and accompanying sections. It may, however, be mentioned that the strike is very irregular — apparently the N.N.W.—S.S.E. direction predominates — but sometimes the E.—W. and other directions appear (Hinlap). From Chanteuk I paid a visit to the abandoned copper mines, situated a few kilometers south of the station. Previously they had been worked by one or two Europeen companies, evidently without much success, and now they are entirely filled with débris and water. Therefore geological investigations were hardly to be made, especially as solid rock is not disclosed in the vicinity. But judging from the appearance of the soil, the red sandstones predominate, transversed by several quartz veins. Amongst the dumps at the shaft head, there were pieces of a granite and a decomposed, green minette.

1. Granite, Chanteuk. A reddish, medium-grained, ordinary granite, consisting chiefly of felspars (c:a 65 %), orthoclase and subordinated oligoclase; somewhat zonal quartz constitutes c:a 25 % oft he rock. The

[1] In DE LAUNAY, La Géologie et les richesses minérales de l'Asie, Paris 1911, a good summary on the geology of Further India is given, and here I refer to this work and its bibliography.

dark mineral is biotite, chloritized and epidote-changed. Big titanites and, here and there, magnetites occur.

2. Minette, Chanteuk. Fine-grained, decomposed. Chloritized biotites constitute c:a 50 % of the rock, the rest is composed chiefly of small felspars. Apatite rather abundant. Pyritegrains and secondary calcite occurs. —

Thus we seem to be in the presence of a contact deposit, though the ore certainly occurs chiefly in connection with the quartz veins. As these are not normal in such unmetamorphosed sandstones they may have a pegmatitic character or, they may in some other way be the result of eruptive intrusion. The ore itself was probably chiefly copper-pyrites and associated decomposed products; if mining ever penetrated the zone of cementation I do not know. It is said that there was a noticeable gold percentage.

Speaking of mines, it may be mentioned that the railway manager, Mr. Gross of Korat, had noticed a considerable magnetic influence near this mountain range, when constructing the railway line.

Proceeding towards Korat, only a monotonous succession of sandstones is passed and they are nearly horizontally layered. W. of Sikin a very gentle anticline is perceivable, running about N.—S. East of the same station a limestone bank, intercalated in the sandstones, is met with, appearing as a gentle ridge, which is due to the fact that it is more resistant. Here occurs a very solid, heavy, red, calcareous sandstone, suitable for building purposes, and a stone quarry has recently been opened in it. From that point to Korat no disturbance of the horizontal position is to be observed. The marked and abrupt contrast between the tectonics of the plateau and the mountain range bordering it to the west, is hardly to be explained unless by the assumption of a discordance between the Permo-Carbonian formation and the red sandstone series. The latter do not seem to have felt more than some slight folding movements. However, this unfortunately could not be definitely ascertained by the railway line, where the contact between the two formations was not visible.

Besides, such a discordance on the eastern border of the Korat plateau is indicated by the French investigations. In the northern parts of Further India, on the contrary, the state of things is different, and there the formations are less sharply differentiated and slightly folded together (Luang Prabang). As will be shown in a following section the northernmost corner of the Korat plateau is also entangled in the folding. In relation to the Don Pia Fai range the Korat plateau should then be a sunken area.

About the tectonics of the Don Pia Fai it ought to be briefly mentioned, that the strata, which are exclusively, or at least chiefly, of Permo-Carbonian age, are irregularly and lightly folded, the strike on the whole running about N.W.—S.E. or N.N.W.—S.S.E. The outcropping beds, poor in fossils and monotonous, hardly permit of any tectonic connection.

From Korat I undertook an excursion to the south for 60 kilometers over the plateau, passing M. Pa (Tong Tchai) and Sa Kerat and reaching B. Ta Pok (= B. Hia Kop?). Here the character of the landscape changes and becomes more hilly, table-mountains of a hundred meters or more in height, and built up entirely of sandstones, rise above the plain. The district round about, especially to the south, is still of the same type, as far as could be observed from these mountains. From these observations it can be concluded that the mountain range, which is generally indicated on the maps as bordering the plateau to the south («Pnom Dang-rek») has no real existence, being only a somewhat hilly landscape of a table character on the margin towards the lower plains in the south. The same is true of the country further east, where the maps are, however, more correct. Thus GARNIER,[1] when travelling to the south-west from Oubon, encountered the precipitous plateau margin. South of this line the same sandstones still occur, and it seems probable that a dislocation runs there in a W.—E. direction.

These sandstone series, which have a striking reddish colour, probably represent a Gondwana formation. There are sometimes subordinate limestone beds intercalated, and they get more frequent towards the north. According to investigations made in connection with some coal and lignite deposits in the French colonies and at Yunnan, Liassic layers can also be included in the series spoken of,[2] but the Korat plateau may be considered as Triassic. Not less characteristic than the colour is that the rock is salt-bearing. In the mountains are springs, the water of which often contains a very high percentage of salt, from which it may be concluded the existence of salt beds. On the plain the occurrence of efflorescences is common in the dry season, giving rise to a relatively important industry for the natives. In the rainy season the same areas are said to give good rice crops.

No coal beds are known to exist in the western part of the Korat plateau, though it is said that a 300 m. deep boring for water has been made (but without success). This fact will be of assistance in estimating of the minimum thickness of the formation. Other sections hardly occur on the plain, because the rivers have not cut down into the plateau, the fall of the river beds being too slight.

In Korat I noticed a remarkable gravel, used at some places in the town, which contains a lot of silicified wood-pieces. Such ones are not known to occur primary in the sandstone, and a preliminary examination, kindly made by Dr. TH. G. HALLE of Stockholm, showed that they were of Dicotelydones. One may therefore assume the presence of more or less

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[1] F. GARNIER, Voyage d'Exploration en Indo-Chine. Paris 1893.

[2] R. ZEILLER, Examen de la Flore fossile des conches charbon du Tong-king, Ann. d. Mines 1882 and Bull. Soc. Géol. 1882—83, 85—86.

local, younger deposits on the plateau, though they have not yet been observed *in situ*. Similar occurences most likely of Tertiary age I met with later on in northern Siam.

The northern railway.

Only a few observations were made from the train and at the stations along this line. From its junction with the Korat railway at Ban Paji to its present terminus, Me Puak north of Outaradit (distance to Bangkok 527 km.), the line passes chiefly over alluvial ground.

Between Lop Buri and the neighbourhood of Nakon Savan, where the railway runs about 20 km. further to the east than the French map shows, a lot of isolated hillocks and ridges rise above the plain. Thus one ridge about 200 m. high of upraised limestone beds is situated between N. Sai Kao and B. Me. A similar one is met with on the western side of the line at Chong Kae, where great quarries have been opened; and at Banta Klee. The limestones, still very folded, strike in a N.—S. or perhaps rather in a N.W.—S.E. direction — the direction cannot be exactly determined from the passing train. It seems as these limestone occurrences should mark a continuation of the Don Pia Fai range and the Pra Bat mountains, giving a connection (as will be later shown, see p. 103) with some mountains along the Me Ping, towards the great, more gently undulating Permo-Carbonian areas of the Shan states at the Burma border. East of the railway the ruffed contours of the mountain range disappear and give place to more level-topped mountains at the horizon. One gets the impression of table-mountains, and it seems possible that they represent the hilly edge of the Korat plateau, though the maps indicate great mountain ranges, just as at the Pnom Dang-rek at the southern border (see p. 71).

Just south of the station of Hooa Dong, on the western side of the line, quarries have been opened in some low hills, consisting of a grey, granular, igneous rock, which may be classified as a quartz-diorite.

3. Quartz-diorite, Hooa Dong. A rather fine grained, grayish rock, composed to the extent of about 60 % of labradoritic plagioclase, not perceivably zonal, and is very euhedral, often surrounded by a zone of granophyric intergrown quartz and plagioclase, the latter orientated in conformity with the big individual enclosed. Quartz amounts to about 25 % of the rock. Orthoclase is not definitely found. Uralite is the predominant dark mineral, attaining about 10 %; common green hornblende also occurs and, sparsely small biotites and magnetite grains. —

North of Outaradit the railway enters a more mountainous landscape. First limestones are passed, dipping 35° to W. At Ton Phung, where the most hilly part is encountered, cuttings have been made through different limestones, shales and shists, irregularly dipping to W. and S.W.,

at an angle of 45°—90°. In the near vicinity of the line may occur an plutonic rock, similar to that of Hooa Dong, used in some parts of the line for building the embankments. Such rocks as these, showing metamorphosed, strongly and irregularly folded layers of varying character, intermixed with a lot of igneous rocks of different ages, are typical of extensive districts here up-country, and may represent chiefly pre-Carbonian formations.

The regions east of Outaradit.

See map, fig. 2.

From Outaradit I travelled along rough tracks — amongst the worst I encountered in Siam — to M. Loye in the east, passing Nakontai and Dansai. From M. Loye I made several excursions in the neighbourhood and went on to Ch. Kan on the Mekong and from there to Tali. Crossing the southernmost corner of the Luang Prabang district (French territory) I came down to N. Pat and returned to Outaradit, once more passing N. Pi. The route is shown on the accompanying sketch-map (see fig. 2). It may be added that the topography, especially along my outward route, is much more hilly than the maps indicate, and offer considerable obstacles to travelling.

The track from Outaradit, after having left the alluvial plain, about halfway to N. Pi, crosses steep, upraised layers of metamorphic rocks, chloritic and sericitic shists, partly of doubtless igneous origin, partly consisting of still recognizable slates.

4. Chloritic shist, near N. Pi. A highly metamorphic shist, with the tuffogene and porphyritic character still recognizable. Much epidote occurs. —

The dip is steep towards N.W. but irregular, as the layers are strongly folded and wrinkled. Nodules and veins of quartz are frequent, and catch the eye, spread out as the pieces are over the weathered ground. Such quartz is characteristic for the soil of the metamorphic regions, and thus especially of the pre-Carbonian formations. It is known among the natives as »the stone like the ponies' teeth».

A few kilometers N.E. of the village N. Pi an old iron mine is situated, widely known in Siam, as it is said to produce the finest iron of the country. But now there is no longer any work carried on, and it seems that there never was mining on any large scale. As is general among the natives in this country, only loose pieces of ore are dug out of shallow pits. Such pits occur over a rather large area of the gently undulating ground, covered by dense bamboo jungle, that always constitutes a great obstacle to geological investigations. The pits are only a few meters deep and do not reach the underlying rock. As a curiosity it may be mentioned that the same thing happened to me as to WAR-

INGTON SMYTH,[1] who had previously visited this place: the natives refused to undertake any digging-work. Later on I was also often met by the same refusal. This seems generally to be due to the great superstition with which they regard all mining work. Nam Pi means «the water of the spirits», which may suggest an explanation.

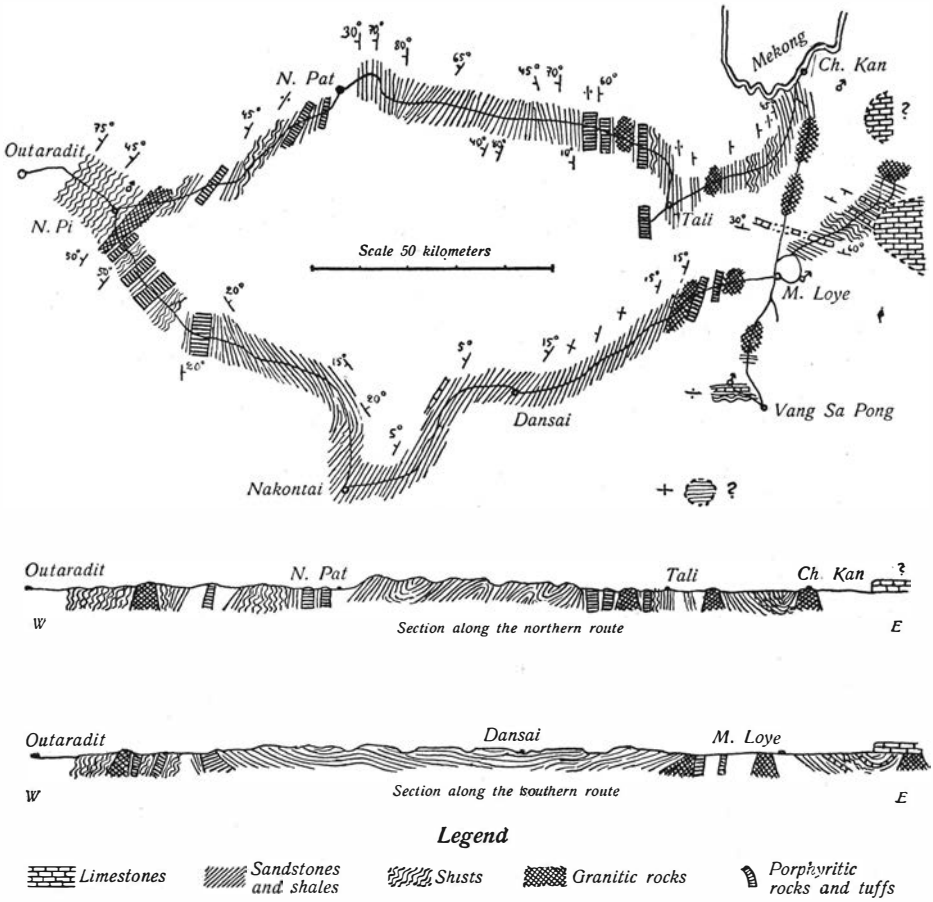

Fig. 2. Map and sections along the authors route east of Outaradit.

Returning to geology, the underlying rocks, to judge from loose stones and an exposure of solid rock close by, seem to consist of the same kind of metamorphic shists as have been mentioned above. No influence on the the mining compass was noted, and I could not secure anything but rusty, weathered ore, though heavy black ore was also said to occur.

[1] H. WARINGTON SMYTH, Notes of a journey on the upper Mekong. Royal Geogr. Soc. London 1895.

The analysis (SKS)[1] of a sample I brought gave:

Fe — 38,8 %, P — 0,024 %, S — 0,02 %.

The quality of the probably underlying ore can not be determined, but the low percentage of phosphorus may be noted. It does not seem that we have to do with any kind of laterite, for the pieces show distinct jointing and are of a much more solid constitution than is common by the ordinary laterites.

Ordinary laterites are very frequent in the neigbourhood of this place as well as in metamorphic regions in general, mostly appearing in the shape of blocks and crusts attaining up to one meter in thickness. In the following pages lateritic soil is not mentioned unless it is of especial interest. Many a laterite could perhaps be used as an iron ore but, as far as I know, they are not worked by the Siamese.

Between N. Pi and B. Sen Kan other similar shists were passed, also reddish shales and various sandstones, not unlike the Triassic of the Korat plateau, were met with. A body of a granitic rock, at least one kilometer thick, was intruded among the sediments and formed a marked ridge along the direction of strike, N.N.E.—S.S.W.

5. Quartz-diorite, E. of Nam Pi. A medium-grained, brownish rock. Euhedral andesines amount to about 50 %. Quartz (15 %) and orthoclase (10 %) appear as anhedral individuals and patches between the plagioclases. Common brown hornblende, often twinned, amounting to about 10 % (not decomposed as, e. g, the andesines are), and biotite (10 %) are the darke minerals, they are mostly surrounded by chloritic zones. The biotite is chloritized and contains epidote. Besides occur apatite, zircon and magnetite. —

Later on thick greenstone beds were crossed, the banks dipping to W.N.W.

6. Porphyritic rock, E. of Nam Pi. In an intersertal groundmass of plagioclases and chloritized minerals large, scattered oligoclase phenocrysts occur, and sparse, corroded quartz phenocrysts. Epidote and zoisite and small decomposed euhedral grains of titano-magnetite also occur. —

East of B. Sen Kan the probably Triassic formation is once more met with. The brick-coloured, sometimes quartzitic and hard sandstones form prominant ridges, where they outcrop from the more shaly layers. These sandy shales are of a violet or grayish colour and are very splintered, the influence of folding having had more effect on them than on the sandstones. The dip is varying between 45° and 60° to W.N.W.

Here occur some eruptive dykes, and also effusive tuffogene beds, intercalating the sandstones.

7. Porphyritic breccia, E. of B. Sen Kan. A somewhat tuffaceous agglomeration of fragments of porphyritic, felsitic and intersertal

[1] The analyses marked (SKS) are made at Statens kemiska station, Örebro.

rocks. Fragments or phenocrysts of felspars and quartz, the latter often crushed, and further calcedony, pyrite aud titano-magnetite.

8. Tuff, E. of B. Sen Kan. A black, compact tuffogene rock with splinters of glass. Pieces of fossil wood are enclosed, but their nature is not recognizable. Probably this tuff is embedded in the Triassic sandstones.

9. Porphyritic rock, E. of B. Sen Kan. This rock is of quite the same character as the green porphyritic rock near N. Pi (see 6).

10. Porphyritic rock, E. of B. Dong. A totally decomposed, red, porphyritic rock. —

On the next day's journey a hilly sandstone landscape was passed. The formation is exactly similar to the Triassic layers of the Korat plateau. Also some conglomerates and limestone beds occur, but all without fossils. The layers are not only characteristic for their colour, but here too they are saliferous. The stratification is not longer as undisturbed as on the Korat plateau itself, but over a wide area the very undulating folding does not exceed a dip of 20,° except at the western border, where the same layers, as already mentioned, seem to be subjected to a stronger folding. The strike is in general N.—S., the gentle dip varying in both directions. Already before reaching Nakontai a less disturbed plateau landscape is reached, the dips seldom attaining as much as 5°. Quite table-shaped mountains are sighted especially to the south.

Two days' journey, in a direction N.E. from Nakontai, sparse limestone boulders were found in some creeks, indicating the presence of a limestone bed, probably intercalating the continental deposits.

At B. Poh Klua («the village at the salt well»), one day's journey from Dansai, salt wells pour out at the bottom of a narrow valley in the sandstone mountains. At the dry season the percentage of salt attains to about 30 %. The wells are only dug down to a depth of a few meters, just in the river bed. I seems questionable whether real salt beds occur in this formation. The inhabitants of B. Poh Klua live chiefly on salt-boiling, and the finished commodity is sent by bullock caravans to considerable distances. It is said to be sold for c:a 1 sh 6^d per 100 kg., and is considered to be of good quality.

