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# Report on
# The Stratigraphical and Palaeontological Reconnaissance in Thailand and Malaysia
# 1963—1964

By
Colombo Plan Experts

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Overseas Technical Cooperation Agency

1964

## Preface

This mission was despatched to Thailand and Malysia from the Overseas Technical Cooperation Agency at Tokyo as a project of the Colombo Plan for the technical cooperation in Southeast Asia. The aim of this project is to provide scientific infomations on details of geology and palaeontology in selected areas of the two countries which bear special imports for the future exploration of mineral resources and land utility.

The party of the mission which consists of eight experts has carried out field works from early December, 1963, to late February, 1964, in close collaboration with many geologists of the governments of these countries.

This report comprises the results of these field works, beside brief notes on some contributions to the regional geology and palaeontology already published in Japanese journals and also the bearing of this kind of projects which is not merely of academic interest as easily so accepted. The reader is requested to understand that this is no more than a preliminary report which will be followed by many important results achieved through laboratory works by various specialists on the collected materials.

On behalf of the mission I wish to express here cordial thanks to the staffs of the Department of Mineral Resources at Bangkok and the Geological Survey, Federal HQ. at Ipoh and all others related to this project for their assistance and cooperation in many ways with which it was only possible for the party to accomplish the project.

Japanese Mission for the Palaeontological and Stratigraphical Reconnaissance in Thailand and Malaysia in winter, 1963-1964.

Teiichi Kobayashi, the leader.

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## I. Introductory Notes

### a. The General Setting of the Project

The stratigraphical and palaeontological reconnaissance survey was undertaken by a Japanese mission of which the Overseas Technical Cooperation Agency was the sponsor, and the enterprise was performed in close collaboration with many geologists of the governments of Thailand and Malaysia.

It was some 20 years ago that Kobayashi has commenced the study on the fossils of Thailand with some palaeontologists. Recently the research along this trend was much improved in accordance with the increase of materials which were submitted him not only from Thailand but from Malaya and other parts of Southeast Asia. They were distributed to many specialists for study and the results published already through scientific journals are also rapidly accumulating.

In the mean time there arised several problems which cannot be solved without field surveys. Therefore a party composed of five experts from three universities in Japan was organized by Kobayashi and a palaeontological reconnaissance was made in Thailand in winter, 1962-63 by the funds of the Japanese Department of Education and the Asia Foundation in addition to some contributions from private companies and in cooperation with the staff of the Royal Department of Mines at Bangkok. This enterprise was very successful and profitable.

On this occasion Kobayashi, the leader of the party, made a short visit to the Malayan peninsula for a preliminary observation. There Dr. J. B. Alexander, director of the Geological Survey, Federal HQ. at Ipoh has suggested him the Colombo plan to make a similar research in Malaysia. Mr. Vija Sethaput, director general of the Royal Department of Mines at Bangkok also agreed to take the next step of the research by the Colombo plan. Thus the applications for experts were presented from the governments of these two countries to the Foreign Ministry at Tokyo where the project was taken up for a part of the Colombo plan in 1963. In considering the climatic condition and the university calender the field works were done in the period from the beginning of December, 1963, to the latter part of February, 1964.

### b. The Organization of the Mission

The postulated governments appointed Kobayashi for the organizer of the party. Therefore he selected the best suitable persons for the objects of the mission from all specialists of Japan. Merit to the warm understanding of the

staffs of the geological institutes of four universities the proper adjustment for the calender of the institutes was made and the party could be organized promptly as follows:

Leader: Dr. Teiichi Kobayashi, Professor Emeritus, University of Tokyo.
Secretary: Dr. Tadashi Sato, Associate Professor, University of Tokyo.
Experts: Dr. Ryuzo Toriyama, Professor, Kyushu University, Fukuoka.
Dr. Junichi Iwai, Professor, Tohoku University, Sendai.
Dr. Toshio Kimura, Professor, University of Tokyo.
Dr. Tadashi Sato, Associate Professor, University of Tokyo.
Dr. Kazuo Asama, Assistant, Tohoku University, Sendai.
Dr. Takashi Hamada, Assistant, University of Tokyo.
Dr. Hisayoshi Igo, Lecturer, Tokyo University of Ecudation.

c. The Subjects of Research and the Investigated Areas

The following subjects and areas were selected as the result of consulting with the authorized geologists of the postulated organizations.

1. The Permian Rat Buri limestone of the Sara Buri district-- the continuation of the previous research.
2. The Palaeozoic formations in Peninsular Thailand-- to search key beds most important for the geological survey in dense jungles.
3. The Permo-Carboniferous formations of the Loei area-- to orient fossiliferous horizons. This is a great help for the exploration of mineral resources which is now in progress in the area as a part of the Mekong project.
4. The sedimentological and stratigraphical studies on the Khorat series of Northeast Thailand containing saline water. The series involves various problems on the development of land.
5. Fossil plant beds in east-central Thailand which bear great importance to analyze the geologic structure and decipher the geologic history of Thailand.
6. The Palaeozoic stratigraphy and the geologic structure of the Langkawi islands, Northwest Malaya.
7. The Mesozoic and Palaeozoic formations in Perlis and Kedah.

8. A preliminary observation of the southern part of the Malayan peninsula for the future research.

The east side of the peninsula was excluded from the present project by the reason that the winter is rainy season.

## d. The Schedule of the Mission-Members

The individual schedules of the eight members are as follows:

| | |
|---|---|
| Kobayashi: | December 1, 1963-December 21, 1963. |
| Toryama: | December 1, 1963-January 10, 1964. |
| Iwai: | December 1, 1963-January 25, 1964. |
| Kimura: | December 12, 1963-January 7, 1964. |
| Sato: | December 1, 1963-February 10, 1964. |
| Asama: | December 1, 1963-January 25, 1964. |
| Hamada: | December 1, 1963-February 24, 1964. |
| Igo: | December 1, 1963-February 24, 1964. |

All of the party but Kimura flew by AF from Tokyo to Bangkok on the first of December. There succeeded busy four days when they made preparation for field works and a short trip to Ban Saen, southeast Thailand, beside the second colloquium which was held at the Department of Mineral Resources on December 3rd, 1964. The field works were begun in Thailand already on the 6th of December.

On the 12th, December Kobayashi and Igo moved from Bangkok to Kuala Lumpur and next day to Ipoh where they made indoor works until December 15 when Kimura arrived. Then they left Ipoh immediately for the field work in the Langkawi islands. (See Kobayashi's Schedule)

The eight members of the mission have constituted various teams by different combinations and made field works to investigate the above eight subjects as shown in the table 1.

Preparation, labelling and other indoor works required one or a few days before and after each field trip. Some days were spent for preliminary studies on the collections deposited in the Geological Survey at Ipoh and the Department of Mineral Resources at Bangkok.

## e. Acknowledgements

The acknowledgements of the members of the mission are made here to the Economic Cooperation Bureau of the Foreign Ministry and the Overseas Technical Cooperation Agency at Tokyo for the arrangement and sponsership of the project, to

Ambassador Hisanaga Shimazu and Ambassador Wataru Okuma and the officers at the Japanese Embassies at Bangkok and Kuala Lumpur for assistances at the destination, to Mr. Vija Sethaput, Director General and Mr. Saman Buravas, Deputy Director of the Department of Mineral Resources at Bangkok, Mr. Kaset Pitakpaivan, chief of the Geology Section of the Department and Dr. J.B. Alexander, Director of the Geological Survey, Federal HQ. at Ipoh, Malaysia (Malaya) for the forceful cooperation in the project and Messrs. Din Bunnang, Pumwarn Komalarjun, Manas Veeraburus, Armon Methikul, Charan Poothai, Angoon Hongnusonti, Boomai Inthuputi and Akanist Sueanasing of the department and Messrs. C. R. Jones and W. D. Procter of the Geological Survey for the guidance, collaboration and assistances in the field works.

Many thanks of the party are due also to Mr. Tem Smitinand of the Forestry Department at Bangkok and Mr. Bala Melon of the Forestry Research Institute at Kepong, Selangor for the kind offer of wood specimens for comparison, to Mr. Masao Sagawa, leader of the survey mission on mineral resources in Thailand, 1963, and now Managing Director of the Mitsui-Yip Mining Company at Haadyai, Sonkhla, Mr. L. Gardner of the United States Operation Mission to Thailand and Dr. C. Y. Lee and Mr. Hideho Sawada of the ECAFE, United Nation, Bangkok for their kindness in various ways, and finally to the following Specialists for their cooperation through the laboratory works on the old and new collections.

Dr. Ryuji Endo, Professor Emeritus, Saitama University, Urawa.
Dr. Seido Endo, Research Fellow, National Science Museum, Tokyo.
Dr. Tadashige Habe, Malacologist, National Science Museum, Tokyo.
Dr. Tetsuro Hanai, Associate Professor, University of Tokyo.
Dr. Wataru Hashimoto, Professor, Tokyo University of Education.
Dr. Itaru Hayami, Assistant, Kyushu University, Fukuoka.
Mr. Yasuhide Iwasaki, Graduate-student, University of Tokyo.
Dr. Taro Kanaya, Associate Professor, Tohoku University, Sendai.
Dr. Kametoshi Kanmera, Associate Professor, Kyushu University, Fukuoka.
Dr. Saburo Kanno, Assistant, Tokyo University of Education.
Mr. Toshio Koike, Graduate-Student, Tokyo University of Education.
Dr. Enzo Konno, formerly Professor of Tohoku University, Sendai.
Mr. Shuji Kudo, Chemist, Petroleum Exploration Company.
Dr. Yoshihiko Kurosawa, Entomologist, National Science Museum, Tokyo.

Dr. Sumio Sakagami, Associate Professor, Hokkaido Gakugei University.
Dr. Tokio Shikama, Professor, Yokohama National University.
Dr. Kiyoshi Takahashi, Assistant, Kyushu University, Fukuoka.
Dr. Fuyuji Takai, Professor, University of Tokyo.
Dr. Yuzuru Ogura, Professor Emeritus, University of Tokyo.
Dr. Katsura Oyama, Palaeontologist, Geological Survey of Japan.
Dr. Juichi Yanagida, Assistant, Kyushu University, Fukuoka.

## II. Geological Survey in Thailand and Malaysia

In the geology of Thailand pioneer works were done by B. Högbom, 1912, W. M. Lee, 1921, 23, W. Credner, 1927-29, A. Heim and H. Hirschi, 1934. The whole picture of her geology however, has not been drawn until "Geological Reconnaissance of the Mineral Deposits of Thailand", 1951, which was the outcome of the cooperative work of Thai geologists of the Royal Department of Mines with the mission of the U. S. Geological Survey.

In the Federation of Malaya the geological survey was founded in 1903 and many reports were published from the survey and numerous papers through Geological Magazine and other journals. In 1931 The Geology of Malaya was published by J. B. Scrivenor and a further advancement has since been made through a third of the century.

The geological surveys of these two countries have, however, been much emphasized in the exploration of mineral resources and the basic researches are not so advanced. It was only a few years ago that Departments of Geology were instituted in the Chulalongkorn University at Bangkok as well as in the University of Malaya at Kuala Lumpur.

Most important at this stage is to establish the stratigraphic sequence of the region provided with many key horizons. It is therefore crucial to discover guide fossils without which scattered exposures of rocks in the tropical dense vegetation can hardly be oriented.

Most palaeontological works, if not all, have been done in Malaya since 1900 and in Thailand since 1920. From the viewpoint of the comparative stratigraphy Kobayashi has paid special attention to this part of the regional geology since

1940, because the region was considered to lie in the south-western extention of the Japanese islands with regard to the history of geotectonic development. With such academic interest in mind descriptive works of fossils from Thailand and adjacent countries were commenced since 1944 and became very active since 1958.

