PROBLEMS OF GEOMORPHOLOGY IN SIAM.

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With Plates 13-21 and five Text Figures.

Introduction.

Geography is the science of the earth's surface. It describes the different parts of the world, their natural conditions and the interactions of man and nature. But it is not a mere description; on the contrary, it aims at explaining the features observed. It begins with the forms of the earth's surface (or the geomorphology) in their relations to the geological structures and form-building forces. It seeks to demonstrate how the geographical position and the principal features of morphology produce the conditions of the climate. Then it deals with the distribution of vegetation, in its relation to soils and climate, and, at last, it makes *man* an object of investigation and tries to explain the general features of his distribution, his life, his industries and his culture, as resulting from the countries he lives in, and from the relations which connect the country in question with other parts of the human world. By doing so geography aims at explaining the essential characters of the different parts of the world.

To-day we have to deal only with one part of the geography of Siam. We will consider the morphology of the country, that is to say, the problem of land forms and their development. There is but very little literature available touching these questions; there is a work of the Swedish geologist Bertil Högbom,[1.)] who travelled in 1912 in the northern and eastern parts of this country, and two reports on his investigations by the American oil geologist, Wallace Lee,[2.)] who, in 1921/22, travelled in the south as well as in the

1.) *B. Högbom.* Contributions to the Geology and Morphology of Siam. Bull. Geol. Inst. of Upsala, Vol XII, p. 65-128. Upsala, 1913.

2.) *W. Lee.* Reconnaissance Geological Report of the Districts of Payap and Maharashtra, Northern Siam. Dept. of State Railways, Bangkok, 1923.

W. Lee. Reconnaissance Geological Report of the Provinces Puket, Surashtradhani, Nakon Sridhamaraj and Patani in Siamese Malaya. Dept. of State Railways, Bangkok, 1923.

north of Siam. They all represent a good deal of valuable work and they have proved of great use to me.

But both authors only touch the questions of morphology where it concerns their particular studies. To deal just with these questions was one of my most important tasks. If I give to-day a short report of the first results of my observations, I do that only with the reservation that my lecture cannot be more than a preliminary report, because I have not completed my observations and the geological literature of the neighbouring districts has not yet been completely at my disposal.

The observations which are taken as a basis for my explanations were made on five journeys, and some more insignificant excursions, in 1927/29. In the autumn of 1927 I arrived in Bangkok. In November I started for my first journey to the *West* of Siam, the district of the river Meklong and its sources Gwe Yai and Gwe Noi After my return at the end of December I made some smaller excursions in the *South-east* of the country, in the districts of Chantabun and Siracha. In the second part of January 1928 I started for the *North* of Siam which I crossed on the following route: Maung Prae —Muang Nan—Bo Kloua near the Eastern frontier, then in a Western direction to Muang Poa—Chieng Kam—Chieng Rai—Chieng Sen—Muang Fang—Chieng Mai. At the end of March I returned to Bangkok and started in the first days of April for the *South* where I made my excursions at first in the tin-mining districts of the northern Malay States. After that I proceeded to the Siamese tin-island of Puket and along the west coast as far as Takuapa. Then I crossed the Peninsula on the line Singora-Satul, visited the mining districts of Tungsong and Nakorn Sritamarat and, after having crossed the northern hills of the Kao Luang from Sichon to Bandon, I returned at the end of June to Bangkok. On the fourth journey, for which I started in September 1928, I went from Chieng Rai down the river Mekok and then the Mekong by raft and boat via Luang Prabang—Pak Lay—Vieng Chan to Nong Kai. From there I crossed *Eastern Siam*, the Korat Plateau, from North to South, and going on in this direction I traversed the Dong Pia Fai range, the southern border of the plateau, till I reached the rice field plains of Prachinburi. I returned to Bangkok at the end of November and started again in the middle of December for Chieng Mai From here I crossed the *North-west* of Siam in the direction of Mehongson and went across the Salwin through the southern Shan States to Mandalay. Returning from Burma I crossed the western mountains of Siam once more, on the route Moulmain—Mesod—Raheng—Savankalok, from where I returned to Bangkok in the middle of February 1929.

Before speaking about the results of my observations, made during these journeys, it will be necessary to explain in short the principles of morphological research in general.

PART I.