From other places up-country, too, such salt wells are known in the sandstone mountains, e. g. in the neighbouring locality of Luang Prabang (the capital of the French Laos states). The small occurrence of Triassic layers at Luang Prabang is known for the fossil vertebrates, found there, and on account of a section having been described by COUNILLON.[1]

East of Dansai the landscape keeps the same character for another day's journey, viz. more or less table-formed mountains, scarcely higher than about 500 m. The folding is still very slight only, and the dip seldom exceeds 15°, generally running to N.W. One and a half day's journey

[1] COUNILLON: Documents pour servir à l'étude géol. des env. de Louang Prabang. Compt. rend. 1896, II.

before reaching M. Loye I arrived at the foot of the mountains. Thereafter only isolated hills rose above the plain. The conical shape of these hills is rather striking (see fig. 3). Such conically shaped hills are frequent in Siam,[1] but I believe especially so in the neighbourhood of M. Loye and Ch. Kan. From here the geology changes, the flat sandstone beds disappear and give place to more varied country with folded, partially metamorphic layers, intruded by several igneous rocks. At the contact of some burnt sandstone and shale beds at the hill-foot appear granitic and porphyritic rocks banked conformingly to the overlying sediments, and dipping 15° to N.W.

11. Quartz-diorite. S.W. of M. Loye. A medium-grained, gray granitic rock, containing 65 % of andesines as euhedral individuals, em-

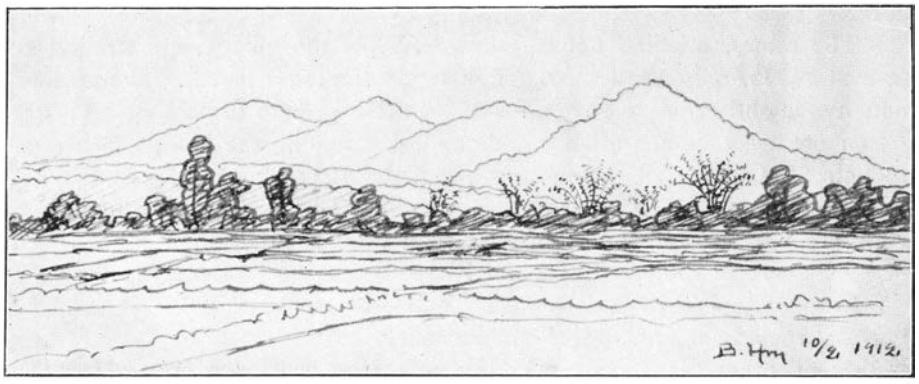

Fig. 3. Conical hills on the M. Loye plain.

bedded among smaller quartz grains (15 %). Orthoclase seems to be absent. Uralitic hornblende is the chief dark mineral (15 %) together with some chloritized and epidote-changed biotites. Magnetite occurs sparsely.

12. Porphyritic rock, S.W. of M. Loye. A strongly decomposed rock, with scarcely recognizable felspar phenocrysts in a felsitic matrix. Irregular agglomerations of magnetic powder.

13. Porphyritic rock, the same locality. Also very decomposed, the groundmass micro-granitic, phenocrysts of kaolinized felspars and chloritized biotites. Accumulations of magnetitic powder in the mica, as well as in the felspars. —

On the way to M. Loye I did not pass solid rock any more, but the boulders in the creeks showed very varied geological features, thus for instance, besides a grano-diorite of the same kind as the last described, porphyrites, different shists and sandstones were observed.

[1] In J. WATSON, Building Stones, Cambridge 1911, are mentioned some conical hills at Petchaburi (S.W. of Bangkok) consisted of trachytic lavas

From M. Loye several excursions in the neighbourhood were undertaken, first Uang Sa Pong, 26 km. to the south, was visited, in order to inspect an iron deposit, known to the natives. On the way to that place solid rock was seldom visible, and even boulders were scarce, but a great many of different rocks were represented among them, such as sandstones, iron-clay-stone, shists, greenstones and a granitic rock, the latter occurring over a couple of hillocks.

14. Grano-diorite S. of M. Loye. A medium-grained, gray granitic rock with euhedral plagioclases (45 %), ophitically intergrown in patches of orthoclase (25 %), mostly perthite-changed The zonal plagioclase is of an andesine character in the centre. Lightly pressed quartz (15 %) appears in small, anhedral individuals. Common green hornblende and some chloritized biotites. Big titanites, zircon and a little magnetite occur. —

The mines, situated about 5 km. N.W. of the village, are similar to these at N. Pi, only shallow diggings to get the loose pieces. The ground undulates slightly and is covered with a dense growth of bamboo. Pieces of iron ore were comparatively common here among the loose weathering products, but still not amounting to more than about 5 %, and they seldom exceeded a few kilograms in weight. The natives said, however, that there also existed lumps heavier than they could lift.

An average analysis (SKS and Z):[1]

Fe — 68,5 — 69,5 %, P — 0,042 %, S — 0,006 %,

thus the rock is a hematite of good quality.

From other places towards Makeng in the east, iron ores were also reported.

The natives collect pieces for melting, which is done in small furnaces, about half a meter in height, at the village, which is the centre of a considerable smithing industry. But nowadays mining has nearly ceased here too, and they use English iron, which can be bought almost everywhere in the country from Chinese traders.

The ore being a hematite, hardly any compass influence was appreciable, and no estimates of quantities can be given. Among the loose stones, occurring together with the ore, were noticed several kinds of sandstones and quartzites, shists (often micaceous) iron-clay-stones and limestones, which may serve to give an idea of the geology. About 1 km. from the mine the next solid rock was observed, a white half-crystalline limestone, vertically upraised and striking E.—W. Here, as well as at N. Pi, the deposit seems to be enclosed in folded and metamorphic pre-Carbonian series, and though igneous rocks occur in the vicinity, the ore is not closely connected with them as any direct product of differentiation, but is more probably to be considered as a metasomatic or contact deposit.

[1] The analyses marked (SKS) are made at Statens kemiska station, Örebro, those marked (Z) are analysed by Amanuens N. von Zweigbergk, Upsala.

The strike observed, running E.—W., does not noticeably diverge from the folding axes observed in the sandstone district in the west.

Far off to S.S.W. one can from here distinguish an isolated mountain of typical table-form, recalling on the above described sandstone mountains, and certainly belonging to the discordant overlying strata, probably it is a remnant of the sandstone districts in the west — or perhaps of the proper Korat plateau. It would have been of interest to know if such was the case, and if the sandstone could be proved to rest directly on pre-Carbonian strata. A discordance between the Permo-Carbonian and Triassic would then be shown in these regions too, because the folded pre Carbonian of the north-west part of the M. Loye plain is directly overlayered by undisturbed Permo-Carbonian limestone beds, as will be shown below. Here in the south and west on the contrary, it seems as if the Triassic rested directly on the folded substratum. If the flat-lying sandstone districts in the west are subsided in relation to the M. Loye plain, with its older formations, one can hardly imagine that the mighty, possibly underlying limestone beds should quite escape observation; somewhere it ought to be observed outcropping. About such a pre-Triassic discordance, it may be mentioned that it is reported to be absent further to the north at Luang Prabang, but there the facies of the Triassic is different. At Uang Sa Pong the natives spoke of limestone hills in the neighbourhood, but the age is dubious as considerable limestone beds also occur in the pre-Carbonian series. One can generally rely on statements about limestones, made by the natives, as they need the lime by the betel-chewing, and also as there often are caves in the limestone mountains, containing deposits, from which is extracted the saltpetre they use for making gun-powder. Later on I got an opportunity of visiting such a limestone cave.

When back in M. Loye, I started for the small hill-village of B. Hoei Tat, situated about 40 km. to the north-east. The track runs over different sandstones, quartzites and shales, dipping steeply to N.E. Two times limestone beds, less than 100 m. in thickness, were crossed and, the second time the dip was in the opposite direction, to S.W., thus marking an anticline. Metamorphosis was hardly perceivable here, and at some places I observed small carbon fragments in the sandstone, apparently burned wood. At one place in the limestone also there were, at the weathered surface, some traces of fossils distinguishable, looking like Gastropodes or Goniatites.

Close by, to the east, a thick limestone series is building up a mountain massive of probably 6—800 m. height above the surrounding landscape. These mountains are of the characteristic shape of the Permo-Carbonian, mighty limestone formations, with rather vertical steeps and ragged tops (see fig. 4). No fossils could be found, and probably the beds are of reef character, being thick and homogeneous, without distinguishable stratification, though the sections are the best possible. These mountains seem to continue far towards the east. Compared with the folded, under-

lying strata these limestones must lie upon them discordantly; if not, one would very likely be right in ascribing the underlying sandstones to the same formation, as these sandstones and shales are less destroyed than generally the pre-Carbonian series.

One of the conical tops of a mountain complex, N.E. of the village of B. Hoei Tat, was ascended in order to visit a mineral deposit, much spoken of among the natives. Just at the top, chiefly in the weathering products there have been made two diggings, some meters deep. One of the walls is a solid rock of rusty, coarse-crystalline quartz. Originally

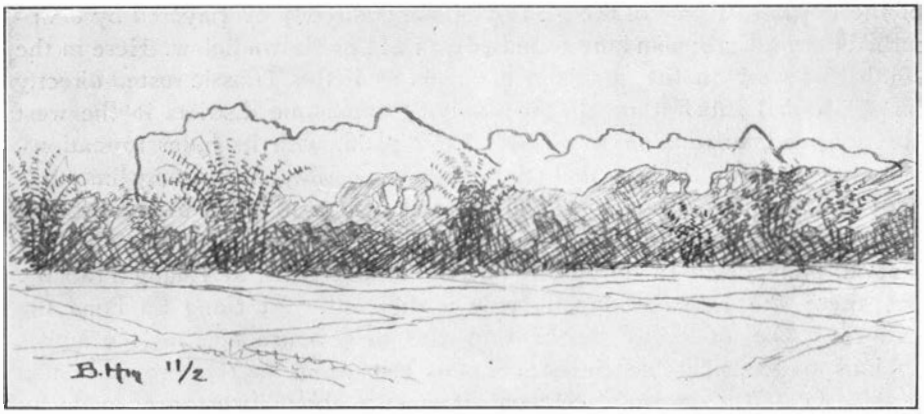

Fig. 4. The limestone massive north-east of M. Loye.

the deposit may have formed a vein, at least one meter thick. The mineral now remaining is an earthy, white, or sometimes a variegated greenish and reddish substance. The analysis (SKS) gives:

$$Fe_2O_3 - 34{,}5\ \%,\ As_2O_5 - 47{,}5\ \%,\ H_2O - 16{,}2\ \%.$$

It seems to be a ferri-arsenate (pharmaco-siderite?) still containing a little arsenic-pyrite. Traces of Ni and Co are found but not of gold, the latter, however, hardly being likely to occur in the very surface material of decomposed ore. The natives melt the ore in small furnaces, sunk in the ground. They fire with charcoal and as blasts they use a sort of bamboo air-pump, of the same kind as they employ in iron melting and forging. They knew about the poisonous character of the smoke, and considered the digging work very dangerous. They told me that even the vegetation could not thrive in the near vicinity of the mine, but I found it to be rather dense. Here too, of course, a great many superstitions were associated with the mining work, which is also considered to be very dangerous. Now work had ceased as they could no longer get any buyers for the ore. They did not themselves know of any other use for the metal than casting bullets.

Formerly people from the south had bought it, for what purpose I could not ascertain, but perhaps for making Budda-images. Their alloys sometimes contained arsenic. A typical alloy from this place was analysed.(Z) and gave:

$$Cu - 93\ \%, \qquad As - 7\ \%.$$

Not far from the mine in question sandstone is abundant, but the adjacent boulders are of a quartz-diorite.

15. Quartz-diorite, B. Hoei Tat. A somewhat fine-grained, gray, unpressed rock, consisting of about 60 % zonal plagioclases (in the centre of labradorite character). Orthoclase (15 %) occurs in anhedral patches, intersected by the euhedral plagioclases. Quartz comprises about 20 %. The dark minerals are represented by green hornblendes, mostly twins, in the centre often granophyric intergrown with augite. A little biotite also appears showing reddish brown pleochroism. Magnetite occurs sparsely. —

In a more basic form the plagioclases are still more predominant, and the dark mineral here is chiefly an undecomposed, light reddish, short prismatic augite.

As a matter of interest it may be mentioned that veins with gold-bearing arsenic-pyrite in connection just with similar igneous rocks are known from California.[1]

At the foot of the hill, sandstones containing shale and limestone beds were noticed. Here a kind of laterite with small hematite layers occurs, which was collected and melted for making bullets. Its composition is (SKS):

$$Fe - 42\ \%, \quad Mn - 15{,}7\ \%.$$

As an iron ore it cannot be of any value, owing to the small quantities in which it occurs. But the desposit can be noted as being of a certain interest in showing a kind of manganese-laterite. The manganese ores of the same nature, worked in India, contain about the double percentage of Mn.

Not far from the village to the S.W. was once a copper mine, but it could not be located. Near the same place the natives collected another laterite containing a rather high percentage of iron, 53,2 % (SKS), and of a more compact appearance than the usual sort. Here and there it also contains seams of a glistening hematite.

The district of M. Loye seems to be rather rich in minerals, certainly thanks to the varied, metamorphic ground, richly intruded by igneous rocks. The natives also kept their mines less secret than was generally the case. A lot of deposits I should have liked to visit and perhaps examine more closely, but I had already stayed for a week in this place, and was running short of provisions, which were scarcely obtainable, as there had

[1] W. LINDGRÉN: The auriferous veins of Meadow Lake, California. Amer. Journ. 1893 XLVI, 201.

been three years of dearth and nearly a famine. Thus I could only spend two days more in visiting some of the gold-washing places, of which there are many along the river Nam Loye and its tributaries. Some years ago work was said to be in progress at 19 different places.

Before describing the gold-gravels, I may mention some ore deposits reported from the district. Thus one copper mine, now abandoned, is situated a few km. south of the town. Judging from descriptions it may have been a cuprite ore. Lead, silver, tin and iron also occur in the vicinity. There were a number of iron mines; one of them situated about 3 km. S.E. of the town, I visited. On a small hillock on the plain loose pieces were picked up. The ore is a hematite of a good quality (SKS):

$$Fe — 67.5\ \%,\ P — 0{,}011\ \%,\ S — 0{,}019\ \%.$$

Among the places yielding gold some small creeks in the mountains are rumoured to be the best. Two such places I had passed when going to B. Hoei Tat, and found that they were only small patches of recent gravel. Work is only carried on here in the wet season, as water is lacking in the dry season.

In N. Loye itself it is more or less cemented conglomerates and shales that afford the real gold-bearing material. This washed out a second time by the river gives a thin, superficial, sandy layer, of course especially rich, and the washing is often confined to just such layers.

As the gold-bearing formation is not very strongly cemented and has a quite horizontal position, it must be rather young, probably Tertiary. In two places I found pieces of silicified wood among the pebbles in the conglomerate, and Dr. TH. HALLE recognized one of them as a Dicotyledone — the other fragment was a Conifere and thus of less value for determining the age. However, they do not fix the upwards age of the conglomerate, where they must be secondarily embedded. Where they originate from, can not be made out as long as no younger formations than Triassic are known in this region.

At B. Kan Pla, north of M. Loye, and B. Na Or further down the river, such conglomerates appear in a series of lenticular sections, cut through by the river, and it seems as if they represented old river beds. In the present river such big pebbles do not occur as in this conglomerate, the current being too gentle. Among the bigger pebbles especially, mostly rusty quartz, chert, greenstones a. o., the sand contains small grains and flakes of gold, which by washing can be separated together with pyrite and magnetite. As the gold is chiefly confined to a few, thin layers, and the gold-bearing areas are perhaps not very great, these deposits hardly can be ascribed any value for working on a large scale. As to the washing, the people seem to understand it very well. They use ½ m. wide, wooden wash-pans, about 5 cm. deep, or a litte more, almost conical in shape, and they handle them skilfully. At first the material is roughly

washed in a basket over the pan, in order to keep out the bigger pebbles. Now work has almost ceased, since three men were «punished to death», as they said, by a land-slide occurring in the river bank a few years ago. And as they think more of the «pis» or spirits than of money they stopped at once. However, according to their statements, the washing must have been a comparatively profitable industry. This fact certainly, as already mentioned, depends upon their choising the small, good layers only, especially the upper parts of the conglomerates, washed out once more by the river. Grains as big as rice corns were said to be not uncommon.

The primary deposit of the gold is not known, but the district is very rich in quartz veins, and there seems also to be a lot of sulfide ore deposits, probably connected with the intruded magmas.

At B. Ho Deng, south of M. Loye, a bluish clay-slate was auriferous. These beds were also horizontally layered, and obviously young.

Scarcely anything was to be seen of the rocks on the plains around M. Loye, and also on the way to Ch. Kan in the north the observations were scarce.

East of B. Na Or, some limestone rocks are exposed in the river bed e. g. at the gold-washing place, and may form a connection between the pre-Carbonian limestone beds, met with when going to B. Hoei Tat, and a limestone hill one or two km. W.S.W. of B. Na Or. The latter, a steep crag, rising about 200 m. above the plain, is of interest for its caves, of which there are at least seven in the vertical face. From these caves the natives get saltpetre for making gun-powder.

As to the limestone it may be said that its age could not be determined, as I found no fossils, but judging from the E.—W.-strike it is probable that it represents one of the pre-Carbonian beds. The dip seems to be about 30° to N. It is also not probable a simple hill only should indicate an outcrop of the mighty Permo-Carbonian formation.

I visited one of the caves, which was one of those reckoned holy and decorated with Budda-images, as they often are. But as it was ramified and inaccessible, a close examination of it was difficult by the feeble light of our torches. The floor was covered with a yellowish, spongy substance, originally of about one meter in thickness, but now mostly carried off for saltpetre-boiling. According to the statements of the natives, the best material was to be collected higher up on the walls, but I was not able to verify this.

A sample was analysed (SKS) and gave:

$$P_2O_5 — 14{,}9\ \%,\ N_2O_5 + NH_3 — 0{,}34\ \%.$$

Thus it is rich in phosphate, and very probable the limestone itself has metasomatically passed over into this material near the surface. No bones or other recognizable fossils at all could be found. Guano seems

to be the origin of this deposit, though nowadays there are no birds living in such caves in this country.[1]

Going north from B. Na Or, I only passed over comparatively flat ground, according to some observations of solid rock and the great boulders scattered over it, constituted by a granitic rock.

16. Granite M. Loye—Ch. Kan. A medium-grained, reddish granite, of a more ordinary type. Quartz makes about 40 %; orthoclase, partially perthitic, 45 %, is often granophyric intergrown with the quartz. Oligoclase 5 %, biotite and somewhat magnetite. —

The granite is horizontally banked and younger than the surrounding upraised formations.

Towards Ch. Kan sandstones, striking N.N.E.—S.S.W., are passed.