Because limestones are bare in the luxuriant vegetation, the older and younger arenaceous series have once been distinguished in Malaya by means of the calcareous series. As the result of recent studies this concept was completely upset, because it was readily proven by index fossils that the Ordovician, Silurian, Devonian and Permo-Carboniferous limestones are repeatedly interbedded with non-calcareous rocks. Further it became evident that the Ordovician Thung Song limestone and the Permian Rat Buri limestone are especially extensive in Thailand. It is quite astonishing that some ten fusulinid zones classified in West Japan were easily recognized in the Rat Buri limestone by Toriyama and Kanmera by naked eyes during the field survey of the Sara Buri district, the fact showing how precisely do the limestones at two remote areas coincide zone by zone. It is also of great interest that the Trigonioides-Plicatounio fauna which is indigenous to the hinter basin of the late Mesozoic Sakawa folded mountains was found at Ban Na Yo on the Khorat plateau near the Mekong river. There are other important discoveries in comparative palaeontology and geology and they as a whole have shown to be urgent needs of such reconnaissances for the geological survey of Southeastern Asia.

## III. The Procedure of the Technical Cooperation

Before the first reconnaissance in winter, 1962-63, Japanese palaeontologists have shared geological researches with field geologists of these countries simply through fossil identification and descriptive work. This was first done by prompt communication of preliminary observations, because such an information is always an important guide for a further geological survey. When the studies published, reprints of these papers were distributed to the geologists and libraries of these countries.

Since the first reconnaissance it was found that the technical cooperation can be schematized into four stages, viz. (1) preliminary report, (2) report of progress, (3) publication of articles and (4) compilation and synthesis, as exemplified below.

(1) This preliminary report is the outcome of the field works in winter, 1963-64, which is of value for the geological survey now in progress.

(2) The second colloquium on the geology and palaeontology of Southeast Asia was held at the Department of Mineral Resources at Bangkok, December 3, 1963, for the informal discussion on the report of progress in laboratory works. On this occasion some new facts in field geology were also communicated by Thai geologists and the Lower Mekong Basin Project was presented by Sawada, an ECAFE member. The programme of the colloquium included 25 lectures which took a whole day. (See Programme 2.)

The first meeting of this kind was the colloquium on the Fossils from Southeast Asia which was held at the same hall on December 6th, 1962 and 15 lectures were presented there including one on the fusulinid fossils of Thailand by Pitakpaivan, chief of the geology section. (See Programme 1.)

At each colloquium professors and students of geology in the Chulalongkorn University, geologists at ECAFE and USOM and other geologists in town were invited. Thus the colloquium became an international meeting of moderate size having some 30 to 40 attendants. Such free talking and discussion are evidently mutual benefit for all attendants and stimulating for students.

(3) The series of the results obtained by the successive reconnaissances in Southeast Asia became to be published through journals with the subtitle of Contributions to the Geology and Palaeontology of Southeast Asia.

Twelve papers of the series have already been published by the end of March, 1964 and five additional papers are in print. (See List of Papers.)

(4) Now 15 papers of the series in addition to two chapters on the geology and palaeontology of Thailand are to be compiled in the first volume of Geology and Palaeontology of Southeast Asia and to be published from the University of Tokyo Press.

Finally a palaeontologist of the Department of Mineral Resources, Bangkok is to come in this summer to the Kyushu University to learn laboratory works.

## IV. The Summary of the Results of the Field Works

### a. Thailand Part of the Project

### 1. Geology and Palaeontology of the Khorat Plateau and the Plant-bearing Formations

The research subjects Nos. 4 and 5 were taken up by J. Iwai and K. Asama in collaboration with M. Veeraburus, A. Hongnusonti, B. Insthuruti, A. Methikul, P. Komalarjun, C. Poothai and A. Suwanasing.

The Khorat series extensive on the Khorat plateau was used to be divided into 3 units, but they classified it into 5 units of formations and clarified the characteristics of their rock-facies and fossiliferous beds. As the result it was ascertained that the main part of the series is Jurassic, instead of Triassic as previously considered and the Upper Triassic Huai Hin Lat formation is added to the basal part and the Lower Cretaceous Ban Na Yo formation to the top. Beside, there is the Upper Cretaceous (?) Lomsak formation between Lomsak and Phitsanulok of which relation to the series is, however, as yet indeterminable.

On the western side of the plateau are two plant beds in the Phetchabun and Loei districts. The Permian formations to which they belong are unconformably overlain by the Huai Hin Lat formation containing Neocalamites and Clathropteris beds. Therefore it is warranted that a strong orogeny has taken place before the deposition of the Huai Hin Lat formation.

The Phu Kadung formation further high up contains Araucaryoxylon and the Phra Wihan formation yields Brachiphyllum and Sphenopteris (?) in a lower and upper horizon respectively. Sequoia concinna was found in the Lomsak formation in association with Pterophyllum, and dicotyledonous woods were collected from Quaternary gravel beds.

The relation of the Permian plant beds to the Permian marine facies and the stratigraphic position of the Lomsak formation are two of the important questions left for future research.

### 2. Stratigraphy and Geologic Structure of the Loei Area

The third subject of research was investigated by T. Sato, T. Hamada and H. Igo jointly with M. Veeraburus and A. Hongnusonthi. The stratigraphic sequence of the area was determined by them in descending order as follows:

7. Middle Permian Pseudodoliolina-Parafusulina limestone of Pha Nok Khao.
6. Sandstone-shale alternation of Nam Pao with Agathiceras (?)
5. Lower Permian formation of Huai Bun Nak composed of shale, sandstone and limestone and rich in fossils.
4. Permo-Carboniferous Triticites limestone of Ban Pha Noi.
3. Moscovian fusulinid-coralline limestone of Huai Luang.
2. Fossiliferous Carboniferous formation of Huai Luang composed of conglomeratic sandstone, micaceous sandstone, calcareous sandstone and shales with intercalation of arenaceous limestone.
1. Shale, sandstone and conglomerate formation in an eastern hill of Loei which contains Upper Devonian (?) or Lower Carboniferous ammonites and brachiopods.
? Volcanic and tuffaceous series in east of Chiang Kan, possibly Devonian in age.

Thus the Permo-Carboniferous sequence below the Rat Buri limestone of the Sara Buri area could be classified here in detail. These formations are folded with meridional axes and cut by major and minor faults. The age of the folding in this area was determined at Triassic by Iwai and others.

3. The stratigraphy of the Peninsular Thailand Area

Toriyama, Sato, Hamada and Igo have investigated with Komalarjun the west coast and the central part of the Peninsular Thailand. As the result it was determined that the area consists of 8 sedimentary units beside the granitic rocks as follows:

9. Prehistoric cave deposits containing marine shells and human artifacts.
8. Quaternary tin placer deposits.
7. Tertiary Krabi series with lignite seams.
6. Granitic rocks.
5. Permian Rat Buri limestone.
4. Carboniferous shale and sandstone formation.
3. Middle Palaeozoic (?) formation including graptolite shale, fossiliferous red mudstone and quartzite.
2. Ordovician limestone and calcareous shale.
1. Upper Cambrian Tarutao sandstone.

In the preceding areas little has been known of the pre-Carboniferous sequence. According to them the so-called Cambrian Phuket series is possibly Carboniferous in age. Because the Mesozoic formations are unrepresented in this

surveyed area, the eastern coast must be investigated to supplement the sequence and to get further informations on the tin-bearing granite.

b. Malayan Part of the Project

The Stratigraphic Sequence and Geologic Structure of the Northwestern Part of the Malaya and the Langkawi Islands

The 6th and 7th subjects of research were taken up by Kobayashi, Kimura, Igo and Hamada and they investigated jointly with C. R. Jones, W. D. Proctor and many field assistants. The Palaeozoic formations are well developed in the islands. Their distribution is extended easterly into Perlis and Kedah where exists the Triassic formation. The stratigraphic sequence of these areas is as follows:

6. Triassic formation including the Carnic Halobia beds and Ladinic Daonella beds.
5. Permo-Triassic (?) chert beds.
4. Permian Chuping formation ; limestone containing Middle Permian fusulinids, corals, bryozoans and other fossils.
3. Carboniferous (and Lower Permian?) Singa formation.
2. Setul formation
   - e. Upper (?) limestone; fault contact with 2d.
   - d. Upper detrital band.
     Fossiliferous red-purple shale in the upper part (Probably Devonian in age)
     Silurian grey-black graptolite shale near the base.
   - c. Middle limestone with trilobites and nautiloids.
   - b. Lower Detrital band with Llandoverian graptolites and Dalmanitina malayensis zones.
   - a. Lower limestone or Ordovician limestone including Llandeilian Discoceras limestone and Caradocian (Black River) Armenoceras limestone.
1. Upper Cambrian Machinchang formation equivalent to the Tarutao sandstone.

All of these formations are intruded by granites.

In the Langkawi islands the Setul formation on the east side is in contact with the Singa and Chuping formations on the other by a great tectonic line. There are various foldings, faults, cleavages and other minor structures. Their history of development can be analysed into three stages where the tectonic line which is a thrust fault was produced in the third stage and presumably after the granitic intrusion.

## c. General Remarks

As summarized above, the stratigraphy of these selected areas were much clarified by the reconnaissance surveys. The age of the formations in these areas will be exactly determined and keen guide fossils are expected to be found when the laboratory works are finished on the collections. There are still untouched areas, the east coast of the peninsula for example, which require a similar reconnaissance. Important improvements were, however, made already not only in the stratigraphy but on the tectonic development of the Langkawi islands and the Loei area. It is very important for the geology, basic and applied, of Thailand and Malaysia to make an intensive study on the tectonic development by the cooperation of stratigraphers and plaeontologists with petrologists, mineralogists and geomorphologists.

From the higher standpoint it is noted that the geologic history recorded in these countries is mostly Mesozoic and older. For the Tertiary and later history one has to look into the Philippines. When the history of the arc described by the Philippines, Malaysia and Thailand will be deciphered in detail, it becomes much easier and surer to search minerals because all of the useful minerals are products in the historical development of the land.

Table 1.

| | Period | Destination | Participants |
|---|---|---|---|
| 1. | Dec. 6- Dec. 8 | Phra Phutthabat area | Kobayashi, Toriyama, Sato, Hamada, Igo |
| | Dec. 9- Dec. 11 | Sara Buri area | Hamada, Igo |
| 2. | Dec. 14- Jan. 8 | Phuket-Satun area | Toriyama, Sato, Hamada |
| | Jan. 25- Feb. 7 | Trang-Thungsong area | Sato, Hamada, Igo |
| 3. | Jan. 13- Jan. 22 | Loei-Wang Saphung area | Sato, Hamada, Igo |
| 4. | Dec. 6- Jan. 9 | Khorat Plateau | Iwai, Asama |
| 5. | Jan. 13- Jan. 21 | Petchabun-Lomsak area | Iwai, Asama |
| 6. | Dec. 15- Dec. 17 | Pulau Langgon Isle | Kobayashi, Kimura, Igo |
| | Dec. 18- Jan. 6 | Langkawi Islands | Kimura, Igo |
| 7. | Feb. 11- Feb. 17 | Alor Star area | Igo, Hamada |
| 8. | Feb. 20 | Pahang district | Igo, Hamada |