There are two groups of forces creating the relief of the earth's surface. We call them the endogene and the exogene forces. The first named, the endogene forces, find their expression in the movements of the earth's crust—the earth's crust, that is to say the exterior part of the globe consisting of some ten kilometers in thickness of solid rocks. The earth's crust we must not imagine as of great stability. On the contrary, it is movable in an extraordinary way The pressures which are at work are so immense that they overcome its stability. But the movements are so slow that only very seldom are we able to observe them by measurement.

These movements of the earth's crust we may divide into two groups. The first we call the orogenetic, or the "mountain-building" movements, the other the epeirogenetic, or the "continent-building" movements.

The orogenetic movements can be of different kinds They may appear as very intensive foldings of more or less extensive parts of the earth's crust, as, for instance, in the Himalayas or the Alps of to-day; or they may appear as simple vertical movements accompanied by faults, which limit the moved parts of the crust against each other. A very good type of this kind of movement is the mountain system of middle Europe.

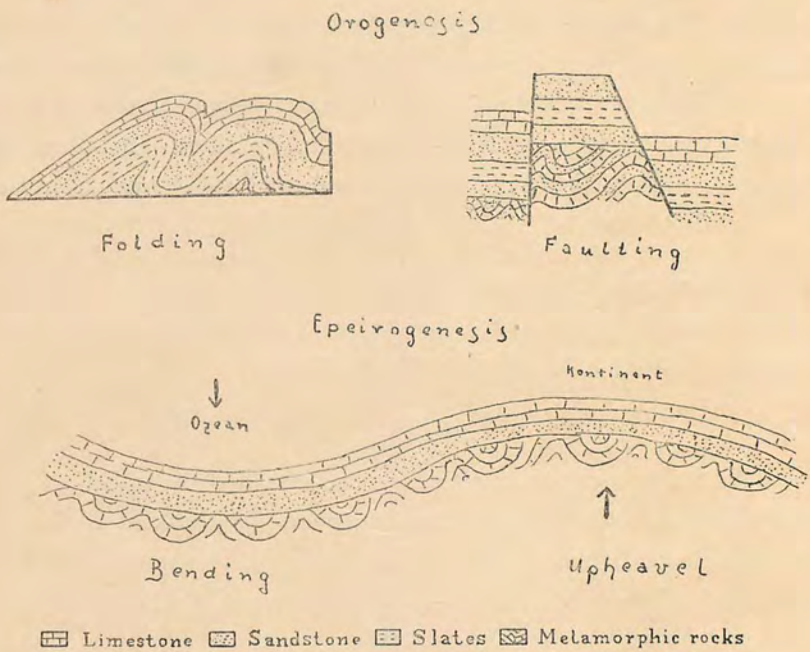

Fig. 1.

The counterpart of the orogenetic form of movements is the epeirogenetic movements, which stretch over wide areas and consist of very slow upheavals and bendings, such as the upheaval of Skandinavia, which is still going on, or the upheaval of Central Asia, also rather young from a geological point of view.

All these endogene forces aim at increasing the relief of the earth's surface. Against them the other group of forces is working, the forces of destruction, which have already been termed the exogene forces. They are those forces which are produced by the climate, the changing of temperature, water which falls in different forms on the earth's surface, ice in the polar regions and on the highest mountain ranges, and finally the wind dominant in the deserts.

For our landscape here only the water is of importance.

Firstly water is the chief cause of chemical weathering. Chemical decomposition working on the surface alters the hard rock into material which can be easily transported. The water falls as rain, it forms small water channels, which run and take their way down the slopes. Penetrating the soils, the water makes them movable, and moving itself it takes fine particles of weathered rock down the slopes. This kind of transport we call "*denudation*".

In the lower parts of the landscape the small water channels flow into bigger watercourses and these into rivers. Now the water possesses not only the power of transport, but a very effective power of "*erosion*," which is able to cut deep valleys, even in unweathered rock. So running and flowing water is forming the relief of landcape through erosion, and denudation. While we see that the endogene forces aim at increasing the relief of the earth's surface, the exogene forces, on the other side, aim at destroying all elevations which arise through the working of the first named, which we call also the "*tectonical*" forces. The aim of the destruction is to level all differences between high and low, to make in the end a *plain*, stretching without any difference over all kinds of rocks which compose the landcape. Such a plain, which will always show some small undulations, a plain which results from a long period of uninterrupted destruction, we are accustomed to call a "*peneplain*", according to the terminology of the American morphologist W. M. Davis. [1.]