The district round Ch. Kan seems to be not less rich in minerals than that of M. Loye, the geology also being similar. In S.E. is said to be «a whole mountain of iron ore». The same statement is also made by WARINGTON SMYTH, who passed the town when going down the Mekong. From a place, two days down-river, I got a sample of hematite, and from about the same place another sample of specular iron, noticeable for the fact that its streak was black and not red. The mineral is an aggregate of thin flakes, which are very brittle. The analysis (SKS) gave:

$$Fe — 48{,}1\ \%,\ Mn — 6{,}16\ \%.$$

From different localities on both sides of the river galena was reported, but in the samples I got, the percentage of silver was very slight. One sample gave (SKS):

Pb — 86,14 %, Ag — 0,017 %, another sample gave (SKS): Ag — 0,02 %.

I got also a piece of a fahlertz containing mainly sulfides of lead, arsenic and 0,053 % of silver (SKS).

Along the Mekong gold-washing was carried on, but the gold had to be extracted by mercury.

On the way to Tali in S.E. I crossed upraised sandstones and various slates and shists. The strike is chiefly N.—S., the dip varying, sometimes almost vertical. In these younger igneous rocks are intruded.

17. Quartz-diorite N.E. of Tali. A medium-grained, somewhat reddish granitic rock, with 40 % of rather basic, euhedral, zonal plagioclases (andesine in the centre). Smaller, anhedral individuals of orthoclase (20 %) and quartz (25 %) between the plagioclases. Biotite (10 %) and a few twins of hornblende, both partly chloritized. A little magnetite. —

S.W. of the village a washing-place for gold was visited. Not much was to be seen at the place — a small, grown-over creek, where work is

[1] My friend Count N. GYLDENSTOLPE has since called my attention to the fact that great colonies of bats often live in such caves in Siam. In Mc. CARTHY (loc. cit. see p. 94) I also found a note, confirming such a suggestion, he sais (p. 12) about a cave on the Malay peninsula thas it was «full of bats, from the dung of which salpetre was collected.»

no longer in progress. The recent gravels contain mainly quartz and greenstones. Just above the washing-place thick beds of a greenstone are cropping out.

18. Porphyrite, Tali. An intersertal groundmass, chiefly consisted of plagioclases. Oligoclase and augite phenocrysts, the latter partly uralite-changed. Epidote and calcite. —

Mines, or properly speaking fairly unknown ore deposits, were reported from this district. I got a sample of a galena, poor in silver (SKS):

Pb — 43,8 %, Ag — 0,009 %.

For want of time I had to take a cross-road from here to N. Pat and Outaradit, passing the southernmost corner of the Luang Prabang governement (French territory), a mountainous and rough region, thinly populated.

First perpendicular sandstone beds, striking N.—S. were crossed. The gently undulating landscape, which succeeds, is, however, of another character, constituted of more or less pressed sediments, especially sandstones with varying dip, strike about N.—S., but chiefly igneous rocks, evidently forming banks and dykes of considerable thickness. Of these, comprising granitic rocks, porphyries, porphyrites, tuffs and tuff-breccias, some specimens may be described.

19. Quartz-diorite, Tali—B. Na Hin. Reddish gray, medium-grained. Euhedral andesines 45 %, bigger anhedral orthoclase patches 20 %, quartz 25 %. Biotite and hornblende as dark minerals. Big titanites, epidote, calcite.

20. Porphyrite, Tali—B. Na Hin. Chloritized groundmass with various sized andesine phenocrysts. The latter have enclosures of matrix and show jagged outlines and growth phenomena.

21. Porphyritic rock (the same locality). A somewhat flowed agglomeration of porphyritic fragments, mostly felsitic and with decomposed plagioclases and hornblendes.

22. Porphyritic or tuffogene rock (the same locality). Of almost the same character as the above, but perhaps more tuffaceous. It contains also quartz fragments and some pyrite.

23. Tuff, Tali—B. Na Hin. A compact, black rock, microscopically showing quartz and felspar fragments and a few bigger felspars of a more phenocryst-like appearance. —

A silver mine, probably galena, was reported from this tract, and if more thickly populated very probable a number of deposits would be known, abundant as the eruptive intrusions are here.

One day's journey west of B. Na Hin the character of the ground changes and the Triassic sandstone series appear. They continue for the whole way to N. Pat, situated on Siamese territory on the Menam plain. The sandstones and shales are quite similar to these passed on the way east-ward, 60—80 km. further to the south. Though this distance is no

greater, a rather striking difference in the tectonics is noted. Here the nearly horizontal stratification is replaced by disturbed rocks, generally with the dip very steep, and the strike somewhere about N.—S. Sometimes the outcropping sandstone banks form sharp ridges. The dip of the layers over this broad district, as far as I could observe, was only to the west; and as the thickness of the formation cannot be so great, this must indicate overturned foldings. However, the rock has undergone no perceivable metamorphosis. It seems as if this sandstone landscape is to be regarded as the northernmost corner of the Korat plateau, which has been seized by the folding movements. This is an indication that we must not reckon the tectonics as a criterion of the formations in upper Siam, especially with regard to the distinguishing of the Triassic series from other reddish sandstone formations. And thus when making geological investigations in these regions further difficulties are added to the lack of fossils.

At N. Pat some mineral deposits were mentioned, but the statements seem to be more than usually exaggerated. One or two day's journey from the place a great copper deposit was known, and at another place a silver ore. According to the report the copper occurred native in quartz(?), covering an area «one day's journey in circumference». In connection with the ore a green mineral (malachite) was said to occur. These occurrences were kept secret, and it was also considered very dangerous to have anything to do with the silver mine. It was not allowed to collect with the hands the pieces of ore, that were scattered over the hill-slopes. One had therefore to pick them up and carry them home by means of split bamboo-sticks. «If not, one could not find the way home.»

In some creeks not far from the village, gold had been washed previously, but now work has ceased, since the the «pis punished to death a whole village of 300 souls».

Between N. Pat and N. Pi solid rock is only seldom to be seen, the road chiefly passing over the flat land along the river. Sandstones and metamorphic shists obviously predominate, and they are vertically upraised or dip irregularly to N.W. and are intercalated with pressed chloritic shists, some of them recognizable as tuffs and effusive igneous rocks. Eruptive dykes, however, are also met with, which are less altered.

24. Porphyry, N. Pat—N. Pi. Groundmass felsitic, big phenocrysts of broken, lightly pressed quartz and troubled oligoclases (somewhat zonal); magnetite.

25. Porphyritic breccia, N. Pat—N. Pi. A conglomerate-like agglomeration of rounded fragments of porphyrites and syenite-porphyries, some with micro-granophyric texture, as well as quartzites, in a somewhat fluidal matrix. —

The ground is extremely rich in quartz, spread out in loose pieces over the soil. Half a day's journey before reaching N. Pi the way goes over granitic soil, obviously forming a continuation of the quartz-diorite ridge spoken of in the account of the start of the journey eastwards from

N. Pi. Thereafter the rocks get still more chloritic and micaceous. The geology beyond N. Pi has already been described in the account of the outward journey.

M. Pre—Ch. Kong—Ch. Mai—Paknam Po.

See maps, fig. 5 and 8.

From Me Puak, the present terminus of the northern railway, the road past M. Pre passes over flat country to B. Rong Kuang, where the mountains begin. From here I started for M. Nan, taking a roundabout way viâ Merem (Me Song) in the north-west, and joined the M. Nan way at B. Natan.

Leaving B. Rong Kuang I first passed limestones, dipping 45° to the N.E., thereafter shales and slates, metamorfic sedimentary and igneous rocks, mica-, chlorite- and sericite-shists, rich in quartz segregations, as well as younger porphyritic rocks.

26. Porphyry, B. Rong Kuang—Merem. A gray-green kaolinic rock with felsitic groundmass, containing a few oligoclase phenocrysts and fragments of quartz.

27. Porphyry, B. Rong Kuang—Merem, a red, felsitic, somewhat pressed rock. Groundmass felsitic or crypto-poikilitic, obviously rich in quartz and with litophyse-like segregations. At the borders of these, euhedral, small albites can be seen. Scattered big perthitic phenocrysts occur. A little magnetite. —

When going down from Merem to the M. Nan road, I crossed a region of similar character again, viz. igneous rocks, metamorphic layers and a rather mighty limestone series. The tectonics are very irregular, the strike on the whole is N.N.W.—S.S.E., the dip mostly steep, as is shown on the sketch-map, where the observations are indicated more in detail (see map, fig. 5).

As no fossils were found in the limestones, their age could not be fixed, and I cannot decide whether they belong to the Permo-Carbonian series or are older. As is indicated N.E. of Outaradit, the post-Triassic folding is rather strong, and intermixed with igneous rocks as the strata are here, their true nature is hardly recognizable.

Towards Vieng Sa chiefly sandstone ground is transversed, the layers are brick-coloured and contain reddish and violet shale banks, thus resembling the Triassic formation, as met with before, but still the age of these strata must be considered doubtful.

Here, as well as later on, numerous pressed, igneous rocks occur. Towards M. Nan the metamorphosis is more pronounced, the shists contain quartz segregations and are irregularly folded, with the strike on the whole running N.W.—S.E.

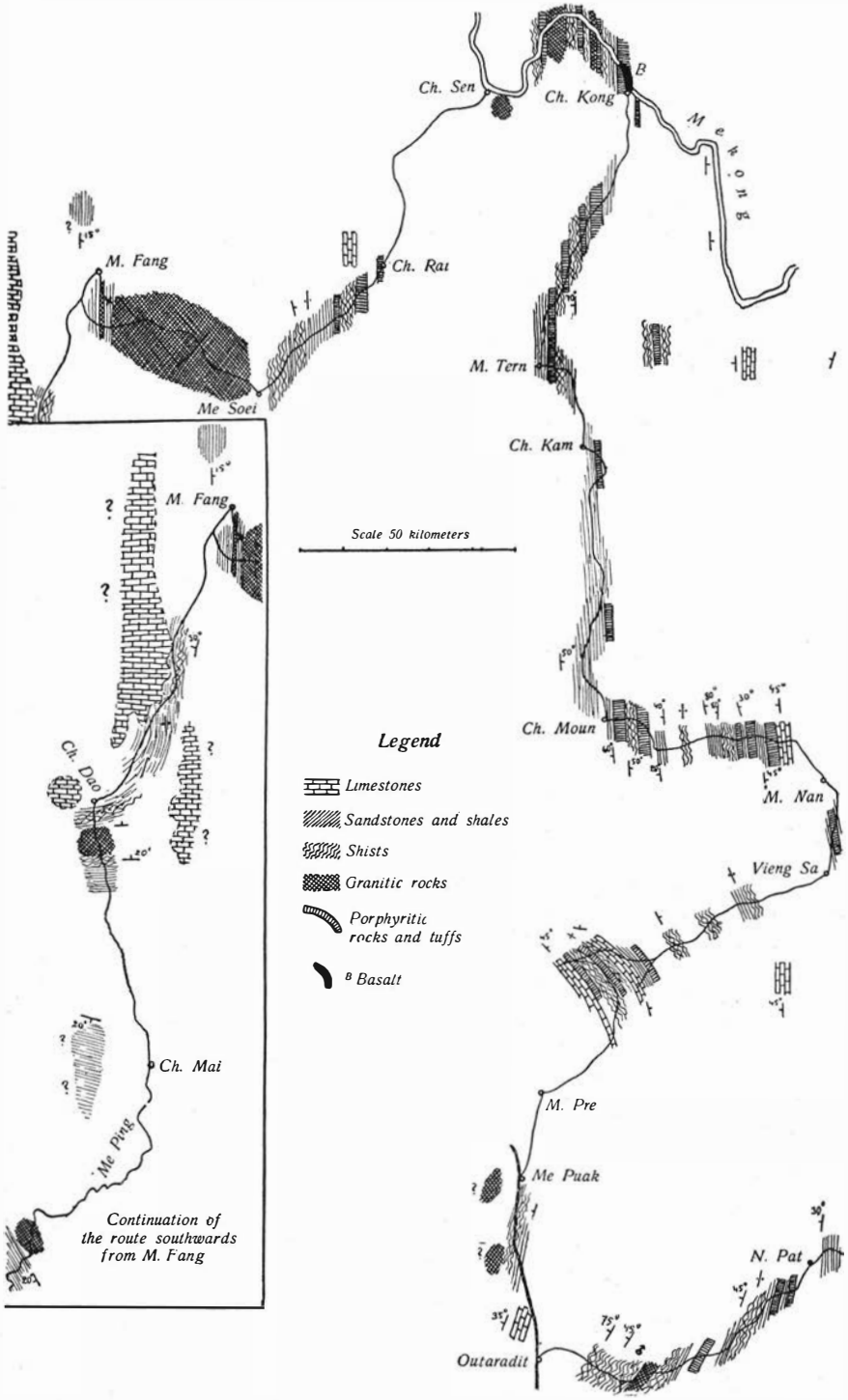

Fig. 5. Map of the authors route in northernmost Siam, Outaradit—Ch. Kong —Ch. Mai.

From M. Nan we passed over a rough track across the mountain range over to Ch. Moun in the west. Here the sediments are chiefly represented by sandstones, shales, and soft clay-slates; besides, one or two small limestone beds are intercalated. The layers are highly disturbed, with the dip varying and the strike N.—S. or N.W.—S.E. Eruptive dykes and beds of porphyries and porphyrites were repeatedly noted, some of them at least some hundred meters in thickness. They are of the same character microscopically as those described above, from the road between B. Rong Kuang and Merem (n:o 26 and 27). A great many of these igneous rocks are unpressed and are probably younger than the tectonic movements, but there are also a lot of them that are older, many of them destroyed past recognization by pressure. Towards M. Souat light yellowish, soft, clay-slates appear over a considerable area, and similar layers were also met with just W. of M. Nan. Their age is unknown to me, but their young appearance makes it very improbable that the series encountered here are all of pre-Carbonian age.

From here to Ch. Moun the red sandstones, with their shales, reappear, together with a number of intruded igneous rocks, some of them of the same character as those, described above (n:o 26 and 27).

28. Porphyritic rock, N.W. of M. Nan. Looks green, compact and fine-grained, microscopically recognizable as a decomposed porphyritic rock.

29. Porphyritic lava, N.W. of M. Nan. Red on account of iron infiltration. Vesicles filled with calcedony and epidote. In the fluidal matrix fragments of porphyritic rocks also occur with phenocrysts of corroded plagioclases.

30. Syenite-porphyry, near Ch. Kam. Dark red, with felsitic or partly crypto-poikilitic groundmass with trachytoidal felspar stripes. Bigger orthoclases as phenocrysts, they are strongly corroded and have enclosures of matrix. A few chloritized biotites. Epidote and calcite decompositions. —

The strike is now chiefly N.—S.; for particulars of the details observed reference may be made to the map (fig. 5).

Between Ch. Moun and Ch. Kam in the north, solid rock was seen only in a few places, and are then represented by red sandstones, dipping first 60° to W., and thereafter 50° in the opposite direction. Boulders of this material are predominant the whole way. In parts this rock, also, showed the influence of pressure, being a little metamorphosed, with quartz segregations. The way along the Me Ing passes over a plain, widening out to the west, where the hills were not visible on account of the haze; on the eastern side, however, the mountains, rather high ridges, are near at hand, and from here originate the igneous rocks, found as boulders in the creeks.

Continuing in a northerly direction, about the same geological features are still met with, though there is a little more variation. And towards Ch. Kong the geology is quite similar to that of the stretch

between M. Nan and Ch. Moun, and probably the same layers are continued here. There are shales and shists, pressed and unpressed, intrusive dykes and beds. Any closer examination of their mode of occurrence could not be made, as solid rock was still very rare along the track and the geology was at most only shown by the boulders in the creek-streams from the mountains close by in the east. The strike has about a N.—S. direction, and the dip, only noted at one place, was steep to W. Some of the igneous rocks, microscopically examined, may be described:

31. Syenite-porphyry, S. of M. Tern. A green, compact, decomposed rock, with trachytoidal, felspar-rich matrix. Big chloritized and epidote-changed, plagioclase phenocrysts. Dark minerals decomposed past recognization.

32. Tuffogene breccia, near M. Tern. A half fluidal agglomeration of felsitic and trachytoidal porphyritic fragments containing plagioclase phenocrysts and chloritized minerals.

33. Shistose, porphyritic rock, N. of M. Tern. Matrix showing a kataclase texture recalling a fluidal structure. Phenocrysts of plagioclases, mostly stretched into pieces, which, however, still keep there orientation. Kataclastic quartz. Much epidote.

34. Porphyry, N. of M. Tern. Grayish, with a secondary texture looking like a micrographic one. Big andesine phenocrysts often with enclosures of matrix. Secondary quartz aggregates, magnetite, epidote.

35. Syenite-porphyry, near Ch. Kong. Obviously the same as described above from S. of M. Tern (see 31). —

Opposite to Ch. Kong, on the other side of the Mekong, is situated B. Hoei Sai, reputed to be a locality rich in gems, the gravels at the river being sapphire-bearing. In the beginning even rubies were reported to have been found, but incorrectly. WARINGTON SMYTH, who visited the place when mining had been recently started (1893) and a lot of Burmese gem searchers had settled down here, prophesied a great future for the place. Now, however, hardly any work at all is carried on any longer, and it is said that no really good stones have ever been found here.

Most of the precious stones were got on the left bank of the river; on the Siamese side I was told, no washings had been made. Also up-stream, on some of the small tributaries on the French side, stones had been found. Just at Ch. Kong and for some kilometers up-stream some basalt rocks appear, and, as WARINGTON SMYTH has already mentioned, the sapphires do not occur further up-stream than these rocks. He believes, however, that some hills on the left bank are the source of all the stone-bearing gravels. These hills «consist of a dark crystalline rock, the exact mineralogical character of which has not yet been determined.» At the famous sapphire mines of Chantaboun in south-eastern Siam, the gem-bearing gravel is found on the surface of a trap-rock, worn out of this

by natural agencies.[1] At Ch. Kong, where the second basalt occurrence of Siam is known, the second sapphire deposit also is situated and it seems doubtless that here too the source of the stones was the basalt. This is so much the more probable as microscopical examination reveals in the basalt the black spinells which are considered by the Burmese to be an unmistakeable indication of sapphires. I have, however, not been able to lay hand upon the sapphires themselves in this rock. Really one would hardly expect to find sapphires in a basic rock like this, poor in felspars and aluminium minerals, but corundum is known elsewhere in basalt and considered as «Ur-Ausscheidung».[2]

36. Basalt, Ch. Kong. The black groundmass consists chiefly of a brownish glass, with small plagioclase stripes and pyroxenes, as well as olivines, partly iddingsite-changed and corroded. Several bigger apatites are also found. Macroscopically distinguishable fragments of obsidian, bigger olivines and millimeter-big black spinells occur, the two latter may be considered as «Ur-Ausscheidungen» as well as the probably existing but unseen sapphires. —

Sapphires are reported also from some other places in northern Siam, e. g. from Vieng Sa (south of M. Nan), but no proper workings were ever established there; «however», said the natives, «the last king said it was a good sapphire mountain».