## Schedule of T. Kobayashi

December 1-21, 1963

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|---|---|
| Dec. 1, Sun. | 10.30 Lv. Haneda, Tokyo by AF 193<br>16.25 Ar. Bangkok |
| Dec. 2, Mon. | Japanese Embassy, and Department of Mineral Resources.<br>Evening: Department Director's reception at Palace Hotel. |
| Dec. 3, Tsu. | Second Colloquim on Geology and Palaeontology of Southeast Asia at Department of Mineral Resources. |
| Dec. 4, Wed. | Science Department, Chulalongkorn University.<br>Tem Smitinand of Forestry Department, (wood specimens for comparative anatomy).<br>L. Gardner, USOM. |
| Dec. 5, Thu. | (King's Birthday). Fernandez and Sawada of ECAFE (Philippine geology). |
| Dec. 6, Fri. | Field trip: Bangkok-Sara Buri- Phra Phutthabat. |
| Dec. 7, Sat. | Field trip: Rat Buri limestone near Phra Phutthabat. |
| Dec. 8, Sun. | Field trip: Phra Phutthabat-Lop Buri- Chai Badan-Khorat series of Ban Khok Khli- Lop Buri-Bangkok. |
| Dec. 9, Mon. | (Condolence holiday on Prime Minister Sarit's death.)<br>Lunch with Minister Arita (Colombo Plan). |
| Dec. 10, Tsu. | (Chulalongkorn day). Lucas of Asia Foundation. |
| Dec. 11, Wed. | Director of Department (Cooperative work.)<br>Malayan trip preparation. |
| Dec. 12, Thu. | 11.00 Lv. Bangkok by ML 311.<br>13.25 Ar. Kuala Lumpur.<br>Geology Department, University of Malaya. |
| Dec. 13, Fri. | Japanese Embassy.<br>Bala Melon of Forestry Research Institute, Kepong, Selangor, (wood specimens for comparative anatomy).<br>16.55 Lv. Kuala Lumpur by ML 652<br>17.35 Ar. Ipoh. |
| Dec. 14, Sat. | Study with survey collection. |
| Dec. 15, Sun. | Morning: study with survey collection.<br>Kimura arrived at noon.<br>Field trip: leave Ipoh by military airplane.<br>Ar. Main Island of Langkawi.<br>Sail therefrom to Pulau Langgon camp base by boat.<br>Survey on northern coast. |

| | |
|---|---|
| Dec. 16, Mon. | Field trip: Ordovician and Silurian localities of Pulau Langgon and Pulau Teng Tembus Dendang. Major tectonic lines crossing the islands. |
| Dec. 17, Tsu. | Field trip: Machingchang series on the main island.<br>Lunch at Langkawi rest house.<br>From Langkawi to Ipoh by military airplane.<br>Deputy director's reception. |
| Dec. 18, Wed. | Study with survey collection. |
| Dec. 19, Thu. | From Ipoh to Kuala Lumpur by Director's car.<br>Japanese Embassy, Ambassador's residence and Malayan Museum. |
| Dec. 20, Fri. | 09.25 Lv. Kuala Lumpur by CX 730<br>11.15 Ar. Bangkok<br>Department of Mineral Resources and Japanese Embassy. |
| Dec. 21, Sat. | 09.30 Lv. Bangkok AF 192<br>19.55 Ar. Tokyo. |

Programme 1

Colloquium on the Fossils from Southeastern Asia

Bangkok, December 6th, 1962.

1. Preliminary Notes on the Older Palaeozoic Fossils from Peninsular Thailand and the Langkawi Islands. By T. Kobayashi and T. Hamada.
2. Fusulinid-bearing Rocks in Thailand. By R. Toriyama and K. Kanmera.
3. Permian Brachiopods from Petchabun area. By J. Yanagida.
4. On Two Carboniferous Brachiopods from Loei. By T. Hamada.
5. The Permian Petchabun Flora. By E. Konno.
6. Preliminary Report on the Upper Palaeozoic Fauna of the Langkawi Islands. By R. Toriyama, K. Kanmera, S. Sakagami and J. Yanagida.
7. Fusulinids from the Rat Buri Limestone at six localities in Thailand. By K. Pitakpaivan.
8. Triassic Ammonites from Malaya. By T. Sato.
9. The Daonella and Halobia Beds in Malaya. By T. Kobayashi

10. Brief Notes on Two Jurassic Fauna in Viet-Nam. By T. Sato and I. Hayami.
11. The Cretaceous Ban Na Yo Fauna of Changwat Nakhon Phanom in the Eastern Khorat Plateau. By T. Kobayashi.
12. Some Fossils from the Khorat Series. By T. Kobayashi, F. Takai and I. Hayami.
13. The Palaeogene Li Flora. By S. Endo.
14. Preliminary Note on Fossil Woods from Thailand. By Y. Ogura.
15. Preliminary Note on Molluscan Shells of the Mae Sot and Krabi Series. By K. Oyama.

## Programme 2

### The Second Colloquim on the Geology and Palaeontology of Southeast Asia at Bangkok, December 3rd, 1963

1. Teiichi Kobayashi and Takashi Hamada: On the Occurrence of Middle Ordovician Fossils from Satun in Thailand near Malayan Frontier.
2. Takashi Hamada: Some Middle Ordovician Brachiopods from Satun, South Thailand.
3. Charan Poothai: The Graptolite Shale of Thungsong, Thailand.
4. Teiichi Kobayashi, C. H. Jones and Takashi Hamada: On the Lower Silurian Fauna in the Langkawi Islands, Northwest Malaya.
5. Teiichi Kobayashi and Hisayoshi Igo: Graptolites Shales in North Thailand.
6. Teiichi Kobayashi and Takashi Hamada: On the New Malayan Species of Dalmanitina.
7. Manas Veeraburus: Geology of Loei Area, Thailand.
8. Takashi Hamada: Some Carboniferous Brachiopods from Loei, Thailand.
9. Juichi Yanagida: Permian Brachiopods from Petchabun Area, Central Thailand.
10. Ryuzo Toriyama Kametoshi Kanmera, Sangob Kaewbindhoon Angoon Hongnusonti: Permian Fusulinid Zonation of Saraburi Area, Thailand (Preliminary Report).
11. Ryuzo Toriyama and Kametoshi Kanmera: Two New Permian

Genera of Fusulinids from Thailand (Preliminary Report).

12. Sumio Sakagami: Permian Bryozoa from Pulau Kong, the Langkawi Islands, Northwest Malaya.
13. Hisayoshi Igo: Permian Fossils from North Pahang, Malaya.
14. Hisayoshi Igo and Toshio Koike: Conodonts from South Kelatan, Malaya.
15. Hisayoshi Igo: Permian Fusulinids from the Triassic Conglomerate in Kelatan, Malaya.
16. Wataru Hashimoto and Shuji Kudo: Chemical Analysis of Oil from Fang, North Thailand.
17. Enzo Konno and Kazuo Asama: On the Older Mesozoic Plants from Wangsaphung (Preliminary Report).
18. Pumwarn Komalarjun and Tadashi Sato: Aalenian (Jurassic) Ammonites from Mae Sot, Northwest Thailand.
19. Itaru Hayami: Some Jurassic Pelecypods from Viet-Nam, donated by Dr. H. Fontaine.
20. Seido Endo: On the Occurrence of an Upper Cretaceous Plant in Central Thailand.
21. Seido Endo: A Supplementary Note on the Li Flora in North Thailand.
22. Seido Endo: On the Younger Tertairy Plants from the Mae Sot Basin, West Thailand.
23. Yoshihiko Kurosawa: A Brief Note on a Mae Sot Insect.
24. Taro Kanaya: Wan It Lampang Diatomite (Preliminary Note).
25. Hideho Sawada: Lower Mekong Basin Project.

## List of Papers

### Contributions to the Geology and Palaeontology of Southeast Asia

### I. Papers published

I. T. Kobayashi: On the Cretaceous Ban Na Yo Fauna of East Thailand with a Note on the Description of Nippononaia, Trigonioides and Plicatounio.

II. T. Sato: Ammonites du Trias de la Malaisie.

III. T. Kobayashi: On the Triassic Daonella Beds in Central Pahang, Malaya.

IV. T. Kobayashi: Halobia and some other Fossils from Kedah, Malaya.

V. E. Konno: On some Permian Plants from Thailand.

VI. S. Endo: On some Older Tertiary Plants from Northern Thailand.

VII. T. Kobayashi, F. Takai and I. Hayami: On some Mesozoic Fossils from the Khorat Series and a Note on the Khorat Series.

VIII. S. Sakagami: Permian Bryozoa from Pulau Kong, the Langkawi Islands, Northwest Malaya.

IX. J. Yanagida: Permian Brachiopods from Central Thailand.

X. T. Hamada: Two Carboniferous Brachiopods from Loei, Thailand.

XI. H. Igo: Permian Fossils from Northern Pahang, Malaya.

XII. T. Kobayashi, C. R. Jones and T. Hamada: On the Lower Silurian Fauna in the Langkawi Islands, Northwest Malaysia.

## II. Papers in print

XIII. T. Kobayashi and T. Hamada: On a new Malayan Species of Dalmanitina.

XIV. I. Hayami: Some Lower Jurassic Pelecypods from South Viet-Nam collected by Dr. H. Fontaine.

XV. Pumwarn Komalarjun and T. Sato: Aelenian (Jurassic) Ammonites from Mae Sot, Northwestern Thailand.

XVI. T. Kobayashi and T. Hamada: On the Middle Ordovician Fossils from Satun in Thailand near the Malayan Frontier.

XVII. T. Hamada: Some Middle Ordovician Brachiopods from Satun, Southern Thailand.

## III. Manuscript

XVIII. T. Kobayashi and H. Igo: On the Occurrence of Graptolite Shales in North Thailand.

# V. Geology and Palaeontology of the Khorat Plateau and the Plant bearing-Permian Formations

Jun-ichi Iwai
Kazuo Asama

## 1 Introduction

The results of the geological survey of the Khorat series extensively distributed in the Khorat Plateau are given in this report. Field work was undertaken in eleven areas of the Khorat series for stratigraphical and paleontological research and also in two areas for a reconnaissance and collection of fossil plants of Upper Paleozoic age (cf. fig. 1).

## 2 General Geology

The so-called Khorat series is typically and extensively distributed in the Khorat Plateau which is situated in the north-eastern part of Thailand. The series has been studied by many authors (Lee, 1923; Credner, 1935; Brown, Buravas et al., 1951; Sethaput, 1956; LaMoreaux et al., 1958; Haward, Javanaphet et al., 1959; Kobayashi, 1960; Buravas, 1957, 1961; Ward et al., 1961-1963; Kobayashi, 1963; Kobayashi et al., 1963).

Lately LaMoreaux and others (1958) subdivided the series into three members of Phu Kadung, Phra Wihan, and Phu Phan in ascending order and considered them to be Triassic or Triassic-Jurassic in age. The next younger formation superjacent to the Phu Phan member has been unnamed, though it was considered to be "Jurassic, Cretaceous (?) and younger (?)" in age (LaMoreaux et al., 1958, table 1).

Because of the paucity of fossils, the geologic age of the series had been undecided precisely for many years. The consideration on the geologic age above-mentioned had been based mainly upon the stratigraphic correlation from the order of succession of the different units and similarity in lithology between the Khorat series and the Mesozoic red beds developed in the neighboring territories such as Burma, Southern China, Laos and Cambodia. Lately, Dr. Teiichi Kobayashi (1963), with his collaborators (1963), described some important fossil molluscs and others which were collected by the geologists of Thailand from the several isolated localities and horizons of the Khorat series. Dr. T. Kobayashi has already discussed (Kobayashi et al., 1963, pp. 183-186) on the chronology of the Khorat in detail on the basis of these paleontological evidences, and suggested the possibility of the occurrence of the Upper

Triassic in the basal part of the Khorat series east of Loei (Kobayashi et al., 1963, pp. 183-186). Mr. Manas Veeraburus collected an important fossil plant of Upper Triassic age at Huai Hin Lat situated at Km. 108 on the Khon Kaen-Loei Highway. The just mentioned fossil plant-bearing formation underlies the Phu Kadung Formation with conformity. Thus the age of the so-called Khorat series in that area has been ascertained on the basis of stratigraphical and paleontological evidences.

The areas where we carried out field work are as follows,

1) Km. 178-Km. 242, First Friendship Highway, Changwat Nakhon Ratchasima.
2) Km. 278-Km. 313, Lop Buri-Nakhon Ratchasima (Khorat) Highway, Changwat Chaiyaphun (Ban Khok Khli).
3) Ban Kut Bot (Phu Moei), Amphoe Kuchinarai, Changwat Kalasin.
4) Highway between Ban Si Yaek Nong Waeng, Changwat Kalasin and Sakon Nakhon, crossing the Phu Phan Range.
5) Ban Na Yo, Amphoe Mukdahan, Changwat Nakhon Phanom.
6) Amphoe Nong Bua Lamphu-Ban Huai Dua (Km. 43.5-Km. 33), Changwat Udon Thani.
7) Mt. Phu Kradung, Amphoe Wan Saphung, Changwat Loei.
8) Huai Hin Lat (Km. 108, Khon Kaen-Loei Highway), Amphoe Chum Phae.
9) Km. 24-Km. 123 Km., Phitsanulok-Lom Sak Highway.
10) Li-Thoen (Km. 658-Km. 623 from Bangkok).
11) Km. 9, Loei-Dan Sai Highway, Changwat Loei.
12) Khlong Wang Ang, Amphoe Ban Nong Phai, Changwat Phetchabun.