Out of the competition of the endogene and exogene powers, just explained, there result the main features of morphology. But of great importance for the details of form development are the material in which the forces of erosion and denudation have to fulfil their work.

From this point of view we distinguish a great difference between the numerous kinds of rock in their resistance to the work

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1). *W. M. Davis.* The systematic description of land forms. Geogr. Journ. xxxiv, London, 1909. A critical discussion of his method and terminology is in the valuable work, *A. Hettner*, Die Oberflächenformen des Festlandes, 2nd. ed. Teubner, Leipzig, 1928.

of the exogene powers. We will explain this for some of the most important rocks of this country.

The chief type of the intrusive rocks is the *granite*. It naturally possesses a great resistance to the exogene powers, but there is no rock which would not become a victim of chemical weathering, if there is only time enough for its work. So we often find the granite in this tropical climate weathered many meters deep into a sandy clay, which on its part is rather easily carried away by water running down the mountain slopes. Water for weathering is always available because the granite is impenetrable by water, so that the water which does not run down along the surface is stowed at the bottom of the weathered cover on the surface of the unweathered rock. Nearly the same conditions predominate in regard to the very hard *crystalline schists*, which are usually found near the granite, by whose intrusion it is metamorphosed from sedimentary rocks of different kinds. Denudation is therefore of great importance in the development of the forms of the granitic and other crystalline mountains, which show, therefore, soft and rounded forms.

The very opposite features to those observed in the granite we find in the *limestone*, which plays such an important role in the morphology of this country. Limestone is penetrable by water. The manner of its destruction is chiefly by solution. The water falling on the surface of a limestone mountain does not run down its slopes, but *sinks* into the numerous cracks and through the limestone itself, and appears again farther down in the valleys as springs containing a very high percentage of dissolved lime. It does not exert any influence on the surface development at all. There is very little denudation working in limestone districts, but the erosion of rivers and bigger streams which, by their rich supply of water, are able to cut deep valleys in the solid and very resisting rock, is of great importance. Therefore in the limestone we find the high, very steep and rocky walls which rise suddenly from the flat bottom of river valleys and plains. Erosion is the predominant power in limestone districts, while denudation has but very little influence.

Between these two extremes, the granite and the limestone, we find very many transitional states. There are the softer metamorphic rocks, the sandstones, the sandy slates and pures slates, where the powers of erosion and denudation find far less resistance, developing much softer forms as a result of quicker destruction than in the districts of the very resistant rocks mentioned above.

After having stated that the morphology of the earth's surface is the work of endogene and exogene powers, we will try by way of deduction to obtain an idea of the development of land forms by different materials and under different conditions of the tectonical movements.

A plain developed in granite, limestone, and sandy slate may be raised to a certain height above the sea level. In all these three cases rivers may cut their valleys down till they reach the base level of denudation as represented by the sea level. We would get in this case three different forms of valleys as shown by fig. 2.

Fig. 2.

The narrow valley in the granite is a result of its great resistance against the forces of destruction. The work of denudation in granite is shown by the rounded off forms of the upper parts of the slopes. Extremely steep slopes are typical of the valley in limestone, where denudation is of no importance. The wide valley with flat and rounded slopes in the third case is an expression of the fact that soft slates are far less resistant against erosion, as well as denudation.

In these cases we have only paid attention to the development of a valley. Now let us see what the whole landscape will look like after destruction has been going on for some time (fig. 3).

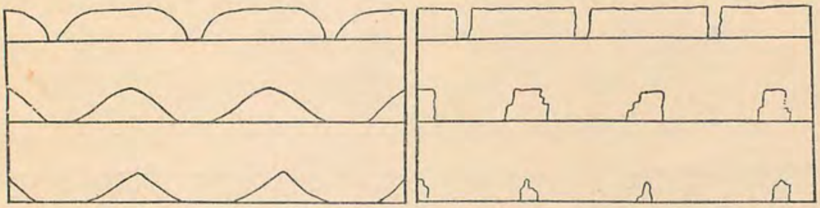


Fig. 3.