From the district of Ch. Kong, also, some other mineral deposits are known. Thus I got samples of an iron ore from a place south of the town. The appearance of the pieces shows that the ore consists of flakes of specular iron, but it certainly only occurs in small quantities intermixed with rock. The analysis gave (SKS):

$$Fe — 68{,}6\ \%,\ TiO_2 — \text{c:a}\ 1{,}0\ \%.$$

I also got a piece of pure, melted tin containing 0,001 % of silver (SKS), produced at this place. In former days there is said to have been a mine, and they gave me a piece of what they considered to be the «ore». Though that was not tin ore, the metal may perhaps occur in contact rocks in the same locality. Microscopically examined the stone in question is an augite-minette.

37. Augit-minette, Ch. Kong. In an opaque grayish mass (composing about 50 % of the rock) occur euhedral biotites (35 %), small individuals of colourless augites and considerable quantities of apatite (10 %). Quartz occurs sparsely as exogene grains, but also as crystallized individuals. —

In Ch. Kong we procured dug-out canoes and poled up-stream to Ch. Sen, this journey now taking nearly three days at low water. On

[1] According to the contribution to a discussion of Mr LOUIS, see WARINGTON SMYTH loc. cit., appendix, p. 105.

[2] A. DANNEBERG: Studien an Einschlüssen in d. vulcanischen Gest. d. Siebengeb. Tschermak's Min. und Petr. Mitt. B. XIV p. 24. Wien 1895.

account of the difficulties presented by the strong current, landings were seldom made. Seen from the boat, nearly all the rocks, black and glistening, as they are, looked very much the same. In point of fact they represent a varying geology, on which some observations may be given.

In the near proximity to the town, by the landing-place itself, the basalt, described above, appears in small, isolated knolls of one or two hundred m. in diameter, with columnar jointing, often somewhat radially arranged. They seem to represent young volcanic necks, standing out from the surrounding pressed rocks. At one place an irregular, but more bed-formed basalt occurrence was noted. They occur up-stream along the river for a tenth of kilometers or more, probably marking a line of dislocation, running N.—S.

For the rest the ground is composed of sediments, strongly folded and generally showing irregular dip and secondary jointing, sometimes they are also rather metamorphic. There are sandstones, quartzites, shales and limestones, chlorite-, sericite-, and mica-shists, and, besides, recognizable igneous rocks of different ages, but most of them are seized by the folding and more or less metamorphic. The strike on the whole runs N.—S., sometimes with a tendency to N.W.—S.E.

It seems as if this cutting on the Mekong shows a more complete, and thus also a more complicated cross-section of the same series of rocks, as were passed west of M. Nan and once more on the approach to Ch. Kong from the south (compare p. 89 and 90).

With regard to the igneous rocks it may be noted, that some of them are obviously younger than the folding, while others are hardly recognizable because of kataclastic metamorphosis. Among the latter also granitic rocks approaching the andine type are found. Where such rocks are to be observed in other places in Siam, I have found them quite undisturbed so that they looked very young. They seem for the most part to be post-Triassic, and my impression is that they appeared because of the post-Triassic folding movements. If all these granitic rocks of the andine type are to be considered as being of the same epoch, the explanation of their kataclastic character here on the Mekong may be that the post-Triassic folding has been stronger here than is generally the case.

Some specimens of the igneous rocks may be described:

38. Hornblende-diorite, Mekong, $^1/_2$ day N. of Ch. Kong. A dark greenish, coarse-grained rock, very decomposed, plagioclases (50 %) and gray-brown hornblendes (40 %), smaller, chloritized biotites(?), apatite, magnetite.

39. Kataclastic granite, $^1/_2$ day N. of Ch. Kong. A rather coarse-grained, gray rock. Kataclastic quartz composes about 50 %, partly myrmekitic. Perthite-changed orthoclase (25 %). Plagioclase (albite?) sparse and euhedral, biotite and much muscovite, big, irregularly shaped turmalines.

40. Dioritic rock, 1 day N. of Ch. Kong. A fine-grained, green rock. Hornblende composes c:a 50 %, zoisitic, zonal plagioclases 30 %, quarz 10 %, pale biotites 10 %. A little apatite. This rock is perhaps a fine-grained, more basic type of that described above (see 38). Macroscopically and also microscopically it shows a striking similarity to an andine rock, described by QUENSEL as being probably an akerite.[1]

41. Porphyrite, 1 day N. of Ch. Kong. A micro-granitic groundmass, containing big, equidimensional, zonal plagioclases (in the centre andesine). Biotite and, sparsely, decomposed hornblende.

42. Porphyry, 1 day N. of Ch. Kong. A micro-granitic groundmass, containing big quartz and perthite phenocrysts. The quartz is generally primarily broken into pieces and also somewhat kataclastic.

43. Tuffogene breccia, 1 day N. of Ch. Kong. Decomposed and iron-infiltered. Contains fragmentary quartz and plagioclase individuals, and pieces of different felsitic and trachytoidal porphyritic rocks.

44. Porphyry, 1 day N. of Ch. Kong. An apparently quite compact, red rock. The groundmass is somewhat flowed, felsitic and partly crypto-poikilitic. Small quartz and plagioclase phenocrysts are found here and there.

45. Porphyry, 1 day N. of Ch. Kong. Micro-granitic groundmass, containing big, corroded quartz phenocrysts. Perthite and plagioclase also occur as phenocrysts, chlorite and epidote.

46. Rhyolitic porphyry, 1 day N. of Ch. Kong. Partly of a lava nature, with small quartz-filled vesicles, partly a felsitic, fluidal groundmass with big phenocrysts of quartz and perthite. Small andesines occur also.

47. Porphyrite, half-way between Ch. Kong and Ch. Sen. The groundmass, spotted felsitic, contains big andesine and chloritized biotite phenocrysts. The latter contain magnetite grains.

48. Katalastic, granitic rock, half-way to Ch. Sen. A coarse-grained, somewhat pressed rock, consisting of 45 % of euhedral andesines and big orthoclase patches, the latter, comprising about 25 %, are generally changed into perthite. Kataclastic quartz comprises 15 %. A somewhat andine character may thus be traced.

49. Kataclastic, granitic rock, half-way to Ch. Sen. Obviously the same as the former, only that it is much more pressed.

50. Tuffogene (?) rock, half-way to C. Sen. A fine-grained, quite decomposed rock, probably tuffogene, also showing porphyritic characters.

51. Porphyritic breccia, half-way to Ch. Sen. This rock consists of fragments of spotted felsitic rocks, with numerous, broken, corroded quartz phenocrysts. Troubled orthoclases and plagioclases, as well as a few, big biotites changed into chlorite and epidote also occur as phenocrysts. —

[1] P. D. QUENSEL: Geol.-petrogr. Studien in der Patagonischen Cordillera. Bull. of the Geol. Inst. of Uppsala. Vol. XI p. 89. Uppsala 1911.

The same geology continues towards Ch. Sen., but the exposures become less frequent, as the river is entering the plains of this district.

A few kilometers south of the old, ruined town of Ch. Sen, there are some hillocks on the plain. Here solid rock was observed at some places and was a typical greissen.

52. Greissen, Ch. Sen, consists of muscovite and quartz, the latter in ramified, oriented individuals, indicating a previous micro-granophyric texture, as is characteristic of e. g. the granitic rocks of the andine type, known in other places in Siam. —

That muscovite-bearing rocks must be abundant in these districts is also to be seen at the Mekong, where small streakes of washed-out muscovite appear at the water-line. In connection with the greissen occurrence mentioned there are traditions of mining said to have been carried on in old times. It seems very probable, too, that tin as well as other metals may once have been produced in these regions, inasmuch as hundreds or even thousands of Budda-images are scattered in the jungle in this ruined town, as well as at some other places in northernmost Siam. Many of these bronze statues are much more than of full size. Also from M. Fang in the south-west and from Wat Lung south of Ch. Kong the occurrence of Budda-images is reported.

Alluvial gold is also reported from this part of the Mekong, and I have seen rather big nuggets from there. At present no more work is carried on. In the river bed, especially towards Ch. Sen, half-cemented conglomerates, of the same appearance as those described from the M. Loye plain, are abundant, and they are possibly the gold-bearing beds.

Between Ch. Sen and Ch. Rai no geological observations were made, as the route passed over flat, covered ground only. Not far from my route are situated the hot springs of Me Ky (= B. Mechan), visited in 1891 by J. Mc. Carthy who writes:[1] «jets at boiling heat played from openings in the rock, in some cases to the height of 2 feet, and all round there was a din and hum as if from many small steam-engines. At one fountain there was a natural sulphur-spray.» Hot water not seldom rises from the ground in Siam, but on my journey I heard of such «hot sulphur wells» in these western parts of upper Siam only. Such a one is reported from Me Souei, S.W. of Ch. Rai; another, a big one, near M. Pa Pao on the way to Ch. Mai, and one from north-west of M. Fang etc. The natives say that wild cattle like these wells, which are thus considered to be good hunting-places. These hot wells and the small volcanic vents near Luang Prabang — also visited by Mc. Carthy (loc. cit) among others -- are the only verified signs of volcanic action in these regions. Though it does not seem very credible, a rumour current among the natives may be mentioned here. They say that some of the highest peaks on the watershed between the N. Lao, Me Kok and Me Ping, have a

[1] J. Mc. Carthy: Surveying and exploring in Siam. Royal Geogr. Soc. London 1900.

peculiar shape, just like extinct volcanoes, and that some of them also have lakes at the top. And there was also a high mountain where «high flames had been burning for three years».

From the district of Ch. Rai some ores, among others also native gold, were reported. For this, as well as for other informations of interest to me, I have Dr. BRIGGS, an American missionary, and Major THORWALDSSEN, the Danish gendarmerie officer, to thank. Ores of silver, lead, tin, antimony, iron, copper etc. are known, and gold is washed in some creeks in the neighbourhood. An old copper mine is situated in a limestone mountain some kilometers to the west; the ore consists of cuprite and malachite, and was worked out of solid rock. In the river bed of the Me Kok loose pieces of coal or lignite are found; the outcrop of the bed was found by a native, according to his own narrative, on the other side the Burmese border. The thickness was about 1 m., and the stratification was said to be undisturbed. A sample I got gave (SKS):

Hygroscopic moisture	11,3 %
Volatile (at dry-destillation)	34,6 »
Carbon	50,6 »
Ashes	3,5 »
	100,0 %

Close to the town there is a small hill some tens of meters in height, where the barracks are situated, which consists of a quite decomposed igneous rock, white and light reddish in colour, containing 5 % of kaolinite. When the rock is dried, traces of a porphyritic structure can be seen. A clay found at the foot of the hill, washed out from its steep slopes, is eaten by the natives. The clay is made into pellets and slightly roasted.

On the way from here to Me Soei, in the south, some observations on the geology were made. The first small hillocks passed were composed of a porphyritic rock, probably the same as that mentioned from the town itself.

53. Porphyry, Ch. Rai. The groundmass is micro-granitic and contains scattered, corroded quartz individuals, as well as orthoclases, oligoclases and chlorotized biotites as phenocrysts. —

Thereafter appear several banks of sandstones and shales, intruded by one or two porphyritic banks, later on reddish sandstones, and dark red shales predominate. Also here occur more metamorphic layers, sericite- and mica-shists, some of them obviously originating from intrusive beds. Near Me Souei small graphitic seams were observed.

The strike in the region passed trough is N.N.W.—S.S.E. and the dip almost vertical.

From Me Soei I started for M. Fang in the N.W., crossing the mountains on very rough tracks. I wanted to visit that place as «petroleum

wells» was marked on some maps, in accordance with exaggerated rumours among the natives. As far as I know, the place has not been visited by any European before.

On leaving Me Souei I entered granitic ground nearly at once. This rock, a coarse-grained, light-grayish granite, builds up the whole highland, continuing to the M. Fang plain.

54. Granite, east of M. Fang. A coarse-grained, gray rock, consisting of about 30 % of quartz, showing traces of slight pressure, and 25 % plagioclases (in the centre andesine). Orthoclase, comprising about 30 %, occurs partly as scattered, long Carlsbad-twins, giving the rock the appearance of an eyed granite. Generally, however, it is anhedral to the plagioclases. Biotite is the dark mineral. It contains apatites and zircons. —

The granite does not show any noticeable traces of pressure and is younger than the surrounding sediments. Sometimes a flat, primary banking is perceivable. Just before reaching the foot of the mountains, at the M. Fang plain, where we descended near to B. Mesalouk, reddish coarse sandstones, containing an intruded granite bank, appeared.

At M. Fang, situated on a plain, no solid rock is exposed, but it is to be noted that the old ruins are built of the same kind of red sandstones and granite as are mentioned above. Thus these rocks may occur in the vicinity. In the surrounding slightly hilly country boulders of the same rocks were also noticed, but besides there seem to occur different metamorphic rocks, with quartz segregations. In the north the mighty mountain Pahom Pok can be sighted, the straight slopes of which indicate sedimentary formations, dipping about 15° to the E. The highlands bordering the plain in the west show the forms characteristic of the limestone districts. It may be the eastern part of the great Permo-Carbonian «Shan-plateau»,[1] known from the Burmese side.

The occurrence of petroleum in this place seems perhaps not quite out of the question, especially in view of the vicinity of the Burmese oil fields. But it should, however, be remembered that in the later place there are folded Tertiary (Miocene) deposits, which are oil-bearing. Here, on the contrary, no Tertiary folding axes are passing over, and the formations are probably of pre-Carbonian age. Thus no analogies ought to be drawn on a geological basis between the two places. Asphalt occurs here, however, and is an article in great demand among the natives, who use it for painting the foundations of the tempels to preserve against the white ants. I visited the asphalt locality, lying about 10 km. S.E. of the town. The asphalt is collected from the bottom of a pit about 5 m. wide and 1 m. deep, filled with water even now in the dry season. On the surface the water is oily. This pit lies in a gently sloping, damp meadow, near the border where it passes over into sandy ground. The asphalt is found only at this spot; by digging close by no signs of it could be found. Thus

[1] It is no tectonic plateau, but the vast limestone highland is chiefly constituted by the folded Permo-Carbonian series.

the area is very small, and certainly the occurrence has the character of a well of oily water, but does not indicate any oil-bearing layers of value.

In the neighbourhood solid rock can not be seen, but sandstones seem to predominate, and an intruded granitic rock may probably occur, as is indicated by the weathering products on some small hills.

Some Siamese officials, acquainted with the Burmese oil-fields, intended to work this deposit, perhaps chiefly as an asphalt mine, but they believe in the future of M. Fang as a centre of great oil-fields. From other places

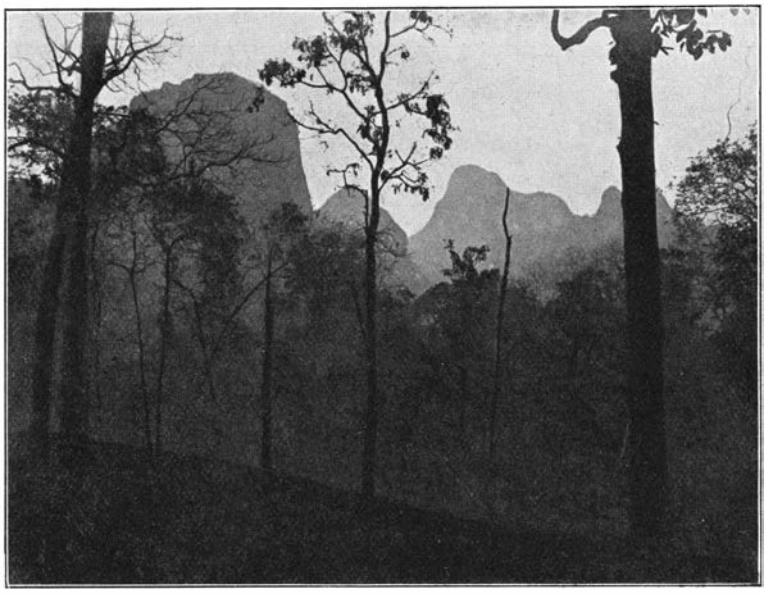

Fig. 6. Limestone crags on the watershed south of M. Fang.

in Siam is also asphalt reported, but M. Fang seems to be the best reputated locality.

Going south towards Ch. Dao I found no solid rock until I arrived in the vicinity of the watershed between the water systems of the Mekong and the Menam. These mountain ridges, which were rather troublesome to cross, consist of shales and limestones; the dip, only once observed, is 30° to N.W. From a distance the pass looks inaccesible, a number of precipitous limestone crags cropping out over the surrounding highland (see fig. 6). They form the remnants of a seemingly horizontal or gently folded limestone cap, the same one as was sighted in the W. from M. Fang, and certainly connected with the «Shan-plateau» on the Burmese border. Here, too, these layers have something of a reef character; no fossils are to be found, and the solid, gray rock does not show any distinct stratification, though the sections are as good as can be desired. The total thickness must be very considerable; at Ch. Dao I estimate it to be

something like 2,000 m. Of the underlying formations very little is to be seen, but at a few places upraised sandstone beds striking N.—S. were passed. The limestone hills, which at the watershed are so near together as to leave a very narrow passage, separate towards the south, and at Ch. Dao they are represented by the famous Doi Ch. Dao, some kilometers to the west, rising abruptly on all sides with almost vertical walls to a height above the sea-level of 2,400 m. (see fig. 7). At the horizon in the east the limestone highlands are still visible behind gentle ridges of obviously less resistant sedimentary formations.

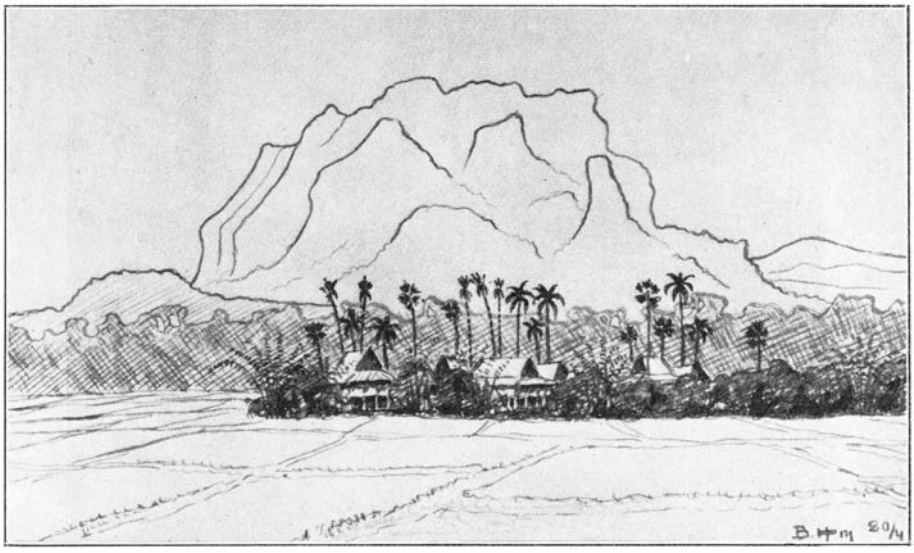

Fig. 7. Doi Chieng Dao, a big limestone mountain.