The two last mentioned are the localities which yielded Permian fossils. In the former ten areas, the Khorat Group* is well exposed. Among these areas, 1), 2), 3), 6) and 7) had been investigated and measured in detail along the continued exposures by Dr. D. E. Ward of USOM and his co-workers of Geological Survey, Department of Mineral Resources, Thailand (Ward et al., 1961-1963). Our field observations led us to the conclusion that the molluscan fossil-bearing Ban Na Yo Formation (Kobayashi, 1963) which overlies the arkosic orthoquartzite in the environs of Mukdahan is correlative of the unnamed younger formation which overlies with conformity the Phu Phan Formation in the western environs of Nakhon Ratchasima. The Upper Triassic fossil plant-bearing formation exposed in Huai Hin Lat underlies with conformity the Phu Kadung Formation in the

* We propose to use "Group" which is the name of rock unit instead of "series" for the Khorat and "Formation" instead of "member" for Phu Kadung, Phra Wihan, Phu Phan, etc. in accordance with current usage of the terminology in stratigraphic classification.

lower course of the stream. We propose the name of Huai Hin Lat Formation for this plant-bearing formation. We have another fossil plant-bearing formation which is named by us as Lom Sak Formation. This formation is distributed in the western environs of Lom Sak, Changwat Phetchabun (Km. 122.5, Second Friendship Highway between Phitsanulok and Lom Sak). The formation which contains Sequoia concinna Heer is characterized with pyroclastic rocks and is in fault contact with the Khorat Group distributed in the western part of the region along the Second Friendship Highway. By the following reason, it may be considered with high probability that the Lom Sak Formation is younger than the Khorat Group. 1) So far as observed, the pyroclastic rocks which characterize the Lom Sak are unknown in the continuous succession of the Khorat Group. 2) The Huai Hin Lat Formation (lowest one of the Khorat) rests with unconformity on the fusulinid Foraminifera-bearing limestone of Permian age. 3) The agglomerate and breccia-tuffs which underlie with unconformity the Phu Kadung Formation seem to have been altered and deformed. 4) According to Dr. Seido Endo (1963), the Lom Sak Formation yielded Sequoia concinna Heer of Upper Cretaceous age. Besides the just mentioned fossil plant, however, we found Pterophyllum sp., which is generally considered as a genus which flourished in the older Mesozoic rather than in the youngest Mesozoic in age. Also we found a fragment of a reptilian tooth ? from the same formation.

Dr. T. Kobayashi (Kobayashi et al., 1963, p. 185) has already suggested that the upper Khorat series (Upper Cretaceous or Tertiary) overlies the Middle Khorat series with slight discordance?. The Lom Sak Formation may be included in his upper Khorat series. As already mentioned, it is known that the Lom Sak Formation is in fault contact with the Khorat Group and stratigraphic relation of superposition between them is not yet ascertained. The precise age determination of the Lom Sak and its direct stratigraphical relation with the underlying formation should be reserved until further investigations are undertaken.

We were successful in collecting at several localities the silicified wood stems and fossil leaves from the known horizons of the Khorat Group.

The Permian sedimentaries are distributed in the western environs of Muang Loei, Changwat Loei and Khlong Wang Ang, Amphoe Ban Nong Phai, Changwat Phetchabun. The fossils from the latter locality have already been described by Dr. Enzo Kon'no (1963). We were fortunate in finding many specimens from these localities as mentioned later.

## 3. Stratigraphy

On the basis of the afore-mentioned field evidences, we propose to redefine the Khorat Group with addition of the inclusion of the Huai Hin Lat and Ban Na Yo Formations, but excluding tentatively the Lom Sak Formation. At the present stage of research, the Khorat Group comprises five formations as shown in Table 1. (see also fig. 2a).

Table 1. Generalized stratigraphic classification of the Khorat Group

| LaMoreaux et al. (1958) | | | | Iwai and Asama (1964) | |
|---|---|---|---|---|---|
| Jurassic | | | | Lom Sak Formation | Upper Cret. |
| Cretaceous(?) & younger(?) | | unnamed | | Fault | |
| | | | | Ban Na Yo Formation | Lower Cret. |
| Triassic | Khorat series | Phu Phan member | Khorat Group | Phu Phan Formation | Jura. |
| | | Phra Wihan member | | Phra Wihan Formation | |
| | | Phu Kadung member | | Phu Kadung Formation | |
| | | | | Huai Hin Lat Formation | Upper Trias. |

We have classified the rocks distributed in the Khorat Plateau based upon their lithologic characters. We attempted to classify the Phu Kadung, Phra Wihan, Phu Phan and the next younger formation along the First Friendship Highway on the basis of our own field observations with reference to the description of Dr. D. E. Ward and his collaborators (1961-1963). The boundaries between these formations classified by us well coincide with those shown in the chart "Geologic cross section along the Friendhsip Highway" (blue print issued by Ground Water Exploration and Development Project, Department of Mineral Resources, Thailand).

Table 2. Areal variation of thickness of the formations comprising the Khorat Group (in meters)

| Area / no. in index map / Formation name | First Friendship Highway | Highway from Lop Buri to Khorat | Ban Kut Bot | Pass of Phu Phan Range | Mukdahan & Ban Na Yo | Udon-Nong Bua Lamphu | Mt. Phu Kradung* | Huai Hin Lat |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Ban Na Yo | 420+ | 400+ | missing | | 100+ | no exposure | missing | non-surveyed |
| Phu Phan | 340 | 335 | 210 | 50+ | 390 | 140 | 100 | |
| Phra Wihan | 580 | 720 | 520 | 200+ | ? | 535 | 725 | |
| Phu Kadung** | 1360 | 400+ | 570+ | no exposure | | 350+ | 590+ | 800+ |
| Huai Hin Lat | ? | ? | ? | ? | ? | ? | ? | 140 |
| Basement | Diorite | | | | | | Limestone | |

* The name of the mountain is called Phu Kradung.

** The name of the formation is used according to P. E. LaMoreaux et al. (1958).

We have also attempted a tentative classification of the Khorat Group distributed in another region on the basis of our own observation and comparing with the measurements and description of the lithologic characters given by Dr. D. E. Ward and his collaborators (1961-1963). The thickness of each formation varies areally as shown in Table 2.

1. Huai Hin Lat Formation

Type locality: Huai Hin Lat, a small creek in the jungle at Km. 108, Khon Kaen-Loei Highway, Amphoe Chum Phae, Changwat Khon Kaen.

Stratigraphical relation: This formation lies with unconformity on the Permian limestone which yielded fusulinid Foraminifera (so-called Rat Buri limestone) and is overlain with conformity by the reddish gray colored, friable shale which occupies the lowest part of the next younger Phu Kadung Formation. These relations can be well observed as shown in the geological route map (Fig. 2b).

Thickness: 140 m.

Lithology: The lower 100 m part of this formation comprises dard-gray limestone conglomerates which mainly consist of medium-to large-sized limestone pebbles of angular and subangular shape, mixed with rounded and subrounded pebbles of rhyolite, porphyrite, chert and others. The dark colored limestones are intercalated intermittently in these limestone conglomerates. The upper part of about 40 m in thickness comprises dark gray, but showing yellowish gray on weathered surface, sandy shale; dark gray to black, very fine-grained calcareous sandstone, and yellowish gray fine- to medium-grained sandstone with intercalations of sandy shale and sandy siltstone. In the middle part of this upper part, a dark gray limestone with limestone conglomerate is intercalated. The formation has a general strike and dip respectively of N35°-40°E and 15°-20°SE.

Fossils: The under-mentioned fossil plants were found in the dark gray to black, very fine-grained calcareous sandstone and tan siltstone. Neocalamites sp., Equisetites sp., Cladophlebis sp., Clathropteris cf. meniscoides Brongniart, and Pterophyllum sp. According to one of the present authors (K. Asama), these fossils may point to the Rhaet-Liassic age.

Distribution: This formation is known at present only from the type locality. But it is suggested with high probability that another locality will be found and also that the lowest part of the formation which has hitherto been

considered as belonging to the next younger Phu Kadung Formation will prove to belong to this formation.

2. Phu Kadung Formation

Type locality: Mt. Phu Kradung, Amphoe Wang Saphung, Changwat Loei.

Stratigraphical relation: At Huai Hin Lat, the Phu Kadung Formation overlies with conformity the Huai Hin Lat Formation as already mentioned. But, in other areas, it has hitherto been considered that this formation is the oldest of the Khorat Group and lies with unconformity on the rocks of Paleozoic age (LaMoreaux et al., 1958). The present authors also observed that the Phu Kadung Formation overlies on limestone, weakly altered andesite, agglomerate, breccia-tuff, and sheared diorite, etc., though the just contact is sometimes obscure. But as already mentioned in the previous article, it is quite probable that the lowest part of this formation will prove to belong to the Huai Hin Lat.

Lithology: The Phu Kadung Formation is characterized with the characteristic color of the rocks. The color is generally purple-gray, red-gray and sometimes mottled gray and green, that is to say, it possesses the characteristics of the so-called "Red beds".

This formation mainly comprises purple-gray and red-gray, fine-to coarse-grained sandstone, micaceous shale, sandy siltstone and siltstone. But sometimes gray, light gray, buff, olive and rarely dark green, fine-to medium-grained sandstones are intercalated. Occasionally the very fine-grained sandstone and siltstone are calcareous, and rarely argillaceous limestone and Wurm-Kalk like limestone are intercalated. The sandstones are massive, thick-to flaggy bedded and cross lamination is generally well developed in the sandstone. Current ripples are also found in the finer-grained sandstone.

Fossils: Except for the vegetable fragments and silicified wood stems, no fossils were found. But Dr. D. E. Ward and his collaborator (Ward et al., 1961-1963) reported on the occurrence of silicified bone fragments. The silicified wood stems were found with jet coal in the yellowish gray, friable shale and thin-bedded, very fine-grained micaceous sandstone at the foot of Phu Jon Jog Mountain and in the valley between the just mentioned mountain and Phu Moei Mountain. Both are situated in the southeastern environs of Ban Kut Bot, Amphoe Kuchinarai, Changwat Kalasin, and may be the same localities from where Araucarioxylon sp. identified by Dr. Ken Ogura and reported by Dr. Teiichi Kobayashi (1960) were collected.

Thickness: Estimated to be more than 1000 m, but variable areally.