In the granite, as well as in the limestone, exposed to the conditions as given above, the area of the plains increases through the erosive work of meandering rivers. The area and the height of the mountains rising out of the plains, are decreasing, but in all stages of development the slopes in the granite and in the limestone will preserve the forms which are typical for the rocks in question, as stated before.

This example is only chosen to show the influence of different *materials* in the development of land forms. Now we know that the material is only of importance with regard to the *detail of* forms, while the *great features* are the result of endogene earth movements and forces of destruction. The proportion in which these forces are acting is the deciding factor. The example as shown above gives a case where at first the endogene powers have been stronger than the exogene. As a result of that proportion, we state the fact that the relief of the landscape is at first increasing. It is imaginable that the proportion might be the reverse, if, for example, the exogene powers are stronger than the endogene, which would be the case if the movements are starting very slowly, then the earth movements on the surface will not be noticeable at all. No relief at all would be developed! The form of the *plain* would be preserved and the only changed feature would be the kind of rocks which appear on the surface of the plain or the hilly landscape, as shown in fig. 4.

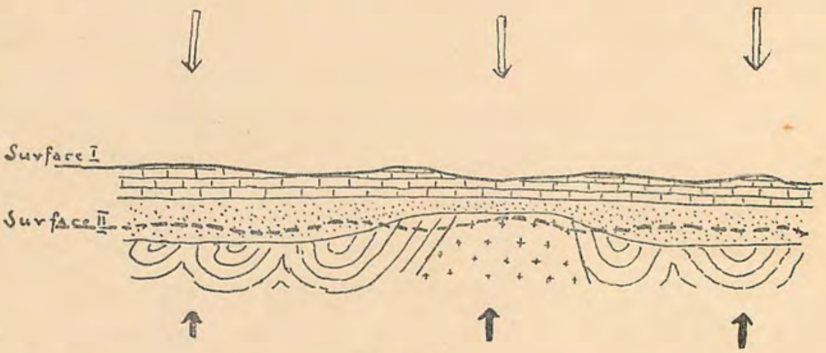


Fig. 4.

There are now innumerable combinations of proportions between endogene and exogene forces imaginable. For the main types we have gained certain distinctive indications, so that modern morphology really is able to give an explanation of land forms on a genetic basis. [1.)]

PART II.

After these general remarks we can now see the direction our investigations should take when we come to deal with the morphology of Siam.

All morphological work naturally is based on observation. The more deductive way I followed in my explanations was only for didactical purposes. The work itself has to be based on induction, but naturally never can go on without a good deal of deduction too, if the work is to be scientific.

In the first place we have to observe the *land forms* themselves, following a descriptive method exclusively. Further there are accessible for observation two very important "factors", the working of the *exogene powers* with their changing conditions in the different

1.) The importance of the proportion in which endogene and exogene forces are working is particularly discussed in the work of *W. Penck*, Die morphologische Analyse, Stuttgart, 1924.

seasons and then the *geological features*, that means, for our purpose in the first place the distribution of the different kinds of rocks, Then we must deal with the land forms observed in their relation to these "factors", and proceeding in this way we will be able to eliminate those features which depend on the last of our working powers, which are not observable themselves, the *youngest movements* of the earth's crust in South-east Asia. After that we may complete the work by giving an explanatory description of the forms resulting from the geological structure and the endogene and exogene forces.

1) *The Main features of land forms observed.* One of the most impressive morphological features in Siam is the *preponderance of wide plains.* We have to distinguish those with mighty alluvial deposits like the Menam plain; those with only a thin cover of alluvial deposits like the plains in the Peninsula, in the South-east and in the North of the country, and those with nearly no general alluvial cover at all, like the Korat plateau.

The second of the main features is the appearance of *mountain ranges all stretching in the same direction*, chiefly from N to S. as well in North as in West and South Siam, and on the other hand the absence of such ranges in the Korat district, or the eastern part of Siam.

The third impressive feature is the *very steep slopes* with which the mountains and mountain ranges ascend from the plains. Everyone who makes the journey along the southern railway will have made this observation. The same features will be found in the district of Kanburi, in the Menam plain north of Lopburi, and along the western slopes of the Korat plateau. Not only these "island-mountains," so called according to the morphological terminology. but also the closed mountain ranges in Northern Siam, which divide the big plains from each other, rise very abruptly from the latter, leaving between plain and mountain slopes sometimes a narrow zone of low "foot hills," so called by Wallace Lee.