Going south towards Ch. Mai the plain gets narrower and the low mountains approach nearer together, forming a hilly landscape, cut through by the river. Red sandstones and dark, quartzitic shales appear here, on the whole striking E.—W., strongly and irregularly folded. In these, probably pre-Carbonian layers a light-couloured granite seemingly[1] of the same character as that east of M. Fang is intruded. The sedimentary series next succeeding is much destroyed by pressure and partially very metamorphic; it contains many quartz nodules. Before the great Ch. Mai plain is reached, a gently undulating region of reddish and light-coloured sandstones is crossed.

Towards Ch. Mai highlands are still seen, not far off to the west, apparently built up of sedimentary rocks, dipping about 20° to S. or

[1] All the samples collected on the journey southwards from M. Fang, were lost, and for the description of them my journal is my only authority.

S.W. all according to the shape of the mountains, e. g. at the Doi Sutep west of the town of Ch. Mai.

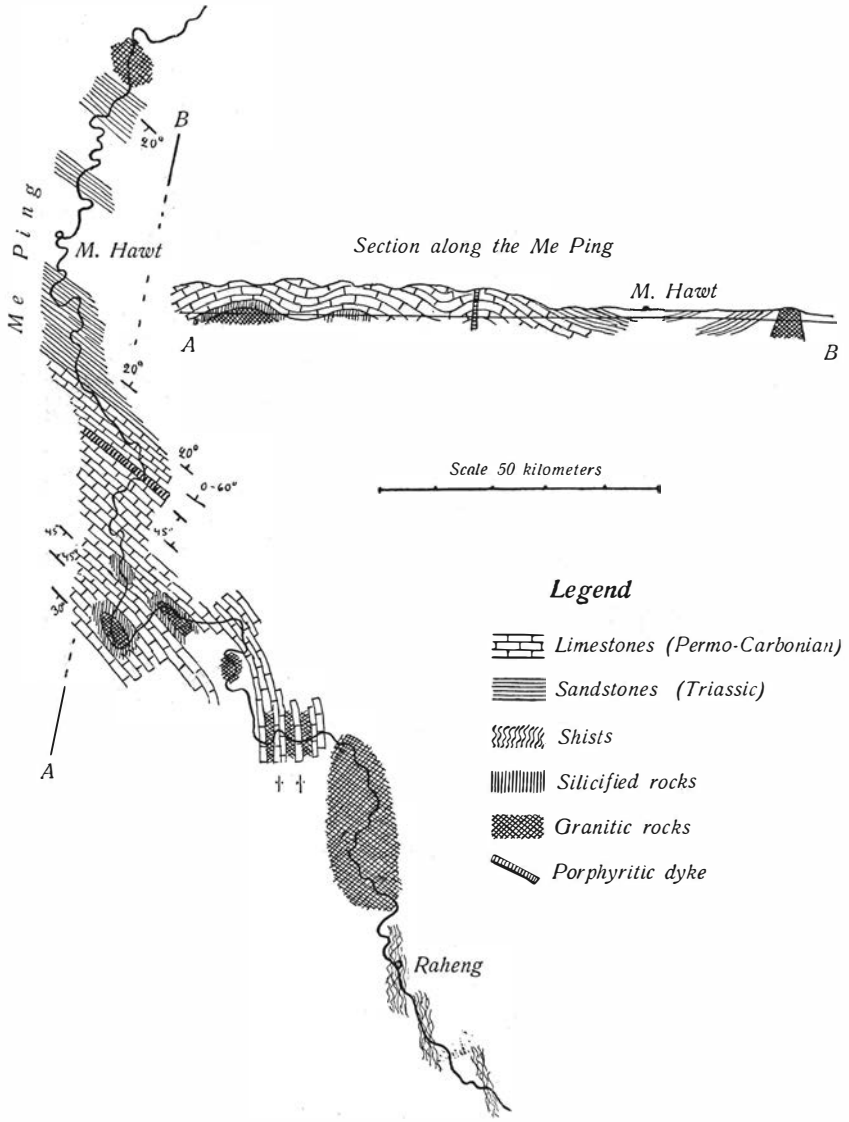

Fig. 8. Map and section along the Me Ping.

The highest peak in Siam, Doi Intanon, is situated here in S.W. and is 2,575 m. high above the sea-level. Unfortunately, in the dry season it is hidden by haze, and so I do not know anything of its appearance, nor had I any opportunity to visit it. As far as I know, no descriptions of the geology of this mountain have ever been given. Generally the

limestone peaks are the highest in this country, and perhaps Doi Intanon is one.

From Ch. Mai we went down the Me Ping in boats to Paknam Po on the railway, and I hoped to get a good geological section, where the river cuts through the highlands. The geological observations along the Me Ping are marked on the sketch-map, fig. 8.

On the first day's journey down-river, however, only flat country is passed through, and solid rock, except for young Tertiary or Pleistocene conglomerate beds, is seldom exposed. One day's journey before reaching M. Hawt some granitic rocks appear by the bank, thereafter coarse reddish sandstones, which are sometimes almost white, with intercalated

Fig. 9. The Me Ping breaking through the limestone highland.

conglomerates, are exposed, dipping 20° to S.W. Below the above mentioned village the position of the layers dips in the opposite direction, 20—30° to N.E.

About one day's journey below M. Hawt a mighty limestone series is met with, underlying the sandstones and showing the same dip to N.E. Without doubt these sandstone and limestone formations are to be considered as representing the Triassic and Permo-Carbonian, known from other regions of the peninsula and of a quite similar character. However, it must be confessed that even accepting this hypothesis, there still remains some doubt in regard to the connection with the geology in the north, where the limestones reappear at Ch. Dao and still further to the north, where I passed over underlying pre-Carbonian formations. Here by the Me Ping, on the contrary, one comes from overlying Triassic layers to the limestone beds. Thus between these two places an unobserved outcrop of the

Permo-Carbonian must exist somewhere, probably it is hidden under the plains passed over. Another possibility would be that a great dislocation had taken place, owing to which the southern part had sunk down. What adds to the difficulty is a certain similarity between the sandstone, sometimes found underlying the Permo-Carbonian, and these overlying sandstones of Triassic age, what is already mentioned as being the case e. g.

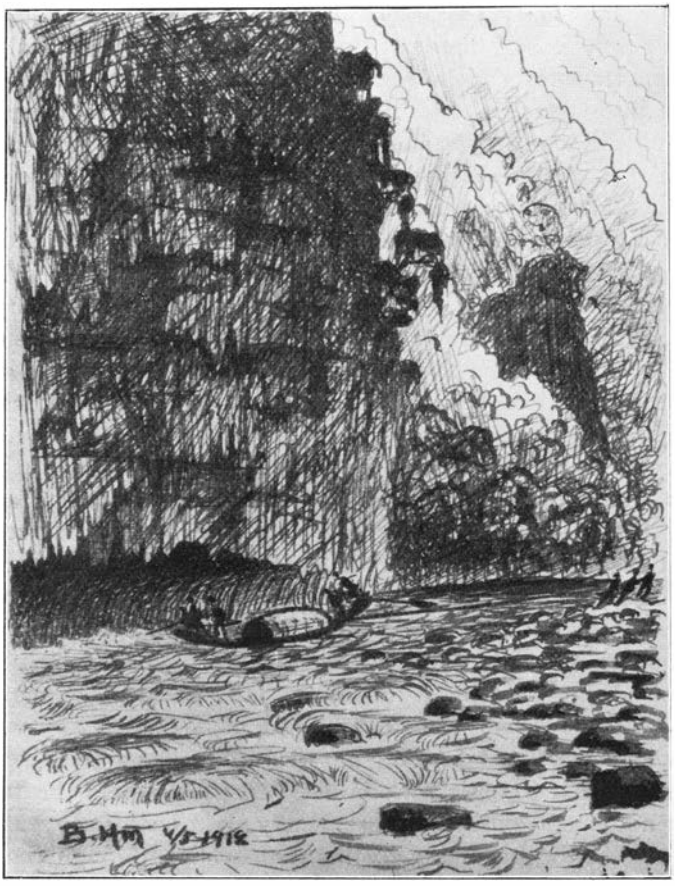

Fig. 10. In the rapids of the Me Ping.

from M. Loye, M. Fang, etc. To the same fact is due the uncertainty of all determinations of geological age in upper Siam especially where the more recognizable Permo-Carbonian limestones are absent in the vicinity. Generally the pre-Carbonian series is much metamorphic and folded, but not always, and sometimes, on the other hand, even the younger formations are very folded and much destroyed.

Returning to the geology along the Me Ping it may be mentioned, that this limestone series continues a long way down-river and builds up

a vast highland of at least 1,500 m. height, where the river breaks through, forming some 30 rapids and showing a drop of nearly 200 m. The valley is very deep and narrow and has in parts the character of a real cañon with quite perpendicular walls (see fig. 9 and 10). But even at such places the stratification is hardly perceptible, though the cross-sections are most ideal. Here also draperies of drop-stones cover a great many of the precipices. I could get no fossils, nor does the compact and often very veined rock look very promising for their discovery. On the whole the layers are gently undulating, but the movements have obviously not been quite unimportant, as can be seen from local folding and crushing zones.

First the layers in question dip 20° to N.E., continuing irregularly for a good distance, whereafter the position of the layers changes, and the dip takes the opposite direction, to S.W. Thereafter two more such flat anticlines are crossed. In the first of them a dark quartzitic or chert-like, probably contact-metamorphic rock underlies the limestone; in the second a still deeper lying granitic rock is exposed. The light grayish, coarse-grained rock, looks very similar to that of the great massive east of M. Fang (see p. 96). Generally it does not show any traces of regional metamorphosis, but some loose boulders I found further down-stream, where the folding of the Permo-Carbonian formation is much stronger, showed nearly the appearance of an eyed gneisse. Unfortunately I have no samples of this granitic rock for more exact examination, those I had as well as all samples collected on the journey down from M. Fang, having been lost before Bangkok was reached. The granite in question, as I have mentioned, is obviously entangled in the tectonic movements, but it may be considered as younger than the limestone beds. No evidently intruded veins of it could, however, be observed in the limestones unless possibly further down the river, where it outcrops alternatively with vertically upraised limstone beds. If this is the effect of strong folding or intrusion could, however, not be determined, as no immediate contacts could be found and examined here or anywhere else along the river. It may be mentioned that granitic rock is not very resistant in the tropics, and thus it is not much exposed, consequently dykes etc. may easily escape observation. At the beginning of this river-section through the limestone mountains two intrusive dykes were, however, noted, cutting through the limestone high up in the face precipice, but, judging by their dark colour, they are probably not of granitic, but of basic character.

After passing the last mentioned anticline, the Me Ping turns abruptly in a more easterly direction. Here the strike of the folding axes is continuously the same, N.W.—S.E., and therefore, before the river makes a fresh curve and resumes its previous direction, it cuts through the same anticline as was first passed. Here, too, the dark, silicified or chert-like rock and the granite could be observed. A little further down the river, where the course is more southerly, such an anticline is again crossed, showing the granite at the bottom. This anticline, too, may correspond

to one of those previously passed. The strike of the strata now changes to a more southerly one and the dip becomes steeper.

Now the mountains retire a little from the river and, as they are more round-shaped and overgrown, clear sections are not longer to be seen (fig. 11). Before reaching the plain itself, however, rocks occur in the river bed at one or two places, causing rapids, and here are still to be seen the same limestone and granite beds alternately, but now vertically upraised and striking about N.N.W.—S.S.E. It seems as if the granite here were folded together with the limestone series, and not only intruded as thick banks in conformity with the limestone layers. In some loose boulders I found specimens of this granite pressed to an eyed gneisse.

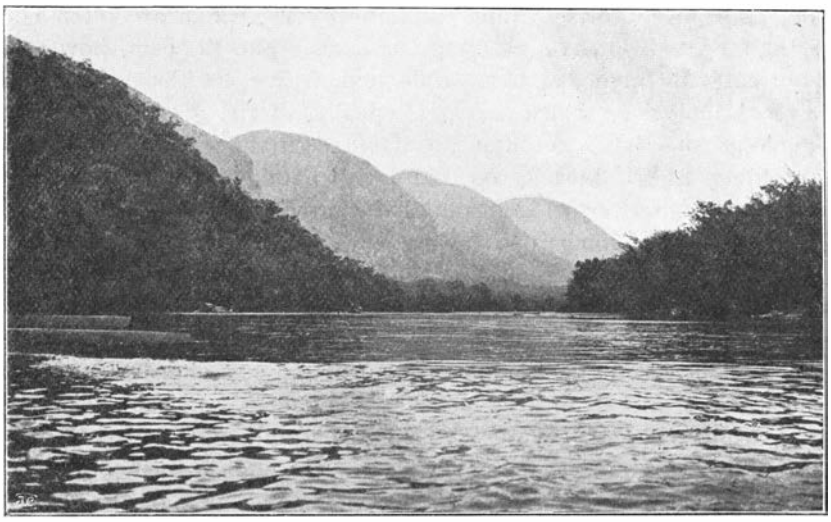

Fig. 11. Rounded limestone hills at the Me Ping.

Towards Raheng the river passes over flat country, and solid rock was but infrequently met with. Only a few granite exposures were seen; and, further down the river, pressed and crumbled shales, without distinguishable dip or strike were observed here and there.

One day's journey before reaching Paknam Po, some crags and ridges are visible, showing the typical shape of the limestone. The strata here are quite upraised and strike along the river, about N.N.W.—S.S.E. Probably these mountains are to be considered as the continuation of the folding axes in the Permo-Carbonian formation, thus giving a connection with the range of Don Pia Fai (W. of Korat) and its offsets at Pra Bat and along the railway north of Ayuthia.

Remarks on the geological map of Siam.

See map, plate I.

In order to get an insight into the rock-ground of Siam, one has to consider what is known of the geology of the surrounding countries, the knowledge of Siam itself, as composed of a few previous notes and my own scattered observations, being very fragmentary.

In L. DE LAUNAY; «La géologie et les richesses minérales de l'Asie» is given a summary of the geology of Further India, which has been my principal guide for this paper. With regard to original papers I may also refer to the evidently very complete bibliography of this work. It has besides not been possible for me to get all the original works, published as they are in all sorts of different publications, which are often hardly to be had. DE LAUNAY's extracts from these papers seem, however, to be very carefully made, and especially exhaustive are these dealing with the French colonies, which are, geologically, of the greatest interest for the geology of Siam, as they are situated in the general strike of the same folding axes. Burma, on the other hand, borders parallel to the strike and is, moreover, of quite another character in parts, showing Tertiary deposits and foldings. Following DE LAUNAY I shall, in the following pages, group the formations as follows: pre-Carbonian, Permo-Carbonian and Triassic.

The pre-Carbonian occupies the greater part of Annam, that is to say the regions bordering Siam to the north and east and thus it obviously continues down into Siam also. In S.E. is situated the so-called Cambodja-massive, which DE LAUNAY distinguishes separately on the map as «gneiss, granite et précarbonifère métamorphisé». He indicates it as extending over southern Annam, Cambodja (where it is, however, partially covered by younger strata) and over a belt in the upper Malay peninsula. I have not retained this on my map of these regions, though they were not visited by me. But it seems to me that no clear difference could be made out between these older and the younger pre-Carbonian formations (Cambro-Silur and Devon, the designation employed by DE LAUNAY elsewhere in Further India) and therefore I have given my marking a wider signification, «pre-Carbonian» only. Because of the absence of fossils, the true age of the different pre-Carbonian strata cannot be fixed. In similar formations, however, Silurian and Devonian fossils are found in Burma and Yunnan.

As has been shown in the previous sections, however, a reservation, which must certainly be made to apply also to Annam, must be made in the case of the marking «pre-Carbonian»: that sometimes, where the folding is strong, younger formations can also very possibly be included under it, especially where no recognizable leading layers are found in the vicinity. This is the case e. g. with the districts between M. Pre—Ch. Mai and the Mekong in the north (see fig. 5), where the folding is strong and

the formations are complicated and are, besides, frequently intruded by igneous rocks. Thus even if chiefly pre-Carbonian rocks are represented under this designation, some strata are very similar to, and perhaps represent, the Permo-Carbonian and the Triassic, as they are developed in other regions of Siam. Against such a presumption of the presence of younger strata among the «pre-Carbonian» one could advance the objection that, in the direction of strike, there are great Permo-Carbonian areas in the neighbouring regions of Annam, e. g. east of Luang Prabang, showing a nearly undisturbed stratification. But in the case of that country too, DE LAUNAY has pointed out that probably only the more undisturbed parts of the younger formations are recognized as such, and that possibly between them may occur folded strata of the same age. Really some other facts point in such a direction; at Luang Prabang, for example, highly folded, fossil-bearing Triassic layers are observed. It seems to me, moreover, that just this occurrence may form the continuation of the Triassic belt I crossed twice east of Outaradit, where, along my more northerly route, it was found to be strongly folded (see fig. 2). The same fact is indicated by the reputed occurrence of salt wells at the sources of the Nam Nan.

Strongly folded and upraised Permo-Carbonian layers are also recorded from Burma, from the Malay peninsula and from lower Siam, which leads to the conclusion that highly disturbed tectonics cannot provide an unmistakeable indication of older formations.

Apart from the limestones and red sandstones that are possibly of Carbonian and Triassic age, the pre-Carbonian strata are represented by different sandstones, shales and limestone beds, the latter, however, not of any considerable thickness. Besides, there appear in this formation metamorphic rocks, as various shists, micaceous, chloritic, and sericitic, as well as crystallinic limestone. Among the shists also igneous rocks are recognizable, especially tuffs and porphyritic rocks; sometimes also granites of a half gneissic appearance. Most of the igneous rocks, intruded in the pre-Carbonian layers are, however, much younger, perhaps chiefly post-Triassic, and they do not show any traces of pressure.