Distribution:

a) Km. 179-Km. 194, First Friendship Highway, ca 1360 m thick, N80°-50°W, 10° ± NE.

b) Km. 278-Km. 280, Lop Buri-Nakhon Ratchasima (Khorat), more than 400 m, generally strikes N20°-25°W, dips 40°-60°NE in the western foot of the escarpment of the Khorat Plateau, while less than 10°NE near the top of the escarpment.

c) Mts. Phu Moei and Phu Jon Jog, Ban Kut Bot, Amphoe Kuchinarai, Changwat Kalasin. More than 570 m in thickness. Striks and dips are respectively N10°-30°W, 10°ENE in general.

d) Ban Nong Khliang and Km. 43.5-Km. 41.5, Udon Thani-Nong Bua Lamphu Highway. More than 350 m in thickness. At Ban Nong Khliang, yellowish light gray, very fine- to medium-grained arkosic, micaceous orthoquartzite strikes EW and dip 20°N. But along the road Km. 43.5-Km. 41.5, generally strikes N40°-45°W and dips 15° ± NE, though rarely change to N55°-70°W and 20°NNE.

e) Mt. Phu Kradung. Thickness of ca 590 m is measured on the mountain slope, while it attains 2740 m, if added with the apparent thickness measured along the Nam Phong River. On mountain slope, strike is N25°-40°W and dips 10°-15°SW in general, while rarely change to N20°E and 8°WNW. Along Nam Phong River, strike is NS-NNE and dips 10° ± W.

f) Km. 95-Km. 107 and Km. 127-Km. 172, Khon Kaen-Loei Highway. Strikes and dips are as follows. Km. 95—N70°-85°E and 10°S; Km.105—N30°E and 30°SE; Km. 137—NS-N5°W and 80°E, probably due to a fault, though its character is not yet ascertained; Km. 144-Km. 152—N8°-10°W and 5°-10°ENE; Km. 157—NS and 5° ± W; Km.169—N40°-50°E and 20°-30°SE. As a whole the structure of the Phu Kadung Formation in this area seems to be an anticlinal axial part of a gentle fold between Mts. Phu Kradung and Phu Wiang.

g) Km. 24 and Km. 98, Second Friendship Highway, Phitsanulok and Lom Sak. Quarry at Km. 24, flaggy bedded, well sorted, greenish gray, very fine-grained sandstone (10 m +), conglomerate comprising medium-sized rounded pebbles of green chert cemented by lime (80 cm), friable shale (20 cm. ±) and greenish gray, fine-grained sandstone in descending order are exposed in the cliff of a quarry.

Road cut at Km. 98, the alternation of shale, siltstone and sandstone, all in variegated colors such as yellowish light gray, light gray, dark gray, greenish gray, red-gray, purple-gray, red and black, generally strikes N10°-20° and dips 60°-75°ENE, sheared and cut by faults (NS, 85°E).

3. Phra Wihan Formation

Type locality: Phra Wihan, southern escarpment of Khorat Plateau. (The writers have not seen the type locality).

Stratigraphical relation: The Phra Wihan overlies with conformity the Phu Kadung Formation, and underlies the next younger Phu Phan Formation.

Thickness: Ranges from ca 500 m to ca 730 m.

Lithology: The Phra Wihan comprises an alternation of fine-to very coarse-grained arkosic orthoquartzite, sandy shale and siltstone. The sandstones are generally light gray or light tan, but sometimes have bands of light red-gray, light purple-gray and pink, and rarely red-gray. The sandy shale, shale and siltstone have variegated colors such as red-gray, buff, and olive. The sandstones are fairly well-sorted, generally quartzose with feldspar, scattered fine muscovite, biotite flakes, augite and/or hornblende. The shale and siltstone are generally micaceous. These rocks are sometimes calcareous and hard, especially the sandstone, hence are used as building stone. The coarse-to medium-grained sandstones are massive, or thick-bedded, while fine-grained ones are flaggy and thin-bedded. Cross lamination is well developed. These lithologic characters are intermediate between those of the underlying Phu Kadung and the overlying Phu Phan Formation.

Due to the lithologic characters, the massive- and thick-bedded sandstones have an excellent tendency to make cliffs where exposed. The escarpments which characterize the borders of the Khorat Plateau are made of this formation.

Fossil: Some molluscs and reptiles have been found from this formation (Ward et al., 1961-1963) and were already described by Dr. Teiichi Kobayashi and his collaborators (Kobayashi et al., 1963). The writers were successful in finding a few fossil leaves at the next two localities, though fragments are abundant.

Km. 41.25, Udon Thani-Nong Bua Lamphu Highway ---- Lower horizon ---- Brachyphyllum sp.

Km. 36.70, Udon Thani-Nong Bua Lamphu Highway ---- Upper horizon ---- Sphenopteris sp.

The molluscan fossils described by Dr. T. Kobayashi and others were collected from a horizon between the two just mentioned.

Distribution:

a) Km. 194-Km. 206, First Friendship Highway. Ca 600 m thick.

b) Km. 280-Km. 287, Lop Buri-Nakhon Ratchasima (Khorat) Highway. Ca 700 m thick. At the foot of the escarpment, strike and dip are respectively N20°W and 5°-60°ENE, but change to N20°-25°W and 5°-10°ENE near the top of the

escapment.

c) South of Ban Kut Bot, Amphoe Kuchinarai, Changwat Kalasin. Ca 500 m, N60°W and 10°-20°SSW.

d) Ban Si Yaek Nong Waeng-Sakon Nakhon (Pass of the Phu Phan Range). More than 200 m in thickness, strike EW and dip 5°S.

e) Km. 41.55-Km. 35, Udon Thani-Nong Bua Lampu Highway. Ca 550 m in thickness. Strikes N55°-35°W and dips 10°-25°NNE. Fossil molluscs, reptile and leaves were obtained.

f) Mt. Phu Kradung. Ca 700 m in thickness. N40°-35°E, 20°-10°NW, but generally 10°NW.

g) Km. 75-Km. 90, 2nd Friendship Highway, Phitsanulok-Lom Sak.

4. Phu Phan Formation

Type locality: The Phu Phan Range, boundary between Changwat Kalasin and Changwat Sakon Nakhon.

Stratigraphical relation: The Phu Phan Formation rests with conformity on the Phra Wihan Formation and is overlain with conformity by the Ban Na Yo Formation.

Thickness: Ranges from ca 100 m to 400 m.

Lithology: The Phu Phan Formation has distinct lithologic characteristics of white-gray, gray, very coarse-to fine-grained, generally well-sorted orthoquartzite and conglomerates mainly consisting of well-rounded, granule-to small-sized pebbles of clear, white and light pink quartz grains, though sometimes mixed with those of white and pink feldspar and chert. The sandstones are massive, thick- flaggy bedded and cross lamination is well developed. The granular and small pebbly conglomerate in the lower part of this formation is well observed at Km. 206, First Friendship Highway; Km. 287, Lop Buri-Nakhon Ratchasima (Khorat) Highway, and Pass of the Phu Phan Range between Kalasin and Sakon Nakhon. In the last mentioned locality the granular and small pebbly conglomerate of about 1 m thick rests on the friable shale which is pale gray with purple patches and purple in the uppermost part. This contact seems to be the boundary between the Phra Wihan and the Phu Phan Formations. The similar relation is also observed at Km. 206, First Friendship Highway.

Fossil: The writers have found no fossils.

Distribution:

a) Km. 206-Km. 220, First Friendship Highway. N70°-80°E, 15°NNW.

b) Km. 287-Km. 297, Lop Buri-Nakhon Ratchasima (Khorat) Highway. N20°-30°W, 3° ± ENE.

c) Road leading from Amphoe Kuchinarai to Ban Kut Bot, Changwat Kalasin. N60°W, 8° ± SSW.

d) Km. 63, Pass of the Phu Phan Range between Changwat Kalasin and Sakon Nakhon. N60°-70°W, 10° ± SSW.

e) Environs of Amphoe Mukdahan, Changwat Nakhon Phanom. EW, 9°S in the southern area, while 10° ± N in the northern environs.

f) Km. 35-Km. 33, Udon Thani-Nong Bua Lamphu Highway. Cross lamination is well developed. Km. 35 -- N15°E, 10°ESE; cross lamination---N10°W and N15°E, 18°WSW and 18°WNW. Km. 33.6 --- N15°E, 10° ± ESE.

g) Summit of Mt. Phu Kradung. Cross lamination is well developed. N35°E, 2° ± NW; cross lamination---N35°E, 12°NW.

h) Km. 71, 2nd Friendship Highway, Phitsanulok-Lom Sak. Subhorizontal.

5. Ban Na Yo Formation

Type locality: Ban Na Yo, Amphoe Mukdahan, Changwat Nakhon Phanom.

Stratigraphical relation: The Ban Na Yo Formation overlies the Phu Phan Formation with conformity.

Thickness: More than 420 m.

Lithology: This formation mainly comprises red, red-gray, purple-gray sandstone, siltstone, and shale and sometimes interbeds calcareous conglomeratic sandstone, sandy limestone, and calcareous siltstone mottled with purple-gray and green-gray. But sometimes light gray sandstones are interbedded. The calcareous sandstone is hard and used as building stone.

The sandstones are generally medium- to fine-grained, thick- to flaggy bedded, and cross lamination is developed, though not so prominent as observed in the Phu Kadung, Phra Wihan and Phu Phan Formations.

According to the boring data for ground water exploration, thin beds or patches of rock salt and gypsum are often interbedded.

Fossil: Nippononaia mekongensis Kobayashi, Trigonoides sp. nov., Plicatounio sp. nov., and Paranodonta(?) khoratensis Kobayashi described by Dr. Teiichi Kobayashi (1963)

were found in the calcareous siltstone at the type locality. Dr. D. E. Ward has reported on the occurrence of silicified bone fragments at the quarry, south of Km. 236.2, First Friendship Highway.

Distribution:

a) Km. 220-Km. 240, First Friendship Highway. N60°-80°E, 10°-20°NNW.

b) East from Km. 297, Lop Buri-Nakhon Ratchasima (Khorat) Highway. Km. 310-Km. 330-EW, 6°-2°S; Km. 300-N35°E, 2°SE.

c) Ban Na Yo (Type locality). N75°W-EW, 10°-5°S.

This formation probably has a wide distribution in the sub-surface of the Khorat Plateau.

Because of the thick blanket of Quaternary deposits, its exposures are rather restricted, but the distribution of this formation is ascertained by the drillings for the exploration of ground water.

The writers exclude tentatively the Lom Sak Formation from the newly re-defined Khorat Group, because the stratigraphical relation between the Ban Na Yo and the Lom Sak is unknown, except for that the Lom Sak Formation is in fault contact with the Khorat Group.

6. Lom Sak Formation

Type locality: Km. 105-Km. 122.5, 2nd Friendship Highway, Phitsanulok-Lom Sak.

Stratigraphical relation: Unknown.

Thickness: Unknown .

Lithology: This formation mainly comprises red-gray tuff, breccia-tuff, and dark green tuff. These pyroclastic rocks interbed the yellowish pale green, fine-grained sandstone, dark gray shale and calcareous shale. The sandstone and calcareous shale are comparatively hard. It seems that this formation is cut by faults, and the rocks are jointed. It has been known that Sequoia concinna Heer reported by Dr. Seido Endo (1963) was found from the sandstone. The writers succeeded to find Pterophyllum sp. and a fragment of a reptilian tooth? besides the above-mentioned fossil leaf. It was also observed that the sandstone has current ripples which are exposed on the surface of road cut.

The structure is rather complicate, probably due to faulting. The measured dips and strikes are variable as

follows.

Fossil locality (Km. 122.5)----N70°-60°W, 45°-30°NNE; River bottom about 250 m SSE of the fossil locality----N60°E, 10°NNW; Km. 118----N60°W, 30°NNE; Km. 110---N30°W, 20°NE; Km. 106---N50°E, 30NW; Km. 104---fault of NS-N30°E, 90°-80°NW.

4 Fossil Plant-Bearing Paleozoic Formation

1. Km. 9, Loei-Dan Sai Highway, Changwat Loei

The rocks are exposed on the road cut of several tens of meters distance along the highway. The rocks comprise alternation of black shale and fine- to very fine-grained micaceous orthoquartzite, attaining together about 10 cm in thickness. The thickness of the couplets comprised of one pair of shale and orthoquartzite ranges from ca 15 cm to ca 20 cm. But sometimes the sandstone attains more than 30 cm in thickness and three sandstone beds each more than 1 m thick are intercalated. These thick beds of sandstone are generally medium- to coarse-grained and have sole markings. The couplets of sandstone and shale show graded bedding, namely the very fine-grained sandstone merges upwards to the shale or the fine-grained sandstone merges to shale through the very fine-grained sandstone and sandy shale.

The apparent strike and dip are N25°-20°E, 55°W in the eastern part of the exposure and N15° ± E, 70° - 80° W in the western portion. Judged from the graded bedding and sole markings, it is evident that the strata are overturned. So far as observed, no repetition of the strata occurred. Pecopteris sp., Taeniopteris sp., Cordaites sp., Sphenophyllum sp. and Validopteris sp. were found. These fossils point to the Permian age.