And the last important feature, not mentioned hitherto in the literature, is the *remnants of plains or of flat mountainous country* *in the higher levels* of the Siamese landscape. I found them developed as well in the mountainous limestone country north of Kanburi as in Northern Siam in the highest parts of the mountain ranges in the extreme north-eastern section of the country, where I first made their acquaintance and in the limestone ranges of the north-west, where they are to be found south-west of Muang Fang in an especially distinct form.

In explaining these four characteristics of Siamese scenery we will answer the principal questions the morphology of this country is putting before us.

2). Let us at first now have a look at the *geological structure* in its relation to morphology. Only those parts of the country which rise over the plains are available for observation. But sometimes, as in the tin-mining districts of the South, in the open-cast mines, we have the opportunity of seeing under the alluvial masses of the plains. The cross sections shown in fig. 5 demonstrate the chief features of structure. All rocks in this country are folded. Only those in the east did not undergo the folding processes. This part of Siam, the Korat plateau, belongs to a very stable part of South-east Asia which we may call the *"massif"* of South-east Asia, including also Kambodja and other parts of French Indochina.[1.)] While we find in the Korat district over wide areas the same young and flat bedded sandstone, the very quick changing of different rocks from east to west is typical for the remaining parts of Siam. Folding accompanied by granite intrusions is the cause of this structure and of the metamorphosis, which the intruded districts, and especially the limestone, have undergone. I distinguish two main periods of folding, of which the last and most effective one may have taken place in late-mesozoic time.

As will be stated later on, the folding process itself is of no influence on the morphology of to-day. But the distribution of the rocks, caused by the folding, is of very great importance. The

1.) *B. Hogbom*, loc. cit, 1913, p. 109 has introduced the name "Massif of Further India", but using it in a wider sense.