It is obvious from what has already been said that it must be difficult to get a complete idea of pre-Carbonian tectonics, as they must be influenced by the younger folding movements. Generally it is not even possible to distinguish the pre-Carbonian folding directions. Thus, when the strike of the pre-Carbonian series runs conformably with the post-Carbonian folding lines (as e. g. at the Burma-border, at the Malay peninsula and in Cambodja, as well as in northern Siam) one cannot, in my opinion, assume that this conformity is a primary one. According to the maps of DE LAUNAY, in N.E. of the neighbouring parts of Annam a strike, diverging from the ruling N.W—S.E. direction, is noted and some folding lines branch off towards S.S.W. It seems not quite impossible that two folding systems of different ages are here represented, and, if that is so, it would be most likely from comparison with northern Siam

that the pre-Carbonian should run N.W.—S.E., and the younger one more in a N.—S.direction.

According to my observations from the lower bend of the Mekong (M. Loye—Ch. Kan) there is found an anomalous strike of the pre-Carbonian strata, going nearly W.—E. in the eastern and southern parts of the M. Loye plain, which direction is probably the original one, as the younger strata in the vicinity are undisturbed. Towards Ch. Kan, however, the strike changes to a more S.—W.direction, thus probably the influence of the post-Triassic foldings (as observed in the mountain landscape in the west) has here caused such a secondary strike of the older series. This reversal of the strike corresponds roughly to the course of the Mekong, and perhaps the deviated course of the river here has something to do with the two prevailing directions of the folding lines. As indicated on the map, there is also an anomalous strike observed in the pre-Carbonian series near Ch. Dao in N.W.-Siam too, but here the observations were too few to be decisive.

The Permo-Carbonian is constituted of a characteristic, mighty limestone series, more or less intercalated with shales, and extremely poor in fossils. Therefore it is not yet possible to determine which subdivisions of the Permo-Carbonian formation are represented; it seems, however, to be the upper Carbonian and Perm (»Ouralien»). At a few places on the peninsula are found Brachiopods and Fusulinas, and I had the good fortune to find Fusulinas in southern Siam (see p. 68), by which find it was indicated that the formation, characterized by the mighty limestone beds, is identical with the Permo-Carbonian as it is known from the neighbouring countries. One may, therefore, in general, be justified in giving the name Permo-Carbonian to similar limestone series when met with in other parts of the country, especially as most of the occurrences in upper Siam are more or less directly connected with the Permo Carbonian districts of the neighbouring states.

From the northern parts of Further India as well as from the Malay peninsula some Triassic marine deposits are known, and it seems to be possible, therefore, that Triassic layers can take part in building up this mighty limestone series. The total thickness is very great; at Ch. Dao I estimated it to be more than 2000 m., the height of Doi Ch. Dao above the plain. It is possible that these grayish, compact limestones, poor in fossils, have the character of reef-stones, as the stratification is, moreover, scarcely distinguishable. From the neighbouring parts of Annam it is noted that the position of these layers is but little disturbed, or that they show gentle and broad foldings only. As I have already mentioned, however, it is very possible that between those areas, often designated as plateaus, may occur more folded parts of the formation, which are not distinguished from the pre-Carbonian series. This is so much the more probable, as the Permo-Carbonian is strongly folded everywhere in the lower parts of Siam and in Burma. As to the known extension of this

formation in Siam it may be said that it occurs in Cambodja at two places, namely by the lower Mekong and on the coast of the golf, showing a strike running about NW.—S.E., conformably with the strike of the pre-Carbonian strata, which have perhaps been influenced by the later folding movements. From these occurrences the continuation of the strike is found in the Don Pia Fai range, which borders the Korat plateau to the west. Here the strike still runs about N.W—S.E., thus obliquely crossing the Menam plain, and continues along the Me Ping, still with strongly upraised beds. After following the river about half-way to Ch. Mai, the range becomes more gently folded, and the layers build up an extensive mountain massive, cut through by the river (see p. 102). The strike is somewhat deviated here, as indicated on the map. This limestone district may be connected with the great Permo-Carbonian area on the Burma border in the west, called the «Shan-plateau», although it is not any tectonic plateau. Towards Ch. Mai the limestones retire, but appear again at Ch. Dao, where they still seem to be only slightly disturbed, and the same is the case towards M. Fang. In the district east of the Me Ping it is possible that Permo-Carbonian layers, not distinguished from the older series, may occur. Thus, as occurrences met with along my line of route may be mentioned the limestone hills east and west of Ch. Rai, which are of doubtful age, as well as occurrences to the east and north of the M. Pre—M. Nan regions (see fig. 5) etc. From the sources of the Nam Nan WARINGTON SMYTH also mentions a mountainous limestone landscape. This and some other of his observations are indicated on my map (see fig. 5).

East of the M. Loye plain (see fig. 8) was observed the Permo-Carbonian, constituting a plateau, the extension of which towards the east is not known. The stratification seemed to be nearly horizontal or slightly dipping towards the south.

It may be mentioned that the topography, as it is shown on some of the maps, indicates that the Don Pia Fai range runs more S.—N. and continues northwards along the western side of the N. Sak, where it should form a considerable mountain landscape. Geologically, however, it crosses the Menam plain in a N.W.direction. But it is not quite out of the question that it should send out a branch in a northerly direction, too. I hardly believe this to be so, however, because of the shape of these mountains west of the N. Sak, when seen from the railway. Their shape more probably indicates table-mountains, which here form a mountainous margin zone of the Korat plateau, similar to the Pnom Dang-rek in the south (see p. 71). My observations on the journey to the east from Outaradit, suggesting a nearly undisturbed Triassic belt, also indicate that the Korat plateau and not a mountain range forms the continuation of these regions.

As Triassic has above been designated a formation, chiefly built up of red sandstones, conglomerates and shales, though the indications of the age are very vague. At Luang Prabang and in Tonkin fossils have

been found, indicating Triassic, perhaps chiefly Rhätic, age. From some lignite occurrences, however, plants are known, probably of Liassic age. These layers are considered to belong to the Gondwana group, and correspond to similar deposits in Tonkin.[1]

In Siam such Triassic layers have their greatest extension in the Korat plateau and its continuation over southern Annam and Cambodja, here mostly quite undisturbed, forming a mighty series of reddish sandstones. In Cambodja they lie discordantly over the folded Permo-Carbonian formation, and the same I consider very probably to be the case on the western border also, by the Don Pia Fai range. In northernmost Siam, as well as at Luang Prabang, and even east of Outaradit, at the northwestern corner of the Korat plateau, the Triassic layers are strongly folded, generally striking N.—S. Gentle flexures are found so far to the south as by the Korat railway (see p. 70). Of course, the same may be said about the Triassic as about the Permo-Carbonian layers in northern Siam, viz. that they might perhaps have escaped detection, where they are strongly folded together with older formations.

I also encountered sandstones of obviously Triassic age where the Me Ping enters the vast limestone highland south of Ch. Mai. These sandstones lie conformably over the Permo-Carbonian formation and have been seized by the same gentle flexures.

I could not discover deposits af any extension younger than Triassic, except the recent, or Pleistocene alluvions. Locally, however, undisturbed, obviously very young shale and conglomerate beds were met with. Probably they are of Tertiary age and of the same character as the Tertiary auriferous deposits, know from the French colonies. Such layers were observed along the Mekong (see p. 94) and on the M. Loye plain (see p. 82), places also noteworthy as being gold-bearing. Probably the pieces of fossil wood I collected in Korat originate from similar beds.

It must be suggested that the Tertiary folding systems have not reached Siam. May be that the local Tertiary deposits just mentioned are too young and too local to prove absence of Tertiary foldings, but the knowledge of the neighbouring countries can do it. An important Tertiary range, marked by volcanoes and folded, sometimes oil-bearing Tertiary strata, runs N.—S. through Burma over Cap Negrais and parallel with (though outside the western coast of) the Malay peninsula, passing

[1] The plant-fossils from the coal beds in the corresponding sandstone series of Tonkin are described by R. ZEILLER in »Examen de la Flore fossile des couches de charbon du Tong-king» (Ann. d. Mines 1882 and Bull. Soc. Géol. 1882—83, 85—86). He has found that about half of the species belong to the middle-Gondwana, the rest are of a Rhätic type.

over to the Sunda islands over Sumatra and Java. In the north the last offsets of the Himalaya system can be followed down into Yunnan, where they are marked by the strikingly parallel courses of the rivers Saluen, Mekong, and Jang Tse Kiang; but they seem to disappear before reaching the northern corner of Siam, where the courses become irregular, each river taking its own direction. In Tonkin, moreover, are found middle-Tertiary deposits in undisturbed position, discordantly layered upon the older folded formations.

Thus the «Cordillera of Annam», suggested by FUCHS[1] and still mentioned in some important geological handbooks (as e. g. in E. SUESS' «Antlitz der Erde»), does not exist in reality. Moreover, undisturbed Triassic layers, forming the continuation of the Korat plateau, reach the coast of the China Sea. Thus the term «the Cambodja-massive» had better to be changed into «the massive of Further India», which could be reckoned from the Saluen in the west to the China Sea in the east. However, Cambodja, with the neighbouring great Korat plateau and its continuation through Annam, is evidently the massive that has longest remained undisturbed, viz. from the Triassic period.

Tertiary faults, however, may certainly occur outside the true folding regions, and thus also further down in Siam. Hot springs and solfataras (at Luang Prabang) are known,[2] and recent eruptive rocks occur in Siam, as well as in Annam and Cambodja. The most important occurrence is that in southern Annam, the vast «Plateau des Boulovens», situated on the eastern part of the greast Triassic table-land and in the direction of the suggested great fault, bordering the Korat plateau in the south (see below). Another is the basalt of Ch. Kong (see p. 91), probably gem-bearing, as are the traps of Chantaboun in Cambodja. Another small, isolated occurrence lies north-east of Saigon. The basalt occurrence of Ch. Kong and the solfataras west of Luang Prabang have perhaps something to do with the anomalous course of the Mekong here at its upper W.—E.running bend, where the river takes an abnormal direction across the strike of the strata and cuts through the mighty highlands at Luang Prabang, instead of continuing southwards, where no considerable heights present any particular obstacle.

The abrupt edge of the Korat plateau, which borders it towards the lower Cambodja plain (also Triassic), is perhaps to be considered as a great fault, that is so accentuated that it probably may be of Tertiary age.

The whole «massive of Further India» lies outside the seismic district of Asia, and earthquakes are very rare. Thus an earthquake in Bangkok, which I had the opportunity of experiencing in May 1912, attracted

[1] EDM. FUCHS et E. SALADIN. Ann. des Mines 1882, 8 sér., Memoires, II.

[2] Described by MC CARTHY (loc. cit.), WARINGTON SMYTH (loc. cit.) JOUBERT (in GARNIER, Voy. d. Explor. II) a. o. LÓCZY (in Ost-Asien; Reise d. Graf. BÉLA SZÉCHÉNYI, I, 1893) believes that these volcanic vents are burning coal beds, in my opinion a very improbable hypothesis.

a good deal of notice. It was rather pronounced as gentle swingings here on the alluvial plain. Afterwards, however, it was stated to be only the slight effects of an earthquake in upper Burma, the Tertiary folding districts of which belong to the seismic regions.

Retrospect on the folding systems. The folding lines of different ages are generally difficult to distinguish from each other in Siam, as the older ones are more or less influenced by the younger, which in northern Siam are represented by the post-Triassic folding, and in southern Siam by the post-Carbonian.

This difficulty is especially appreciable as regards the pre-Carbonian systems, but at some places, where the Carbonian deposits are less disturbed and the discordance is perceptible, it seems as if these folding axes of the older formations ran chiefly in a direction about N.W.—S.O., the same probable being the case in Annam.

In southern Siam the post-Carbonian, pre-Triassic foldings also go in about the same direction. To the north the original, older folding lines are less distinguishable, as no difference is to be observed here between the post-Carbonian and the post-Triassic movements. Remarkable are the gently undulating Carbonian plateaus in upper Siam and the neighbouring parts of Annam, which probably form more resistant parts between highly folded belts. One might suggest that these «plateaus» were overthrusts, but nothing is known that would support such a supposition. Moreover, they show no metamorphosis.

The post-Triassic folding is strongly developed and determines the usual N.—S. strike.

The folding lines in Siam are more or less erroneously indicated on DE LAUNAY's maps, based as they are on the topographical features of the rather incorrect maps over the country, owing to the lack of geological observations.

Summary of the Petrography.

The petrographical studies I had opportunity of making on my journey in Siam were mainly confined to the collecting of specimens and thus the results are, for the most part, only scattered notes. As solid rock is very seldom exposed and immediate contacts could not generally be observed, their mode of occurrence, differentiation products etc., can be but imperfectly known, especially as I only passed over them during a rapid journey over great stretches of country. From the regions surrounding Siam detailed studies of the petrography seem to be lacking. However, the igneous rocks of Further India are obviously worthy of interest, especially inasmuch as some of them present less ordinary types.

The igneous rocks occur partly as intruded dykes and stocks, but generally they are of a more superficial character as effusive beds.

The igneous rocks are marked on the special maps, but, as their extension and mode of occurrence could not generally be satisfactorily observed, these indications must be approximate only. From the general map (Pl. I), however, they are entirely omitted, their occurrence being generally quite local only. Their existence elsewhere than along my route, it would, moreover, be impossible to know anything about.

The igneous rocks are of different epochs, as is shown by the fact that there occur quite shistose rocks together with such as do not show any perceptible traces of pressure. Most of them are found in the pre-Carbonian series, often metamorphosed beyond recognization, but others are met with penetrating the Triassic strata; finally the Tertiary or recent basalts may be mentioned. Independant of age, porphyritic eruptives predominate. The granitic rocks ought generally to be considered as relatively young and at least partly penetrating Triassic strata; I have but seldom found gneissic granitic rocks.

Several short descriptions of the different rocks, based on microscopical examinations, and dealing with the early observations made along my route, are given in the previous sections; here only a few general remarks will be added.

Granitic rocks I met with at numerous places in Siam; I found them especially abundant and of different types in the neighbourhood of M. Loye and Ch. Kan. The most extensive occurrence, I passed, was the massive situated east of M. Fang, the breadth of which is about 35 km. across the strike of the surrounding strata (see fig. 5). Of a perhaps still greater extension are the granites intruded under the mighty limestones at the Me Ping (see p. 102), the scattered exposures of which probably represent a continuous massive.

Among the granites there are some of a rather common type, with orthoclase and quartz predominating, e. g. the granite of Chanteuk (n:o 1), the granite of the M. Loye—Ch. Kan plain (n:o 16) and some others. Most of the granitic rocks, however, are of another, more interesting type of rather andine characters, or they at least approach this type. They are noticeable for the preponderance of rather basic plagioclases, occurring as zonal, quite euhedral individuals, mostly of andesine and labradorite. The orthoclase, which occurs more sparsely, is often either micrographic intergrown with the quartz or occurs in biggish anhedral patches, penetrated by the euhedral plagioclases, in which case it generally attains a higher percentage. For those of a more markedly andine type of texture and poor in orthoclase I have, in this paper used the name quartz-diorites. Their dark minerals are hornblendes, augites, or biotites. As subordinate minerals occur apatite, zircone and magnetite.

Thoug all kinds of medium types seem to exist, I have not been able to find that the common granites and those of the quartz diorite type occur as differentiation products of the same massive, though it is very

probable that they do so. It may also be noted that they are found in the neighbourhood of each other, as e. g. at the M. Loye—Ch. Kan plain.

It is very probable that in some cases the quartz-diorites have given rise to contact ores, as e. g. on the M. Loye plain. Thus I have previously mentioned the arsenic minerals appearing at B. Hoei Tat, at the border of such a massive, noticeable, inasmuch as similar igneous rocks are connected with auriferous arsenic-pyrite deposits in California (see p. 81). If the tin-bearing rocks of the Malay peninsula are quartz-diorites I do not know. I have, however, found such a granitic rock of a very marked andine type near Singapoor.[1]

It may be mentioned that at Ch. Sen I found a greissen of considerable extension, which seemed to belong to a granitic rock of this andine type (see p. 94), but from which granites the tin-bearing gravels in upper Siam originate, I do not know.

In norternmost Siam, on the Mekong, I found some half-gneissic rocks that seem to have been granites of, perhaps, a somewhat andine type. But among the few gneissic rocks I met with I did not find any of a more marked andine character.

I have not been able to determine the age of these «quartz-diorites», nor if they all belong to the same epoch. But it seems as if most of them, or perhaps all, were younger than the pre-Carbonian foldings, which has often caused strong metamorphosis to those strata intruded by the unpressed quartz-diorites. The minimum age is also not fixed either, but some were observed penetrating layers of probably Triassic age (e. g. n:o 11).

The same may be said of the granites of a more ordinary type; kataclastic granites, however, of this or a medium type, were observed from the Mekong as has been mentioned, but in this case the post-Triassic folding is rather strong, perhaps strong enough to have caused their metamorphosis. In other places, e. g. at Chanteuk (n:o 1.), they occur penetrating the Triassic formation.

Porphyritic and tuffogene rocks, such as quartz- and syenite-porphyries, porphyrites, eruptive breccias and tuffs are very abundant. They generally occur as beds and dykes, often of considerable thickness. Some

[1] As this rock is very representative and, moreover, less decomposed than the most of the samples I was able to procure in Siam, it seems worthy of a short description.

Quartz-diorite, Sea View, Singapoor. A grey, medium- to fine-grained rock with a macroscopically distinguishable fluidal arrangement of the table-formed felspars. The zonal plagioclases, in the centre of andesine or more basic character, make about 60 % and are very euhedral, not only to the orthoclase and the quartz, but also to the hornblendes, micas and titanites. Quartz and orthoclase make about 10 % each, green hornblende, in the centre sometimes micrographic intergrown with augite, and biotite also about 10 % each. Biggish individuals of titanite can be seen, as well as several smaller apatites.

In J. WATSON, Building Stones, Cambr. 1911, are two Singapoor granites mentioned designated by Mr. A. HARKER as Quartz-Monzonite and Quartz-Diorite.

are seemingly unaffected by pressure, and these, when found in northern Siam — where the post-Triassic folding is rather strong —, may be considered younger than the folding movements. Rocks of this type are also found penetrating the Triassic strata; but, a great number of them are doubtless much older, and they are also much more abundant in the pre-Carbonian than in the younger formations. They are often metamorphosed beyond recognization and are represented by shistose, chloritic or sericitic rocks, sometimes, however, showing recognizable phenocrysts.