2. Klong Wang Ang, Amphoe Nong Phai, Changwat Phetchabun

The locality situated about 8 km northwest from Chaibadan-Phetchabun-Lom Sak Highway.

Khlong Wang Ang is a small creek in the thick jungle. The rocks are exposed along the river bottom and banks. The geological route map is shown in Fig. 2c. The fossil-bearing beds are black, carbonaceous and calcareous shale intercalated in the flaggy bedded, dark gray limestone which is considered to belong to the Rat Buri limestone. These rocks have a general strike pointing to N45° - 60°W and dips 30° - 40°NE, though change to EW, 30°N in the upper reaches of the creek. The black shale is intruded by a porphyrite dike which has the

same trend as the neighbouring strata. Dr. Enzo Kon'no (1963) has already described the fossils from this locality.

The writers succeeded to obtain the following fossils, namely; Taeniopteris sp., Cordaites sp., Alethopteris sp. and Psygophyllum sp. These fossils point to the Upper Permian age.

## 5. Description of Fossil Localities

I. Fossil woods

1) Locality: Gravel pit, 3 km southwest of Km 242, First Friendship Highway (Saraburi-Nakhon Ratchasima), Changwat Nakhon Ratchasima (KR-KR-5)
Lithology: Gravel Bed
Fossils: Silicified woods (Dicotyledon)
Age: Quarternary?

2) Locality: Southeast of Ban Kut Bot, Amphoe Kuchinarai, Changwat Kalasin (KR-KC-6, KR-KC-23)
Lithology: Yellowish gray friable shale and thin bedded micaceous very fine sandstone (Phu Kadung Formation)
Fossils: Carbonized or silicified woods (Araucarioxylon sp.)
Age: Jurassic?

3) Locality: Ban Kham Duang, Amphoe Ban Phue, Changwat Udonthani (KR-UD-39)
Lithology: Gravel Bed
Fossils: Silicified woods (Dicotyledon)
Age: Quaternary?

4) Locality: Top of Mt. Phu Kradung, Amphoe Wang Saphung, Changwat Loei (KR-PK-27)
Lithology: Gravel Bed
Fossils: Silicified woods (Dicotyledon)
Age: Quaternary?

II. Fossil plants

1) Locality: Km.41.28, Highway Udon-Nong Bua Lamphu, Road cutting (KR-UD-29)
Lithology: Pale olive fine-grained snadstone (Lower Phra Wihang Formation)
Fossils: Brachyphyllum sp.
Age: Jurassic

2) Locality: Km. 36.70, Highway Udon-Nong Bua Lamphu, Road cutting (KR-UD-36')
Lithology: Pale green siltstone (Upper Phra Wihan Formation)
Fossils: Sphenopteris? sp.
Age: Jurassic

3) Locality: Km 108, Highway Khon Kaen-Loei, Huai Hin Lat, Amphoe Chumphae, Changwat Khon Kaen (KR-HH-2)
Lithology: Black calcareous fine-grained sandstone and yellowish brown siltstone (Huai Hin Lat Formation)
Fossils: Neocalamites sp., Equisetites sp., Cladophlebis sp., Clathropteris cf. meniscoides Brongniart and Pterophyllum sp.
Age: Rhaet-Lias

4) Locality: Km. 9, Highway Loei-Dansai, Road cutting (KR-LE-2)
Lithology: Black or dark gray coloured thin bedded shale and whitish gray micaceous fine-grained sandstone.
Fossils: Pecopteris sp., Taeniopteris sp., Cordaites sp., Sphenophyllum sp. and Validopteris sp.
Age: Permian

5) Locality: Khlong Wang Ang, Amphoe Non Phai, Changwat Phetchabun (KR-KW-1)
Lithology: Black calcareous shale
Fossils: Taeniopteris sp., Cordaites sp., Alethopteris sp. and Psygmophyllum sp.
Age: Upper Permian

6) Locality: Km 122.5, Second Friendship Highway (Lomsak-Phitsanulok), Road cutting (KR-LS-1)
Lithology: Yellowish pale green sandstone
Fossils: Sequoia concinna Heer and Ptrophyllum sp.
Age: Cretaceous?

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## VI. Stratigraphy and Geologic Structure of the Changwat Loei area

Tadashi Sato
Takashi Hamada
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Changwat Loei area is a half inlier of folded Paleozoic rocks surrounded by the Khorat Series in its eastern and western parts. Paleozoic rocks gradually submerge under the Khorat Series toward the south, while toward the north they continue in High Laos across the Mekong river. Tectonically it represents the southern extremity of the axial part of Paklay anticlinorium described in High Laos (Högbom 1914).

Geomorphologically it is a widely dissected valley of the Loei river, branch of the Mekong. Folded Paleozoic rocks are evenly eroded away, except some limestone or dolomite peaks or ridges which are highly resistant to weathering, and remain as abrupt relict hills or towers over the flood plain of the valley, but their altitude never exceeds 1,000 m, while surrounding Khorat Series dominates the valley with their escarpment of over 1,300 m in altitude in the western and southern margins of the area.

Because of the tropical climate, weathering advanced in considerable degree and rocks constituting the basement of the area are thickly covered by soils and alluvial deposits, so that their stratigraphical relation is, in most cases, hardly ascertained from the field observations.

Therefore, fossils capable of indicating ages take the most important role to establish the stratigraphy of the area. Those which collected the authors through their survey are enlisted below in full detail, but here the general idea of stratigraphy and geological structure is summarized.

Geological survey of this area was carried out in the period of a week from Jan. 14 to Jan. 20, 1964, in close cooperation with the following Thai officials from the

Department of Mineral Resources at Bangkok.
Mr. Manas Veeraburus, Senior Geologist,
Miss A-Ngoon Honnusonthi, Junior Geologist.

1. Stratigraphy:-

Surveys were restricted to the Paleozoic rocks, regardless of the Khorat Series, which will be reported by other experts, Prof. Iwai and Dr. Asama.

Every spot ever known as fossil localities was visited. However, even if the stratigraphical sequence at each spot has been taken in detail, correlation with each other has no firm basis except fossils. The general idea of the sequence will be given below, but it is far from definitive and satisfactory, and much more refinement is required for the more precise interpretation of the stratigraphy of the area.

Lowest Carboniferous or upper Devonian

Conglomerate and shale exposing on the southern slope of a hill east of Changwat Loei is presumably the oldest rock known in the area. Ammonites and Brachiopods are picked up from the debris of the exposure but the exact age should be determined only after paleontological investigations of the fauna.

Other particular rocks are known along the Mekong valley, east of Chiang Kan, which are mainly altered tuffs, lavas, keratophyres and porphyries. No fossils have been found. No similar rock is known around Loei area, but it may be included to the Devonian formations in Laos.

Carboniferous

Conglomeratic sandstone, micaceous or calcareous sandstone and grey or brown shale intercalated by arenaceous limestone are exposed in Huai Luang and surrounding area west of the Phu Phan Sing ridge, 5 km east of Wang Saphung. White massive limestone is known on the east of Huai Luang, in superjacent relation to the former (cf. fig. 3a). The former is characterized by various kinds of fossils suggesting Carboniferous age, while the latter bears undoubtedly late Middle Carboniferous Fusulinids and Corals. The stratigraphical relation between the two is likely to be normal. The age of Huai Luang fauna should not be older than late Middle Carboniferous (Moscovian) but paleontological investigation is required for more precise correlation.

## Permian

Generally speaking, the limestone ridges which are projected from the flat plain of the valley are Lower Permian in age, as indicated by containing Fusulinids. They are more or less dolomitized on the surface or recrystallized into marble in some places. This is the most conspicuous Lower Permian deposits of the area by their particular topography.

The black argillaceous limestone lenses are frequently inserted within the detritic sediments and they indicate various horizons of Permian.

The most important part of Permian is mainly composed of fine-grained detritic rocks, such as grey micaceous shales or feldspathic shales, with subordinate intercalations of chert bands or arenaceous or sometimes rudaceous rocks. They are, as a rule, poor in fossils, except some parts which are rich in Brachiopods, Ammonites and Trilobites. They are easily weathered and form actual flat plain of the valley. They are most likely to range in different ages, as suggested by their stratigraphical positions in relation to Fusulinid-bearing horizons.

A rich fauna of Brachiopods in the dry creek of Huai Bun Nak, about 4 km E of Wang Saphung, where stratigraphically basal parts are characterized by Triticites-bearing Lower Permian or Upper Carboniferous limestone layers, should not be older than Lower Permian. On the other hand, fine-grained sediments from which Ammonites were found, on meridionally elongated narrow ridge about 4 km W of Wang Saphung-Loei line, might be younger than Middle Permian, because they are just superjacent to the black argillaceous banded limestone which is dated as Middle (?) Permian by Fusulinids.

Some of the fine-grained sediments may be attributable to Carboniferous, as exemplified by Huai Luang sediments with abundant Ammonites and Brachiopods.

In short, dominantly fine-grained detritus deposited through younger Paleozoic, and occasionally dark impure limestone layers were formed rapidly, especially in Upper Carboniferous, Lower Permian and Middle Permian. The most important massive pure limestone deposited in Lower Permian age.

## 2. Geological Structure:-

The essential feature of the structure of Paleozoic rocks are summarized as follows:

1) Every bed participates with the folding of the concentric fold type, of which axis is nearly parallel to the meridian and gradually curves to NNW-SSE direction toward the south. The wave length of the fold is of order of 5 km. In any exposure observed, no trace of slaty cleavages is known even in the axial part of the fold, while frequently slipping traces are observed on the bedding planes.

2) In the surveyed area, fold axes of the Paleozoic rocks gently plunge to the north. This is also corroborated by the fact that all the poles of bedding planes observed in the area form a girdle on the equal area projection with a pole plunging about 11 degrees in N 12°W (fig. 3b).

3) The particular S-shaped distribution of limestone ridge in the south of Wang Saphung has to be resulted from the plunge of fold axes.

4) Faults and minor faults observable in the area are various in type and in attitude. As observations were restricted within very sporadical exposures, and as systematic observations could not be made, the interpretation of the mechanism of faulting in the area cannot be given here. However, some of them are undoubtedly related to the folding, as seen in Huai Yee Laurt (drag folds of less competent beds in the eastern limb of the anticline gives the most probably the evidence of the contemporaneity of folding and faulting). The thrust fault combined with the antithetic reverse fault observable in the exposure at km 9 Loei-Petchabun highway would be the same phenomenon in opposite limb of the same anticline, even if the disposition of its principal stress axes are slightly deviated from that of the former (fig. 3c).

Besides, major faults are presumed between Huai Luang and Huai Bun Nak, because of the important dislocation of Lower Permian to the position where the older rocks should be expectec under the Huai Luang Carboniferous beds. The same is true between the Huai Yee Laurt Permian and Wang Saphung, judged from the distribution of the characteristic limestone ridge.

Oblique faults in relation to the general trend of the Paleozoic beds are expected in the direction of NE-SW and NW-SE because of the displacement of the Permian banded limestone ridge running in N-S direction, in the west of Loei-Wang Saphung line.

3. Description of fossil localities

1.100 m east of Huai Luang, along the highway Wang Saphung-Udon Thani (Loc. LE-14).

Lithology: White grey massive limestone
Fossils: Fusulinella giantic form
Ozawainella n.sp.
Fusulina konnoi
Psuedostaffella sphaeroidea
Eoschubertella
Staffella
Caniniid corals of Campophyllum type
Age: late Middle Carboniferous (Moscovian)

2. Huai Luang, east of Huai Bun Nak, SE of Wang Saphung.
Lithology: Conglomeratic sandstone with chert-shale pebbles gradually becoming feldspahtic downwards (LE-6B)
Lens of arenaceous thin bedded limestone (LE-6C,E)
Micaceous fine-grained sandstone and shale
Calcareous sandstone with Conodonts? (LE-6A)
Grey shale yielding Trilobites, Ammonites and Brachiopods (LE-6)
Arenaceous bedded limestone
Brown shale
Fossils: Thaiaspis
Schizophoria
Palaeonucula
Spirifer
Christites
Squamularia
Dictyoclostus
Agathiceras like Ammonite
Age: Carboniferous?