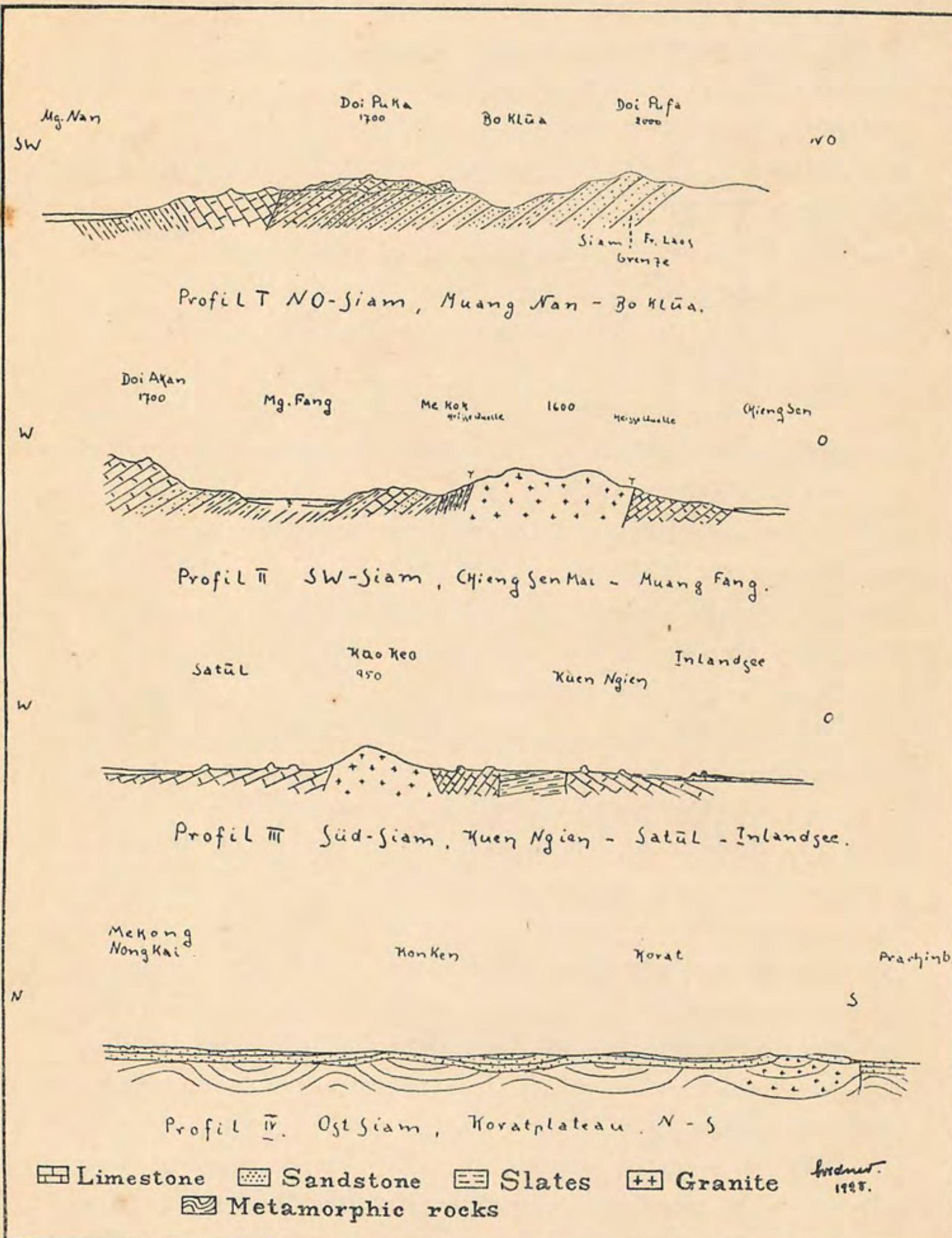

Mg. Nan
Doi Pu Ka
1700
Bo Klüa
Doi Pu fa
2000
SW
NO
Siam
Fr. Laos
Grenze
Profil I NO-Siam, Muang Nan - Bo Klüa.
Doi Akan
1700
Mg. Fang
Me Kok
1600
Chieng Sen
W
O
Profil II SW-Siam, Chieng Sen Mai - Muang Fang.
Satūl
Kao Keo
950
Kuen Ngien
Inlandsee
W
O
Profil III Süd-Siam, Kuen Ngien - Satūl - Inlandsee.
Mekong
Nong Kai
Kon Ken
Korat
N
S
Profil IV. Ost Siam, Koratplateau N - S
Limestone
Sandstone
Slates
Granite
Metamorphic rocks
1928.

Fig 5.

rivers cut their beds down in the less resistant rocks and therefore they follow in their course the chief direction of structure from N to S. So we see already that the direction of the mountain ranges is the work of river-erosion which makes them reflect in a degree the old folding-structure. The single mountain ranges, in their turn, reflect in their forms the different kinds of rocks which are exposed to the agencies of the exogene forces (plate 20).

3). The investigation of the *exogene forces* will make us understand that the monsoon climate has the tendency to enlarge the area of valley-plains in the more mountainous parts of the country. In the rainy season the forces of destruction—decomposition of rocks and transport of material—are working in the *mountains* as well as in the *plains*. In the dry season conditions are quite different. While the surface of the *mountains* and the beds of the *mountain rivers* in the dry season are drying out very quickly, in the plains, water, collected in the main stream, is available all the year around. At the bottom of the alluvials, which are filled up with water, the weathering is going on and makes the materials movable in a very high degree. I had the opportunity of making this observation especially in the plains of the tin-mining districts of the Peninsula, where the tin-bearing granite at the bottom of the alluvials is decomposed to a very soft clay mass. So the rivers meandering over the plain are able to undercut the mountain slopes, thus enlarging the area of the plains and preserving the steep slopes of the mountains rising out of the plains. The "island mountains", well known to everybody, and already mentioned, also those rising to-day out of the sea, are the work *not* of *marine* forces, but of the same subaerial process as described above. The alteration of sea level is only a deciding factor as to whether such a limestone or granite hill appears as a real island rising out of the sea, or as an island-hill towering over the plains, sometimes very far inland. In my opinion the sea has only had a secondary influence in forming the slopes of the "islands."