In the previous sections a number of especially less metamorphosed rocks of this charakter are described, representing a multitude of different types of structure, groundmass, phenocrysts etc., which need not be mentioned again here. Only the more or less marked eutaxite- and breccia-like appearence they very often present, may be indicated, some of them approaching true tuffs, consisting of porphyritic fragments only. There are also such as consist of porphyritic fragments embedded in a quite rhyolotic, lava-like mass. True tuffs are also very common, and often clearly of considerable extension, embedded as they are in the sedimentary series. In a black, compact tuff (n:o 8) I could distinguish pieces of fossil wood, but the structure of it was not preserved sufficiently for closer determination.

It seems probable that most of the ore deposits, known in Siam, are connected with the abundant intrusions of a porphyritic character, as is also considered to be the case in the neighbouring French colonies.

Basalt I only found at one place, near Ch. Kong on the upper Mekong, where it seems to be the source of the sapphire-bearing gravels in the river bed. For a description of this rock the reader may be referred to p. 91 (n:o 36). Basaltic rocks are also known in other places in Further India, viz. in Cambodja, at the sapphire mines of Chantaboun and near Saigon, as well as from southernmost Annam, the vast «plateau des Bouloven», situated in the continuation of the supposed great fault at the southern border of the Korat plateau (se plate I, where the fault can be represented approximatively by the French border, that is drawn along the watershed).

I also met with some other igneous rocks, which are not included under the above headings, such as the minettes of Ch. Kong (n:o 37) and Chanteuk (n:o 2), monozonitic rocks as one from the upper Mekong (n:o 40) etc., for which reference may be made to the previous detailed descriptions.

Mining and mineral deposits.

A number of mineral deposits have been mentioned in the above sections, though perhaps they are too little known geologically to be of scientific interest. My journey being only a first general surveing, no closer examination of their mode of occurrence was possible.

In some cases I have also given more or less uncorroborated narratives of the natives about ores and abandoned native mines, but I consider them worthy of mention, inasmuch as they in a way indicate the common occurrence of mineral deposits, in which respect there is a likeness to the Malay peninsula and the French colonies, due to a corresponding similarity of the geology. Certainly it will be found that most of the ores of Siam will have no value for serious mining.

The list of ore finds, given below is, of course, not at all complete, as most of the statements were only collected during my short journey. Hardly any geological survey has been made at all, and the natives themselves do not take much interest in mines, and thus certainly only a small portion of the existing occurrences can be enumerated here. Really it is remarkable that ores are so often found and recognized by the natives, as the rock-ground is very seldom uncovered, and then it is generally superficially decomposed. Nowadays especially native mining is very unimportant and our interest in it is rather of an etnographical than a commercial nature. Iron, copper and silver can easily be bought from abroad, and as for the many examples of the silver-smith's art met with everywhere in the country, they are made from silver coins. However, a good deal of metals must have been produced in earlier times, as is shown by the numbers of bronze Budda-images in this country. Abandoned mines also seem to be rather common.

Except for the tin mining in the Malay peninsula, which I do not deal with in this paper, there is no mining on a large scale in Siam. During my stay in Bangkok, however, I heard about a newly discovered, valuable galena deposit in Canbury, in southwestern Siam, which was said to be well surveyed and considered to be very rich, but the difficulties of transport would be a drawback. In Bangkok I heard about the galena ore of Hinlap, mentioned above (see p. 69), but it was kept secret when I visited the place.

A few attempts at European mining have been made, but they were not succesful. The copper mine at Chanteuk has already been mentioned (see p. 69), and I was told that another one was started at Raheng. Gold mining has also been tried at Watana (200 km. E. of Bangkok), and subsequently at M. Lom (government Pechaboun), also without success. At the gem fields of Chantaboun, in south-western Siam, Europeans have tried to get control of the work and monopolize the sapphire trade, but

they only raised trouble with the Burmese gem diggers, and, moreover, the deadly climate was a great obstacle.

In the following list, as I have already said, I bring together chiefly such statements as I have collected myself, but some are taken also from other papers, which casually mention them. The latter are chiefly published by WARINGTON SMYTH (loc. cit.), a geologist once in the Siamese service, who to some extent crossed the same ground as I did.

Gold. In Siam, as well as in China, French Indo-China, the Malay peninsula etc. alluvial gold is washed by the natives in many places. In the French colonies closer investigations have also been made, and the sources of the gold has been discovered to be chiefly veins of quartz, often in the vicinity of igneous rocks, intruding the sediments, especially the metamorphic pre-Carbonian formations. Mining on a large scale has seldom been succesful. As has been mentioned, it has also been tried on in Siam, at Watana and M. Lom. Besides, the alluvial gold is sometimes found in small creeks and in the river beds in quite recent alluvions, and it is contained in older (Tertiary?) more or less cemented conglomerate beds. Some localities are: Outaradit, Nam Pat, Tali, many places along the N. Loye and at its junction with the Mekong, the Mekong in northernmost Siam, and the vicinity of Ch. Rai. According to WAR. SMYTH gold is also found at Lop Buri, near M. Boua Soum (west of the Don Pia Fai range) and N.W. of M. Nan.

Silver seems mostly to be obtained from galena ores, though the natives often declare it is from «pure» silver ore. They spoke of such ore as occurring in the neighbourhood of N. Pat (see p. 86) and at a place north of M. Loye. In Ch. Kan I got a sample of a fahlerz (analysis see p. 84).

Led. Galena seems to be rather common in Siam, but probably most of the deposits are quite unimportant. The newly discovered deposit at Canbury (see p. 114) and Hinlap (see p. 69) have already been mentioned. Some other places are: near Outaradit, N. Pat, Ch. Kan at several places (see p. 84) and in the M. Loye district, according to WAR. SMYTH also near M. Boua Soum. The samples I got were all rather poor in silver. A connection between these deposits and intruded igneous rocks seems to be probable.

Tin. Besides the Malay peninsula there seem to be numerous places up-country where alluvial tin occurs, but no work is carried on as far as I know. Tin is reported from the M. Loye district, near Ch. Rai, N. Pat (?), Ch. Kong, Lampang (?), a. o. No indigenous tin industry exists, however, nowadays among the Laos, but Budda-images etc. of tin are common. The occurrences of tin in upper Siam may be connected with the numerous granitic intrusions.

Antimony. Sometimes I was shown samples of the ore as well as the metal, but where they came from was kept secret. A great deposit was spoken of as occurring in the vicinity of Lampang. Antimony is known from many places in the French colonies, but not in commerci-

ally paying quantities. Mc. CARTHY (loc. cit.) says that M. Tering (= M. Tern?) is known for «the working of antimony, which is found there in large quantities».

Wolframite is known from the regions along the coast, and I have also seen a sample up-country.

Copper. Besides at Chanteuk (see p. 69) and Raheng occurrences are reported: near N. Pat (see p. 86), Ch. Rai (see p. 95), at two places near M. Loye, Lampang (?) etc, WAR. SMYTH also marks copper mines on his map S.E. and W. of M. Nan. The natives seem no longer to work copper at all, but previously they did so, certainly chiefly for making statues of Budda.

The copper ores here, as well as in the French colonies, may have the character of contact ores.

Arsenic minerals may be mentioned as a curiosity from B. Hoei Tat (see p. 80), they are contact deposits to a quartz-diorite.

Iron. Besides the generally abundant common laterites, there are such, partly changed into hematite, and also manganese-bearing ones (see p. 81). But real iron ores are obviously not infrequent in Siam. Some I visited at M. Loye (see p. 78) and one at N. Pi (see p. 75). From Ch. Kan, M. Loye—Makeng, the neighbourhood of M. Pre, Ch. Kong etc. iron ores were also reported. As to the quantities of these ores very little is known, as also of their geological mode of occurrence. Those of M. Loye and N. Pi are limited to the pre-Carbonian, metamorphic rocks, where igneous rocks also appear; they do not seem, however, to be directly connected with the latter. The quality is generally good (for analyses see p. 75, 78, 82).

Nowadays the natives do very little iron mining, and it is doubtful wether even in times past they could supply their own wants of the metal. The iron they produced was of good quality, however. It is not to be expected that iron mining in Siam will ever become profitable in the near future, perhaps not even if good coal was discovered, which would render it possible to melt it in the country.

Coal. As the natives have no need for coal — except a little charcoal — it is not therefore likely to attract their attention. It is called «the blood of the great sea-serpent». Very probably coal or lignite occurs in Siam; in the neighbouring countries it is known in the Triassic as well as in some continental Carbonian beds. At the easternmost part of the Korat plateau, near Bassac, it has been discovered by French explorers, but in the western part it is not found, though a deep boring has been made near Korat. I did not discover any coal layers or loose pieces in the river beds. In the folded districts of northern Siam I heard of coal in a few places: N.W. and S.W. of Ch. Mai («brownish coal») at B. Soung, not far from M. Pre, at Lampang (?), near Ch. Kong (at this place, itself, however, the people said they did not know of coal), and in the upper Mekok (analysis see p. 95).

If coal of somewhat good quality and of important extension were discovered near the railway or the coast, it could probably be worked with profit, here as well as in the French colonies and Burma, because prices run high in Further Indian harbours, where chiefly English coal and rather inferior Japanese coal is imported.

Asphalt occurs at M. Fang (see p. 96), previously rumoured to be oil. Real oil-fields are not known in Siam.

Salt effloresces and is collected on the Korat plateau (see p. 71) and is characteristic for the red sandstone series, which is probably of Triassic age. In the mountains salt wells are not very uncommon (see p. 76).

Phosphates containing some saltpeter seem to be common in the caves, which are abundant almost everywhere in the limestone districts (analysis see p. 83). The phosphates are used by the natives for extracting saltpetre for their gunpowder. The origin of these deposits is not quite certain, but they may probably be considered as guano. —

If Siam will ever become a mining country of importance is a question that can not of course be settled yet; the first condition, however, is that the means of communication are developed and that the country is opened up and surveyed. The railways now existing are not unimportant, but for mining they are of less use as they pass almost exclusively over the plains, these being the rice districts and most densely populated parts of the country. To this lack of railways over great parts of the country must be added the lack of roads. Transport has to be effected expensively by means of carriers, bullock-, mule- or ponny-caravans, or in some regions elephants, which also is rather expensive. It is only on the Korat plateau and in some parts of the Menam plain that bullock-cars are used, and they are of the most primitive construction.

There is scarcely any intercourse between the rice cultivating population, and the topography and the tropical vegetation are severe obstacles to travelling along the rough tracks. As an example of how bad the communications are, can be mentioned that a bullock caravan from Outaradit to M. Loye can hardly cover the distance in less than a fortnight, though as the crow flies it is only 160 km.

It should, however, be mentioned that the Siamese government has made very praiseworthy efforts to improve the road system, but the results can hardly be great as long as there is no real demand for roads on the native population. The «new-cut» roads also are mostly broad clearings through the jungle, running without much consideration for the topography and they are not at all convenient for vehicles. Bridges are also very rare.

All transport is regulated by the seasons, some regions, e. g. the Korat plateau, not being passable at the rainy season, when the rivers become difficult to wade. In the dry season, on the contrary, water fails in many places, and then most of the rivers are too shallow for navigation.

As to the river transport it may be said that it is mostly carried on by means of dug-out canoes only, except on the lower reaches of the Menam system. Since the French have made costly efforts to make the Mekong more navigable, this river is now used at high water by small steamboats to Luang Prabang, and thus relatively good communication with some parts of Siam is provided, e. g. to the N. Loye—Ch. Kan district.

A question of great importance is how to obtain good miners, because one can hardly count on the Siamese or the Laos, both lacking the qualities of industry and perseverance. Here, as well as on the Malay peninsula and in the French colonies in the west, Chinese coolies are certainly the only labourers to count on. At present their wages are about 1 sh. a day.

In Further India it has been found very difficult to get the European experts necessary for all mining industry, except the tin-washing, which is well managed by the Chinese. This is partially owing to the bad climate, but it is also due to the fact that the Europeans still are too few and isolated.

Remarks on the Physiography.

Notes on insolation and weathering phenomena.

In these latitudes the influence of insolation would be very strong, if a dense vegetation did not generally shelter the rocks. Traces of arid weathering are, however, often perceptible, especially in the sandstone districts, which are comparatively dry and lacking in shade owing to the fact that the vegetation consists of Dipterocarpaceæ and other defoliating trees. The material is also rather liable to crumble into pieces and thus desintegrates by the weathering. Thus in places more exposed to the sun weathering phenomena resembling such as occur in deserts appear on rocks and boulders, viz. desquamation and development of hollow-weathering. As has been mentioned, it is especially the sandstones that show these phenomena, but I have also observed the same on granitic rocks and limestones.

The desquamation, owing to the contraction and expansion caused by insolation, does not occur on any great scale here, or give rise to special mountain forms. But on a smaller scale the effect of the insolation is to be seen almost everywhere. The superficial parts of rocks and boulders are generally half broken off as scaly flakes and crusts. Limestones, generally less liable to desquamation and similar effects of insolation, I have also seen affected by it occasionally. From some precipitous limestone rocks I once saw a few, thin flakes peel off leaving a light-coloured spot on the dark surface of the rock. These flakes were not bigger than

one or two squaredecimeters and hardly thicker than one centimeter. Such weathering, together with the dissolving of the stone by water, may explain the rounded forms, recalling water-worn surfaces, that this kind of rock often shows, even where running water does not reach it.

Insolation works in this way on a small scale even where the rock is exposed to the sunlight only occasionally, and the effects can even sometimes be seen in rather dense forests. The influence at work is the sudden and repeated alternation from sun-heat to shade, and also the cold of the nights at the beginning of the dry season, and of heavy rains, giving contrast to the hot days.

One effect of the hot climate that is akin to desquamation, is the remarkable weathering out of certain parts of the rocks, which remain as loose boulders on the soil — something rather characteristic of tropics like Siam. Granitic rocks afford the most pronunced examples of the phenomenon, and the ground is often covered with scattered loose boulders, looking like erratic blocks. Where the granite is banked, the outcrop of certain harder beds can give rise to rather morain-like ranges of such boulders, which are sometimes piled up on each other.

In fresh-cut sections, e. g. at the edges of ravines or at places where a well-trodden bullock path crosses the river banks, the crumbled banks contain boulders of half embedded, more resistant parts. On a larger scale I have seen the same thing on the edges of the table-mountains of the Korat plateau, the steeps of which at some places show huge pillars and boulders.

More as a curiosity, but also as an example of the power of the insolation, one phenomenon may be mentioned, which, as far as I know, has not been described before. It was a kind of polygone structure on the surface of sandstone rocks, and struck me rather forcibly as it reminded me of a peculiarity of arctic soil. Here I met with it in several places, but more fully developed at the surface of some slabs near the path to B. Na Hin (in southern Luang Prabang, French Laos states). The surface of the rock was ornamented with a network of shallow cracks and scores, arranged in regular hexagonals of about 2 dm. in diameter. Because of the weathering these cracks, only a few millimeters deep, were not quite sharp, but still very distinct. The likeness to the Arctic structure-soil lies in the evident tendency to the hexagonal shape of the meshes in the net, that is to say the shape for polygones, lying adjacent to each other, that is nearest approaching the circle, in this case, however, in solid stone, not in loose mud and gravel. In their regular form lies an obvious difference between them and ordinary drying-cracks in loose material, which always run irregularly. That they were not fossil drying-cracks is also beyond doubt as the surface of the rocks in question did not correspond to the stratification. Here one must suggest a work of insolation, by means of strong changes of the temperature, causing expansion

and contraction in the superficial parts of the rock. Even if they where not real cracks they offered certain lines of weakness to the weathering.

On some river beds, especially at the Mekong between Ch. Kong and Ch. Sen, I noticed that the rocks, chiefly consisting of sandstones, shists, granites and other igneous rocks (see p. 93), were covered with a black, lustrous, ferruginous or manganese crust, standing out against the white sandbanks. It seems as if sun and water together produced this superficial covering of the rocks as in true desert regions.

Efflorescences of salt (NaCl) are rather common on the Korat plateau in the dry season as noted above. As the Triassic sandstones are strongly salt-bearing, a very dry and hot climate is not perhaps necessary to cause the salt come out. The climate of the Korat plateau is, besides, not a desert climate at all, the mountain ranges, shown surrounding it on the maps, do not exist, and even where its borders are somewhat hilly, the hills do not attain any height to render them climate-barriers. Nor are the «salt plains» of the Korat plateau really dried up, undrained depressions; on the contrary, vast areas are quite inundated in the wet season, and the salt plains are said to be good rice fields. It must, however, be suggested that in the dry season the drought must be very strong to draw up the salt to the surface from deep down. When the first rains are coming, the absolutely dried-up soil absorbs the water and the salt at once, the latter thus not being washed away by subsequent rainfalls, the water of which can more readely run off the surface.

Notes on the Orography.

The correspondence between the tectonics and the morphology is even less marked than one would expect; thus the landscape features of the mountainous table-lands, for instance, and the folded districts are not very different. Though on a closer examination it is not difficult to recognize e. g. the Korat plateau as a table-land, the general appearance of it is that of an alluvial plain, inasmuch as the rivers have not cut down into it and exposed the layers, but have, on the contrary, deposited sand and silt. On the higher parts of the plateau too, the table-character of the mountains is little marked. When seen from a distance, with their gently undulating contours, reaching about the same height, their true character is more obvious. But on the place itself, the general features are less appreciable, because they seldom show flat top and sharp-cut, steep sides. Probably the same fact is generally the case with other well-vegetated countries like Siam. The common idea of typical table-landscape may in reality be obtained from desert or arctic regions, where the destruction on account of temperature-changes, insolation or frost, is very strong, and were the loose material can be carried away by the wind, running water, glaciers or soil-flowing.

In Siam such abrupt edges of the plateau mountains are seldom, and then only more locally, developed. I met with some south of Korat and east of Outaradit, where the steep sandstone precipices also presented, on a small scale, something of the typical desert configuration on naked rocks, such as rounded cliffs, and isolated outposts, etc. The long steep edge of the Korat plateau itself against the low-lands of Cambodja according e. g. to GARNIER (loc. cit.) seems to be a well-developed table-margin of that sort on a greater scale; probably, as mentioned above, caused by a great fault.

In regions of folded layers, more resistant banks occasionally form ridges at their outcrop, thus marking the tectonics topographically. Often, moreover, one of the slopes of such a ridge corresponds to the dip of the layers, the other, somewhat steeper slope cutting off the outcropping beds. But in general the topography gives very few indications as to the tectonics, and much less can be gained on the maps, as they do not give a correct idea of the landscape. Thus, even the great features of the folding lines can seldom be seen from the maps, where even mountain ranges that do not exist are indicated. As pointed out before, the last Siamese edition contains fewer errors. For the morphology the kind of rock is often of more importance than the tectonics, especially in the details. Thus we may mention some peculiarities, occurring in connection with the more important rocks.