3. Ban Pha Noi, exposure in the river stream near the confluent of Nam Puan, NE of Loei (LE-13)

Lithology: 5 horizons of different fauna are distinguished, mainly brownish siltstone with occasionally intercalated dark grey fine-grained sand stone, carbonaceous shale, overlying dirty limestone lenses.

Fossils: 13C, Brachiopods, Gastropods
13B, Triticites?
13A, Productids, Triticites.
Age: Lower Permian? or Upper Carboniferous?

4. A small hill 4 km east of Loei (LE-17, 18)

Lithology: shale and conglomerate
Fossils: Ammonites and Brachiopods
Age: Lowest Carboniferous? or Upper Devonian?

5. Huai Bun Nak, SE of Wang Saphung, parallel to the highway Wang Saphung - Udon Thani (LE-5).

Lithology: Greenish grey, or kaki calcareous well sorted siltstone or micaceous shale with Brachiopods (Linoproductus, Squamularia, Rhynchonellid, Chonetes, "Schizophoria")
Including lens of dark grey chert-nodule bearing finely crystalline limestone, yielding
Wentzelella
Chaetetes
Waagenophyllum etc.
Greenish brown shale, non fossiliferous
Greenish grey micaceous shale, with
Dictyoclostus
Thinly banded black argillaceous limestone with Foraminifers
Waagenophyllum
Sinopora etc.
Black thinly bedded calcarenite with
Triticites
Algae etc.
Brown-grey fine-grained sandstone and shale with intercalation of limestone yielding
Small Foraminifers
Algae
Fragmental Brachiopods
Triticites?
Black algal limestone
Calcarenite

Black algal limestone
Black crystalline limestone with crinoid stems
Black algal fine-grained biomicrite with Pseudoschwagerina ?
Black calcarenite
Black algal limestone
Black algal limestone with Corals (Lopophylloids)
White grey limestone,
Dark grey calcarenite with Triticites
Conodonts?
Black argillaceous limestone with Triticites

Besides, a rolled block yielded Pseudofusulina.
Age: Lower Permian.

6. South-western flank of Tham Nam Maholan, south of Wang Saphung (LE-11, 12)

Lithology: Massive white limestone, several fossil horizons are to be expected.
Fossils: Parafusulina
Schwagerina
Triticites
Quasifusulina
Schubertella
Pseudoschwagerina
Neospirifer
Purdonella
Dictyoclostus
"Squamularia"
Trilobites
Gastropods
Age: Lower Permian

7. Phu Pha Sing limestone ridge, 1 km E of Huai Luang
Lithology: Pink-white marble
Fossils: Triticites ? - Schwagerina ?
Age: Lower Permian

8. West of the above
Lithology: Grey dirty limestone
Fossils: Fusulinids (Schwagerina?)
Age: Lower Permian?

9. Wat Tham Tha Phu, NW of Loei (LE-19)

Lithology: White brecciated limestone
Fossils: Schwagerinids
Triticites
Caninid Corals of Campophyllum type
Age: Lower Permian

10. Earth Fill Dam at Huai Yee Leurt, 4 km west of Wang Saphung (LE-8)

Lithology: Black banded limestone underlying
Black banded chert and laminated cream shale

Fossils: Parafusulina
Psudodoliolina (gravitesta-type)
Crinoid stem joints from limestone
Ammonites
Conodonts
Radiolarians.....from banded chert

Age: Permian

11. Nam Pao, 4.5 km NW of Loei (LE-9)

Lithology: Alternation of fine-grained bluish brown feldspathic sandstone and white cream shale

Fossils: Agathiceras-like ammonites
Crinoid stems

Age: Permian

12. Pha Nok Khao (LE-4)

Lithology: dark grey finely crystalline limestone

Fossils: Pseudodoliolina
Parafusulina

Age: Upper Permian

## VII. Stratigraphy of Peninsular Thailand

Ryuzo Toriyama
Tadashi Sato
Takashi Hamada
Hisayoshi Igo

Geologically the major structural trend is slightly oblique to the extension of the peninsular part of Thailand. Limestone series of various ages ranging from Ordovician to Silurian and from Carboniferous to Permian, i.e. the Thung Song limestone and the Rat Buri limestone series respectively, make the remarkably pronounced ranges in the area. They show steep cliffs or overhanging walls. Other lithological units such as sandstone and shales are almost hidden beneath the widely covering fluvial deposits in which were contained some important cassiterite placers. The granitic rocks intruded into the Palaeozoic beds form the massive and high mountains especially at the anticlinorial parts. The small basins of marine and lacustrine Tertiary sedimentary series are scattered in this area.

The palaeontological and stratigraphical reconnaissance was mainly carried on the Palaeozoic rock formations. Being prevented by the restricted exposure and rigid topography, the stratigraphy is still tentative. Our efforts have been made mainly to know the fossil assemblages and their horizons in the rock sequences. Many samples more than a ton were collected. The listed fossil names in this report are only tentative and should be revised after the minute palaeontological investigation.

The reconnaissance of this area was carried out in the periods from Dec. 14, 1963 to Jan. 8, 1964 and from Jan. 26 to Feb. 3, 1964 by the above listed Japanese experts in cooperation with a Thai official, Mr. Pumwarn Komalarjun (Senior geologist), of the Department of Mineral Resources at Bangkok.

### 1. The Phuket - Phangnga - Krabi district

This district is geologically composed of the younger granite, from which are derived many tin placers, and the Palaeozoic sediments intruded by it. The latter comprise the Permian limestone, or the Rat-Buri series, and the underlying pebble-bearing shale and sandstone series. The Tertiary Krabi series makes several small troughs and basins on these basements.

## Stratigraphy

The Phuket Series:

The Phuket series or the so-called pebbly rock series has been regarded as the Lower Cambrian on the basis of an occurrence of "Eophyton" and fucoid-like fossils from the Phuket Island where is the typical locality. The lower part of this series is mainly composed of pebble-bearing sandstone and phyllite. The upper part is black shale without pebbles. The stratigraphical relationship between the two parts is almost conformable as seen on the southeast coast of the island (Lam Si Re). Many fucoid-like Lebensspuren were preserved on the bedding plane of the black shale of the upper part, but not any index fossils were found there.

Structurally the series is monoclinic being inclined to the east at Lam Si Re, or gently folded as at Lam To Khun (fig. 4d). The lower part of this series yields sporadically various kinds of pebbles, the largest of which attains 17 x 13 x 8 cm. in size. Hard medium-grained quartzite is the common pebble species, and some granitic rocks and granite gneiss are found. They are almost semi-angular in shape, and sometimes the smaller pebbles among them are well rounded. A small number of limestone pebbles are also detected, but no fossils are found in them as far as by naked eyes.

Near the Thian Wanith Co. Mine and Sap Nai Din Co. Mine (tin), north of Phangnga, medium to coarse-grained massive sandstone is exposed along the river wall and also makes the basement of the tin placers. It contains small quartzite and granite pebbles, and seems to be equivalent to the "pebbly rock" series in the Phuket Island. As mentioned later the similar pebble-bearing massive sandstone is known along the road side of the highway 5 (16 km. from Phatthalung) at Khuan Din So. This sandstone yields some poorly preserved pelecypod, fenestellid bryozoa, brachiopods, etc., and presumed as Carboniferous in age.

The pebbly massive sandstone series is also widely distributed near Khao Nang Hong. The boundary between this sandstone and eastwardly exposed black-gray shale series seems to run in the N10-20W direction along a small river near the highway 5 (181.5 km.).

## Description of Fossil Localities

1. Lam Si Re, east of Phuket town (WPH-4,5).
   Lithology: Black sandly shale.

Fossils: "Eophyton" ? and Lebensspuren.
Age: Presumably Carboniferous.

Permian:

The Permian limestone of the Rat Buri series is fairly widely distributed being gently undulated in this district. At a small quarry south of Khao Chiang, and an outcrip behind Wat Pra Chum Yothi, east of Khao Wong near Phangnga it yields some fossils such as corals, brachiopods and crinoid stems. An ill-preserved Pseudofusulina ? was found in slightly recrystallized gray limestone of the former locality. At the southern foot of Khao Chiang Verbeekina and smaller foraminifers and corals, brachiopods, gastropods were also recognized in light-coloured limestone. This limestone is underlain by bedded quartzite as seen at Tham Khon Chiang, Khao Chiang. This clastic sediment as well as the sandy shale exposed along the highway 5, close to the Public Girl School of Phangnga may belong to the upper part of the Kanchanaburi series.

Description of Fossil Localities

1. A small quarry, south of Khao Chiang (WPG-3).
Lithology : Gray medium-grained limestone.
Fossils : Pseudofusulina ?, tetracorals, brachiopods,
Age: Middle Permian.

2. Tham Khon Chiang, southern foot of Khao Chiang (WPG-7).
Lithology : Black medium-grained, slightly recrystallized limestone underlain by thinly bedded quartzite bed.
Fossils: Bellelophontid gastropod.
Age : Permian.

3. A quarry behind the Public Girl School, Phangnga (WPG-9).
Lithology : Light-coloured limestone.
Fossils : Tabulate corals, tetracorals, brachiopods, bellelophontid gastropods, calcareous algae.
Age : Permian.

4. An exposure behind Wat Pra Chun Yothi, east of Khao Wong near Phangnga (WPG-12).
Lithology : Bedded gray limestone with black cherty nodule and band.
Fossils : An abundant number of brachiopods, especially rhynchonellid.

Age : Permian.

5. Tham Kop, Wat Khiri Wong, highway 5 (179-180 km.) (WPG-15).
Lithology : Slightly recrystallized gray limestone.
Fossils : Small fusulinids.
Age : Carboniferous ??

6. A quarry at the road side of the highway 5 (176-177 km.) near Khao Lai (WPG-16).
Lithology : Gray - brown limestone with colite.
Fossils : Microforaminifers.
Age : Permian ?

Tertiary :

At Lam Pho near Krabi the upper part of the Krabi series is well outcropped. This is the thinly bedded sediments with poor iron deposits and lignite seams which are gently and northwardly dipped. Stratigraphic succession of this part is shown on fig. 4b. "Viviparus" and Melania" are quite common in this sediments especially in the coquina limestone. These gastropods were said to be marine although the name has not been mentioned in the U.S.Geol. Surv. Bull. 984 (1951) on page 40. A limonite bed is superposed on this fossiliferous deposit to the north. Lignite beds, of which the thickness is said to attain 15 m. at a maximum, are also developed and mined as the fuel for the Krabi Electric Power Plant. Some plant leaves and seeds were found in the lignite exposed in the creeks in the Power Plant.

## Description of Fossil Localities

1. Lam Pho, near Krabi (WKB-1,2).
Lithology : Brownish - bluish gray mudstone and coquina with thin lignite bed.
Fossils : "Viviparus" and "Melania", etc.
Age : Plio-Pleistocene ?

2. Krabi Electric Power Plant (WKB-3,4).
Lithology : Black lignite.
Fossils : Plant leaves and seeds.
Age : Plio-Pleistoeene ?

Quaternary Tin Deposits :

The Thian Wanith Co. Tin Mine is situated at 15 km. north of Phangnga. The cassiterite grains are contained in the huge boulder-bearing fanglomerate which measures 4 - 7 m. thick. The boulder is mainly composed of the younger granite with tourmaline pegmatite vein. Rosy quartz and lepidolite were found as the pebbles in the fanglomerate. The basement of the tin placer is massive pebbly sandstone probably of a member of the Kanchanaburi series. At the Sap Nai Din Co. Tin Mine, just south of the above mentioned mine, the same pebbly rock is widely exposed as the basement of the tin placer which is less coarse-grained fluvial gravel and sand deposits.