4) But the development of the *wide river plains*—I am not

referring to the Menam plain—can not be explained in this way alone. The wide plains of Northern Siam, for example, do not seem to stand in any reasonable proportion to the rivers flowing over the alluvials of their bottom. Mr. Wallace Lee has therefore come to the conclusion that the plains in general have arisen as faults and tectonical flexures, bent down, as he believes, in the late tertiary age. There is really an important fact to support this explanation. That is the bore hole made near Muang Fang in the wide plains of the Nam Fang. Here, while searching for oil, they went down in the alluvials not less than 216 m. without having touched the rock. For my part I am inclined more to the opinion that the conditions described above are the result of local faults which have taken place just there, along the line which separates the granite from the western limestone. There are many observations, which speak against a tectonical explanation of the wide plains in general. In the Peninsula the alluvials, as I stated, usually do not exceed a thickness of 20 or 30 m. Here the origin of the plains as a result of the work of erosion by rivers is undoubted. In the North no exact statements can be made owing to the lack of sections in the alluvials. But in the northern plains we often find flat hilly country overlooking the alluvials, often in the middle of the plains, corresponding in height sometimes to the foothills surrounding the plain. In these foothills I found in many places old levels of denudation as remnants of an older plain which once upon a time was developed at foothill level, a plain which developed through erosion of a meandering river and which stretched over a still larger area than the plain of to-day. There are also remnants of still higher levels which support my opinion that a very slow process of upheaval caused the development of this scenery. So the river, while the upheaval was going on, had only to carry away the deep weathered bottom of the valley, in that way denuding down the whole plain until it reached the level of to-day.

This opinion, gained from the observations in the lower parts of the landscape, grew to certainty, when I found the remnants of an old flat landscape just on the highest parts of the north Siamese landscape. At Doi Pulanka near Chieng Kam and at Doi Ankan south-west of Muang Fang there are these remnants, which are shown in plates 19 and 20. This high flat landscape is the one from which a genetic description of land forms in Siam has to start.

Regarding the remnants of this old landscape; it was the most important result of my last journey through the Southern Shan States that I found there the same high plateau, on a much bigger scale, stretching over wide areas, west of the Salwin. There they are developed in different levels from 800 m. up to 1,400 m. above sea-level. Through further investigation of these remnants it will be possible to connect the land forms of Northern Siam with those of the neighbouring parts of South-East Asia.

PART III.

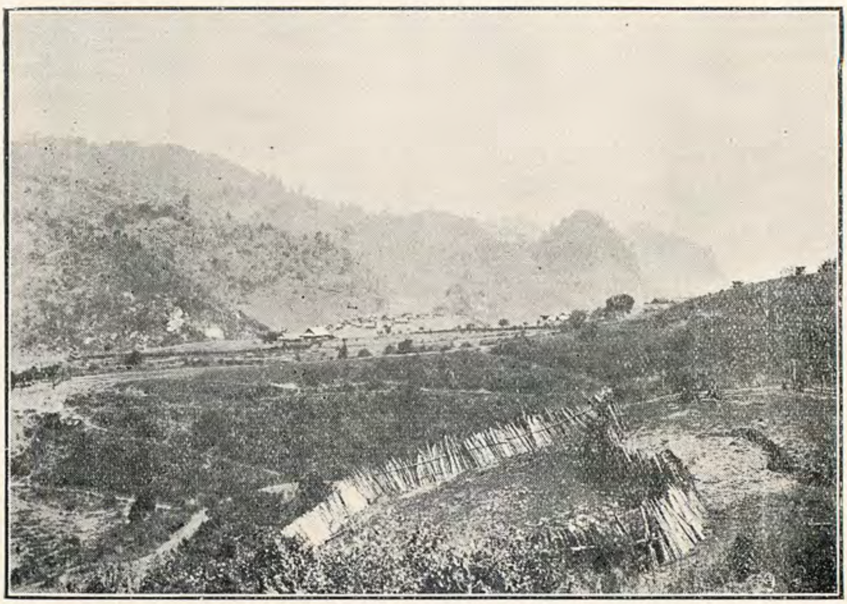
I have finished the analysis, and now shall try to describe the development of land forms in Siam by a synthetic sketch.