Limestones. Especially in the neighbouring states, but also in Siam, travellers have noted the Karst-like landscape with disappearing rivers, caves etc. and the sharp and striking shapes of the limestone mountains. It is especially the mighty Permo-Carbonian limestone series that occasion such striking landscape features, with isolated crags and lofty peaks, or vast highlands with narrow valleys and abrupt borders (the so-called «plateaus» of the Burmese Shan-states, of Annam N.E. of the Mekong a.o.). Similar extensive highlands I also met with in Siam, e. g. in the north-western parts of the country, where they probably form the continuation of the «Shan-plateau»; and N.E. of M. Loye I found another, more isolated district of the same character.

When these limestone series are upraised and intercalated with less resistant shale beds, the mountains become very peculiar, for example those of Pra Bat. S.W. of the Me Ping, stiff, naked ridges, showing the stratification very clearly. But often this formation is quite homogeneous, and then the stratification is very obliterated, even in the best cuttings, as for example at Ch. Dao and further to the north, towards M. Fang. There it is difficult to detect the dip, but, as the isolated limestone peaks do not form a straight-lined series, they may be outposts of more horizontally ayered beds, and not parts of outcropping beds.

The famous Doi Ch. Dao, 2,400 m. in height, is a very good example of the limestone mountains, with its mighty body rising perpendicularly, and its isolated peaks and offsets, as shown on the contour-sketch, fig. 7.

A very characteristic limestone landscape is also shown in fig. 6, taken from the watershed north of Ch. Dao. Of the more uninterrupted, plauteau-like massives, fig. 4, may be considered representative.

In Siam, and also in Annam (e. g. near Luang Prabang) the highest mountains are generally built up of limestone. If this is so in the case of Doi Intanon, the highest peak of Siam (2,575 m. above the sea), I do not know. Along the coast of the Malay peninsula, lofty limestone peaks often remain as islands.

Forests cover the highest mountains of Siam, if they are not too precipitous or too dry. Only on the mountains in northernmost Siam did I meet with pine forests instead of the tropical vegetation.

The explanation of the great resistance to weathering that the limestones are able to offer must be that this rock is very homogenous and compact, and thus less liable to crumble than grained rocks. This fact, together with the jointing, may also contribute to the forming of the precipices and fantastic peaks of the limestone mountains. They do not give rise to accumulations of talus and debris, perhaps such products chiefly passing away in solution. Owing to the fact that such mountains in that way do not become covered by loose products they can keep their naked, stiff forms. North of Ch. Dao, and also at Doi Ch. Dao itself, almost quite uncovered precipices reach down to the plain itself, and only a few boulders, broken down from the walls, are found at their feet. As pointed out before such precipices are often draped with dropstone, a circumstance that also shows the resistance and age of their present forms.

Caves are very common in the limestone districts. They are often held sacred, and adorned with statues of Budda; pilgrims sometimes come to visit them from great distances. As mentioned above (see p. 83) they also are of value to the natives, who get salpetre from phosphate deposits in them. Some of the caves are certainly very extensive and ramified, e. g. the one at Doi Ch. Dao. An old man told me that he had lost himself in it and walked about for three days.

The caves seem to occur along certain geological levels, as, for example at B. Na Or (see p. 83), where I saw a series of seven caves in a line conformingly to the dip of the strata. In such cases one may suggest the presence of less permeable layers, over which the water has to find its way. At Ch. Dao and in the limestone hills towards M. Fang in the north, the caves issued just at the foot of the hills, probably from the bottom layers immediately above the underlying, pre-Carbonian formations.

Most of the caves I saw were dry at the bottom, and many were situated high above the level of the present drainage system; only the cave at Ch. Dao had a small streamlet issuing from it. But at other places, I was told, rivers disappear into them. Mc. CARTHY (loc. cit. p. 184) describes a cave in the neighbourhood of Luang Prabang, where the Nam Ngum is subterranean for a distance of 500 m. Similar phenomena are known also from the Burmese side.

Generally the caves are beautifully draped with dropstone, and the same phenomenon is also often seen in the case of the steeps of the mountains.

Though the limestone districts generally build up the most considerable highlands, it does not seem to be the rule that they constitute the watersheds, probably because of their «Karst»-nature. Moreover, the courses of the rivers may have been determined before the topography got its present features.

Various other sediments and shists. Most of the other sedimentary formations, as well as the shists do not show any peculiarities as to the topography. It is even hardly perceptible that, e. g. shales and such softer rocks are less resistant than the more solid and strong sandstones. Probably the latter are more liable to crumble into pieces as they are more grain-textured. Therefore the rocks under the heading above, do not show any characteristic topographical features, or any marked correspondance to the tectonics. In most cases the hills and mountains composed of these rocks have very gently sloping contours, and they are generally of a rounded or conical shape, characteristic for a mature landscape.

Sometimes the conical shape of such hills is very pronounced, as is shown e. g. in fig. 3.

The igneous rocks do not show much of interest from this point of view. As they are more or less grained and often also pyritic, they easily disintegrate. Generally igneous dykes are not at all marked in the topography, nor do the more extensive eruptive bodies build up any prominant heights. The greatest granitic massive I met with — the one east of M. Fang — however, forms a considerable highland, and it also forms the watershed between two tributaries of the Mekong, and probably also of the Menam.

The conical shapes, spoken of above, seem to be not less characteristic of the granitic hills than of the sedimentary and shistose rocks.

The rivers and the drainage.

A look at a map of Further India shows us how striking are the parallel courses of the rivers Saluen, Mekong and Jang Tse Kiang in Yunnan, caused by the Tertiary folding systems. The Jang Tse Kiang begins to run in an irregularly easterly direction even at 27° Lat., while the Saluen continues in its previous direction, parallel to the N.S. running mountain ranges.

The Mekong, on the other hand, which is of especial interest in connection with the regions spoken of in this paper, continues in its original direction towards the uppermost corner of Siam, but here it begins to show some peculiar features in its course. At Ch. Sen, on about 20° Lat., it shifts over, semingly without cause, to an easterly direction, and

continues this course to Luang Prabang, where it joins the Nam U and assumes the direction of this river, which runs along the post-Triassic folding lines which are very marked in this region. The above-mentioned reach, running east, cuts the upraised strata right across, and in its lower parts it has to break through mighty highlands. This deviation of the course of the river is the more remarkable as the country south of this reach is not high. Here the low watershed towards the Menam system lies very close by the Mekong. On this, the right side the Mekong, is joined only unimportant tributaries, the most considerable of which, the Nam Kok (which joins the river just at the first curve, near Ch. Sen), shows an anomalous deviation corresponding to that of the Mekong itself, it comes from the north and has to shift over to an easterly direction. As a matter of fact, that may perhaps have something to do with the deviations of the rivers spoken of, can be noted that the Saluen shows a considerable westerly deviation which occurs at just the same latitude as the bend of the Mekong.

As mentioned in a previous section, we have here, as I should suggest, indications of the existance of young, E.—W. running faults, and probably it is not mere chance that the basalt of Ch. Kong and the solfataras near Luang Prabang occur just at this sharply deviated reach of the Mekong. A lower E.—W. running part of the same river, perhaps due to something else, begins on 18° Lat. As pointed out in a previous section (see p. 106), two different directions of the strike are observed in these regions, which may be considered to be of different ages. The zig-zag course of the river here has perhaps something to do with these two directions of the strike, but if such a conformity can be shown in the river bed itself, I do not know. As it is at present, the Korat plateau should offer no great hindrance to the river's continuing straight down to the south; but, on the other hand, running in the direction it does, the Mekong has no highland further down to break through.

Below this reach the Mekong again turns in a direction along the common strike of the mountain ranges of Annam, till it flows out in the delta of Cochin-China.

The Triassic plateaus of Korat and the lower Cambodja plain present some noticeable drainage conditions.

The whole Korat plateau drains estwards to the Mekong chiefly through the Se Mun and its many tributaries. If, geologically, the plateau really has the great extension towards the west that I have suggested (see p. 72), the only exception will be the Nam Sak, which flows into the Menam. Similar is the case with the drainage of Cambodja, where all the waters flow to the great lake Ton Le Sap and its outflow into the Mekong. The sharp watershed between the two plateau districts just named is rather remarkable, formed as it is by the southern egde of the Korat plateau only, the so-called Pnom Dang-rek.

On the Menam system less is to be said: it consists of several tributaries about equal in length, draining the depression left undrained by the Saluen and the Mekong systems. The three most important of these tributaries join at one place, Paknam Po, just before they reach the half-submerged limestone range, which runs in north-westerly direction from Don Pia Fai. No remarkable irregularities in their courses are shown, except their deviation at the same latitude as the lower Mekong curve occurs; and this is perhaps only accidental. If here, too, it were a case of a fault-line there would probably be three such ones, running in the same E.W. direction, viz. that of the upper Mekong curve, this of the lower Mekong curve, and a third one along the southern border of the Korat plateau.

Intermontane plains. In many places in upper Siam the valleys widen out to real plains of considerable extension. When one travels over them, especially in the hot season, as I did, one finds that the haze conceals the surrounding mountains, and one might imagine one was passing over the vast alluvial plains of lower Siam. They are scarcely noticeable on the maps, as the topography is too exaggerated on them to allow room for any plains; and where rather narrow valleys are marked, the rivers in reality often wind over broad plains, not seldom several tens of kilometers in width.

As examples of some more important intermontane plains that I passed over on my route, can be noted: those in the valley of the Me Ping, as e. g. that of Mai and that of Ch. Dao; those by some tributaries of the Mekong as e. g. those of M. Fang, Ch. Rai, Ch. Sen, Ch. Kong, M. Loye—Ch. Kan; those in the upper Menam valley as e. g. that of M. Pre and that of M. Nan etc. The two sketches fig. 3 and 4, are from such a plain, — that of M. Loye. These plains appear as ordinary alluvial plains, but they are not uninterruptedly connected with the great delta lands. And the difference between these two kinds of plains is thus that the intermontane ones are caused by a damming-up threshold, that has the same checking effect as the sea at the outflow at the common delta plains.

It seems probable that also the upper parts of the extensive, ramified Menam plain are to be considered as such intermontane plains, inasmuch as the limestone range that runs along the Me Ping towards the south-east crosses the plain, and it seems as if the river system were not entirely unaffected by it, though the same seems to be submerged. A look at the map shows how the three chief branches of the river all join at Paknam Po, just where it crosses this range, and above this place they meander and ramify, giving to the country the character of a true delta land. No rapids or torrents, however, mark any treshold here, and the range is only marked by small, isolated hillocks, standing out over the plain.

The origin of the intermontane plains is not easily discovered. Probably they may be tectonic basins, filled with alluvions. However, in

many places (especially at the gold-washing places, where I had more reason to make closer examinations) I found that the rock-ground was not far below the surface and very often solid rock was seen in the river banks, without being in view at the surface of the flat close by. Thus, in general, these plains do not seem to be real basins — at least not today, or the thresholds should be eroded down to about the flat bottom of the basins. Unless one suggests the existence of flat tectonic depressions, one must explain these plains as being caused by the side-erosion of the rivers and their tributaries, which have to pass over resistant thresholds further down, presenting during long periods a practically constant pass-height. But the relation of the plains to the character of the rock-ground, necessary for such an origin, is not yet discovered. In favour of it we can only point to the presence of a seemingly flat rock-ground.

As the rivers often meander over these plains and do not cut down into them it can be understood that the eroding of the thresholds has now practically ceased. Exceptionally I have been able to trace the remnants of older river planes, situated at a few meters above the present high-water level. Such observations would thus indicate a slow sinking of the river bed, because of the progressive sinking of the threshold. I observed these older planes in the vicinity of Outaradit, and at M. Tern (in the northernmost corner of Siam).

The thresholds of these plains are marked in the river course by rocky obstacles, causing rapids and torrents. The fierce rapids of the Mekong are well known, as they form a great obstacle to navigation. Another example of a river breaking through a highland is the Me Ping, where it penetrates the mighty limestone massive south of Ch. Mai. Here a cañon-like passage, more than 1,000 m. deep, is eroded, as related in a previous section (see p. 102). The almost perpendicular walls of this narrow valley show the considerable work the streaming water has had to achieve. It seems as if the soluting power of the water has also taken part in this work. Often the river has cut half tunnel-like excavations at places where the stream is turned by the rock-precipices (see fig. 10).

Land-rising.

Some authours have suggested a recent rising of the coast round the Golf of Siam, e. g. WAR. SMYTH,[1] who mentions that some harbours are getting shallower. It is, however, questionable if that is not caused by silting up only. In other papers I have not found any clear evidence of the rising of the land, in the form of marine deposits or shore lines etc. above the present sea-level — proofs that ought not to be difficult to find, if they existed.

[1] WARINGTON SMYTH. Five Years in Siam, 1891—96. London 1898.

SUESS (loc. cit.), who gives a summary of the changes of level, has also come to the conclusion that nothing is known to prove such rising in the golf of Siam. He also points out that the constitution of the Mekong delta shows that no noticeable elevation can have taken place in recent times. Nor have I been able to find any traces of noticeable change in the level of the Menam delta, though I had my attention called to the matter. I had, however, no opportunity to visit the coast, wich of course is the best place for making investigations of this nature.

The Menam delta, which in my opinion ought not really to be reckoned as extending further upwards than to the crossing over limestone range below Paknam Po, has still at its proximal part the character of a true delta land, with numerous meandering branches. Here, too, the river was said to inundate the surrounding plains at high water. And, for the rest, it has not cut down deep into the delta land, as it ought to have, if any noticeable rising of the land had taken place. Here, more than 200 km. from the outflow, the height above the sea-level is only 26 m. I could nowhere trace older, and higher delta planes. Nowadays the delta grows very slowly only, the addition of new land at the edge being hardly perceptible. The same thing is indicated by the history of Bangkok, the existence of a permanent bar at the river-mouth a. o. Thus the upper parts of the delta may be considered to be very old.

In the matter of the history of the Menam delta some deep borings existing at Bangkok might certainly have afforded interesting information. I heard about fossil wood or «lignites», marine mollusks etc. that are said to have been met with at considerable depths, but I had no opportunity of getting further information from these borings.

Remarks on the map, Plate I.

I have drawn this map according to my own observations and in correspondence to the geology of the surrounding countries, the Malay peninsula and the southeastern coast of Siam as given by DE LAUNAY. I have, however, not kept his distinction of older pre-Carbonian formations for the southeastern parts of Further India (the «Cambodja massive»). These regions continue the strike of the pre-Carbonian («Silurien et Devonien») of the northern districts, separated from these only by the discordantly superimposed Triassic plateau.

As already mentioned, I must make the reservation to the designation «pre-Carbonian», that very probably there occur among these folded and generally pressed layers strokes of younger, not yet recognized formations.

Less the recent basalts, no igneous rocks have been marked on this map, as they generally are of more local extension, and the knowledge of their distribution is unsatisfactorily known.

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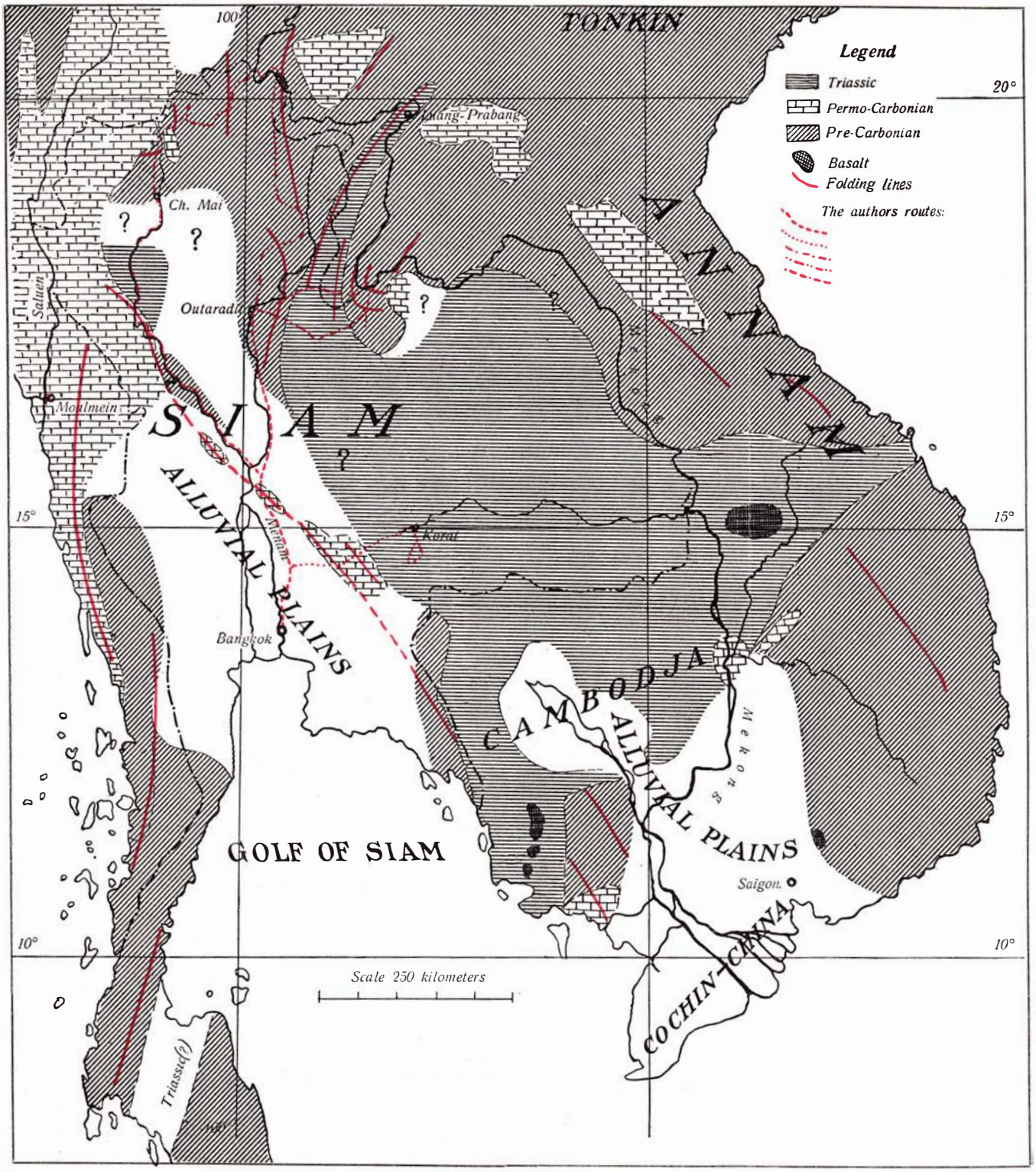

Geological Map of Siam and surrounding Countries.