All geological happenings that took place before the last decisive folding in the late-mesozoic age are of no interest from a morphological point of view. It is not certain whether mountain ranges were developed in Siam after the foldings in this period. Such a supposition is not necessary because the folding can have taken place so slowly that the forces of denudation were strong enough to prevent the mountain building. I for myself do not believe that mountain ranges of a large size were ever developed here. Otherwise the young rocks of the unfolded Korat plateau would show another appearance. But it is certain, that after the folding there has been a long period of denudation which has destroyed all characteristics of such a hypothetical mountain landscape. The remnants of such a flat landscape are to be found in the highest regions of the northern Siamese mountains as well as in the limestone country north of Kanburi. It seems to me as if these old landscapes whose contemporaneity is not sure, have had the character of wide plains with more insignificant hilly districts scattered over them. I incline to guess, that the high plateaus of the

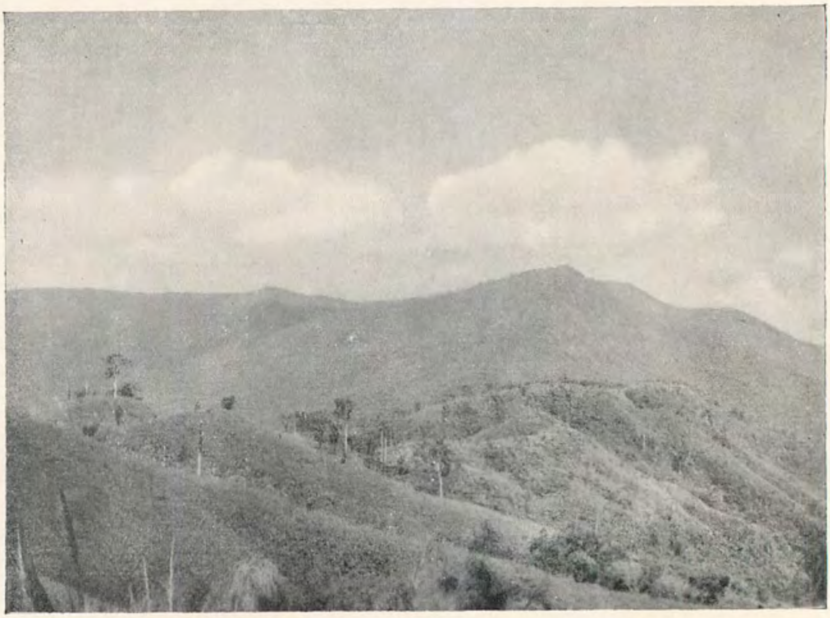
Southern Shan States, which I found there up from 1,300 to 1,500 m. in height, reflect still in our days the character of scenery which stretched once all over South-east Asia. It may be possible that this landscape was lying in a level not very different from that of the Korat plateau of to-day, which also reflects in its present form the character of the old scenery.

Then younger movements started, perhaps in connection with the last folding period in the Himalayas, in pliocene or old pleistocene time. The *Korat plateau*, may be as a "pièce de résistance", has held its old level. The *Menam plain* has been sinking down as a syncline with increasing intensity in its southern parts. The Peninsula, Western and Northern Siam began a slow movement in the opposite direction. In the rising parts the old landscape was destroyed and the wide plains, as river plains already pre-existing on the old landscape, sunk down in the raised country through erosion of meandering rivers. The smaller water courses cut their valleys in the rising mountains which separate the river plains from each other. Denudation has been working on the mountain slopes, till these formed the long-stretching combs, so typical for the north part of Siam, as well as the west and south. Only in the biggest mountain-*massifs*, and especially in the limestone, the denudation had not the power to cut away the last remnants of the older flat country. In the lower parts of the Siamese landscape, especially in the Menam depression, the rivers have been depositing the fine alluvial ground for thousands of years, building up in the struggle with the sea the wide plains, where in our day a peaceful folk is cultivating the fertile soil, the gift of the mountains in the north.

Limestone range south of Kanburi, Western Siam, towering with steep slopes over the Meklong Plain west of the river.



Doi Ankan, south-west of Muang Fang in Northern Siam. Remnants of an old flat valley at 1240 metres altitude, near the summit of the limestone *massif*, which rises with very steep slopes from the plain of the Nam Fang. On the flat bottom of the valley are villages of Meo, Yao, Musso and Lissao.



Doi Pulanka, south-east of Chiengkam, Northern Siam, taken from the south. In the foreground slates, denuded down, showing undulating relief, due to the working of denudation on slates impenetrable to water. The Pulanka *massif*, of more resistant sandstone and limestone, is in the background. Remnants of an old flat landscape in its high parts are occupied by some Meo and Yao villages.

" Island mountains " of limestone south of Haad Yai, Southern Siam, east of the railway line. The plain is about 4 metres above sea-level.