Prehistoric Cave Deposits:

In some limestone caves of this district, for example, at Khao Tham and a small quarry south of Khao Chiang, we found several shell mounds with many Cyrena, Ostrea, Mactra, and other molluscan remains and a few fragmental potteries. These deposits were preserved on the cave floor without overlying sediments. They are supposed to be the relicts of the Prehistoric man. The altitude of the mound above the sea level is approximately 5 metres.

## Description of Fossil Localities

1. A small quarry, south of Khao Chiang, Phangnga (WPG-3).
   Lithology : Cave deposits with fragmentary potteries.
   Relicts : Mactra, Cyrena, Ostrea, etc.
   Age : Alluvium (Prehistoric).

2. Khao Tham (WPG-6).
   Lithology : Cave deposits with fragmentary potteries.
   Relicts : Mactra, Ostrea, etc.
   Age : Alluvium (Prehistoric).

## The Thung Song - Trang - Satun District

Both of the central range area and the southwest coast of the Peninsular Thailand belong to the same geological belt which makes an axial part of an anticlinorium. The Cambrian and Ordovician fossiliferous strata are well outcropped along this axis which runs approximately N-S direction and further extends to the south to the Langkawi - Perlis district of the northwestern coast of Malaya. Generally speaking, the younger granite seems to occupy this

axial area. The Permo-Carboniferous Rat Buri limestone is also distributed in these districts.

## Stratigraphy

Cambrian :

The Upper Cambrian red - purple sandstone is exposed on the east and west coasts of the Tarutao Island, hence the name Tarutao sandstone. Pagodia, Thailandium and other Upper Cambrian trilobites were described by Kobayashi (1957). These trilobites occur as shell laminae in the medium-grained and rather massive reddish purple sandstone at Ta Lo Phao (Fig.4c) and Ta Lo Ban Thai Ma La Ka of the west coast, and Ao Kung of the southeast coast of the island. The base of this sandstone is limited by fault. The upper part, on the other hand, seem to become gradually to thinly bedded and finally transferred into the laminated limestone, which is a member of the Thung Song limestone at Ao Hin Ngam as shown on the route map in fig. 5.

## Description of Fossil Localities

1. Ta Lo Phao, northwest coast of Tarutao Island (WTT-9).
   Lithology : Medium-grained reddish purple sandstone.
   Fossils : Apheorthis ? sp., "Eosaukia" buravasi Kobayashi Thailandium solum Kob., Pagodia thaiensis Kob., etc.
   Age : Upper Cambrian.

2. Ta Lo Ban Thai Ma La Ka, northwest coast of Tarutao Island (WTT-10A,B).
   Lithology : Medium- and fine-grained sandstones in alternation. Gently dipping to the west.
   Locality A is 10.1 m. lower than Loc. B.
   Fossils : A lot of Thailandium solum Kob., "Eosaukia" buravasi Kob., Pagodia thaiensis Kob., Coreanocephalus planulatus Kob., etc.
   Age : Upper Cambrian.

3. Ban Thai Ma La Ka, northwest coast of Tarutao Island (WTT-11).
   Lithology : Alternation of sandstone and thin shale in variegate colour with thin limestone intercalation.
   Fossils : Trilobite fragments.
   Age : Upper Cambrian ?

4. Ao Kung, southeast coast of Tarutao Island (WTT-14).
Lithology : Alternation of medium- and fine-grained variegate sandstone.
Fossils : Brachiopod and trilobite fragments.
Age : Upper Cambrian ?

Ordovician :

The Lower Palaeozoic formations are inclusively called the Setul (Satun) formation, and the Thung Song limestone series represent its calcareous facies. As far as we surveyed the oldest formation of the series in Thailand is Middle Ordovician (Mohawkian) limestone exposed in a dense jungle of Khao Sai Phet near Ban Thung Din Lum, east of Thung Wa. Kobayashi and Hamada (1964) and Hamada (1964) distinguished several brachiopods, gastropods, cephalopods and trilobites in this limestone. The stratigraphic succession of the Middle and Upper Ordovician limestone is uncertain because of the poor exposures in the jungle.

Cephalopod-gastropod limestone of Ordovician age is fairly widely distributed throughout this district. In some places small brachiopods are found in association with these fossils, and calcareous sponge is also common in the fauna. These Thung Song limestones are almost black in coulour and characterized by its siliceous nodules or laminations of irregular shape. Sometimes they yield conodont so abundant that in future the subdivision of this limestone series will be established by means of conodont stratigraphy.

At a small quarry of Khao Pa Teo near Kantang the muddy black limestone contains Labechia-like stromatoporoid ? and small orthid brachiopods. But the geological age of this fauna is uncertain.

## Description of Fossil Localities

1. Khao Sai Phet near Ban Thung Din Lum, east of Thung Wa (WTW-1-4).
Lithology : Weakly bedded black muddy limestone with intercalated calcareous shale beds.
Fossils : Rafinesquina komalarjuni Hamada, Opikina ? bellicostata Ham., Cyrtonotella thailandica Ham., C. transversalis Ham., C. sp., Multicostella ? sp., Lophospira sp., Ormoceras ?, Endoceras, gigantic cephalopod, Basiliella satunensis Kobayashi and Hamada, B. sp.
Age : Middle Ordovician (Mohawkian).

2. Khao Pa Teo quarry, between Trang and Kantang (WTR-1).
Lithology : Muddy black limestone.
Fossils : Labechia-like stromatoporoid ? , small orthird.
Age : Ordovician ?

3. An Yin Islands (WTT-1).
Lithology : Black or gray bedded limestone with argillaceous laminations.
Fossils : Small brachiopods.
Age : Ordovician.

4. Hat Ka Sing near Khao Bo Chet Luk (WTT-2).
Lithology : Gray thinly laminated cephalopod limestone.
Fossils : Armenoceras, gigantic cephalopod, Taffia-like brachiopod.
Age : Ordovician.

5. Ban Thai Ma La Ka, northwest coast of Tarutao Island (WTT-12).
Lithology : Gray argillaceous limestone.
Fossile : Many small cephalopods and colulariids ?
Age : Lower ? Ordovician.

6. South of Ban Thai Ma La Ka (WTT-13).
Lithology : Gray argillaceous limestone.
Fossils : Conodonts (?).
Age : Ordovician.

7. Ao Kung, southeast coast of Tarutao Island (WTT-14).
Lithology : Thinly laminated black - gray limestone.
Fossils : Trilobite fragments were once obtained.
Age : Lower ? Ordovician.

8. Khao Nam Phai quarry, 19 km. from Trang on the highway 5 (CP-5).
Lithology : Gray - black thinly bedded limestone with reddish shalstein-like laminae.
Fossils : Large brachiopod ? fragment, lebensspuren.
Age : Ordovician ? or Silurian ?

9. Ban Na, near Na Born, northeast of Thung Song (CP-14,15).
Lithology : Pink cephalopod marl with labyrinthine pattern of clay film on it probably produced by coagulation, being underlain gray - black limestone.
Fossils : Gigantic cephalopod, trilobite fragments, cystidean plates, brachiopods, gastropods in pink

marl ; cepahlopod, stromatoporoid, gastropods and sponge in gray limestone.
Age : Upper - uppermost ? Ordovician.

10. Khao Thep Hanom Chuat, Rhon Phibun (CP-16, 17).
Lithology : Gray - black argillaceous limestone.
Fossils : Helicotoma-like gastropods, cephalopods, brachiopod fragments, sponge.
Age : Ordovician.

11. Rhon Phibun new quarry (CP-18).
Lithology : Laminated but rather thickly bedded gray limestone.
Fossils : Armenoceras chediforme Kobayashi, gastropod, sponge.
Age : Ordovician.

12. Khao Tham Talot, south of Thung Song (CP-22).
Lithology : Black argillaceous limestone.
Fossils : Armenoceras.
Age : Ordovician.

Silurian - Devonian :

The undoubted Silurian and Devonian fossils has not been recorded only in this district but also throughout this country. However, the Lower Silurian graptolite fauna was quite recently discovered at Ban Na, near Na Born by Mr. Charan Phootai, geologist of the Department of Mineral Resources at Bangkok. Furthermore the red bed exposed on the islands near the Thai-Malaya border was found during the reconnaissance to contain the similar fauna as that from the red bed in the Perlis and Langkawi Island area of Malaya where it lies directly on the Lower Silurian graptolite shale bed. This red bed is intercalated in the bedded quartzite strata at Ko Yao as shown in fig. 6.

Several specimens of Syringoporella-like simple tabulate coral were obtained from the beach pebbles of quartzite at Ko Bu Ron Don where the similar quartzite is widely exposed along the western coast. The precise generic identification of this coral is not made as yet, but it looks like Devonian if not the Ordovician Eofletcheria.

At Ban Na, the Lower Silurian graptolite shale is exposed as a thin black shale lense in the limestone series (Fig. 4e). The stratigraphic succession is as follows.

| | |
|---|---|
| Silurian | gray limestone<br>white limestone of a few metres |
| Lower Silurian : | black graptolite shale |
| | (white limestone) |
| Ordovician | pink marl and limestone<br>black laminated limestone |

The pink marl is also fossiliferous, especially in cephalopods and supposed to be Upper Ordovician. The overlying limestone is poorly fossiliferous at the exposure, but it undoubtedly belongs to the Silurian formation. Further study is needed to establish the stratigraphy of an Ordovician - Silurian transitional formation of this locality.

Description of Fossil Localities

1. West coast of Ko Bu Ron Don (WTT-7).
   Lithology : White fine-grained laminated quartzite; partly brecciated.
   Fossils : Silicified Syringoporella-like tabulate coral in the quartzite subangular beach pebbles.
   Age : Devonian ? ?

2. Ko Yao near Satun (WTT-15).
   Lithology : Red mudstone intercalated in bedded quartzite.
   Fossils : Brachiopods, Posidonomya-like pelecypod, crinoids, ostracods, trilobites in the red mudstone.
   Age : Silurian - Devonian.

3. Ban Na, near Na Born (CP-13).
   Lithology : Black bituminous shale lying on the pink cephalopod marl.
   Fossils : Monograptids.
   Age : Lower Silurian.

Carboniferous :

The Carboniferous stratigraphy in this district is not so clear as in the northern part of this country. The Carboniferous brachiopods such as "Linoproductus" cf. umariensis and spiriferids were obtained from the conglomerate beds in the sandstone and shale series beneath the fossiliferous Permian limestone at Ko Muk (fig. 4a) and also at Ko Klang. The so-called pebbly rocks at the Phuket Island is thought to be Carboniferous as mentioned already. The similar pebbly rocks are fairly widely

distributed in this district, and in some places brachiopod and other fossils were obtained from them. At Khuan Din So along the highway 5, 16 km. from Phatthalung, the pebble-bearing sandstone yields pelecypod and brachiopod, in which a fragmental linoproductid was found. From the fine-grained mudstone intercalated in this sandstone we also obtained a lot of another kind of brachiopod. These pebbly rock series look like underneath the Permo-Carboniferous limestone series with some distance, though the precise stratigraphical relationship is not ascertained as yet. At Khao Wang Yuan, south of Thung Song, the Posidonomya ? and crinoid bearing pebbly series dip eastwards gently and appears to superpose on the Thung Song limestone series. These stratigraphical situation of the pebbly rocks strongly suggest that it does not belong to the Cambrian formation but to the Kanchanaburi series and probably of Devonian - Carboniferous in age. The almost similar stratigraphy was found at the Langkawi Island, northwest Malaya as described in the other chapter of this report.

The calcareous deposits of Carboniferous age have not been recorded in this district. However, in the Phangnga area at Wat Khiri Wong (highway 5, 179-180 km.), the doubtful Carboniferous small fusulinids were found in slightly recrystallized gray limestone during this reconnaissance trip. This fossiliferous horizon occupies the basal part of the limestone at that locality.

Description of Fossil Localities

1. Southwest coast of Ko Muk (WKM-11,12).
   Lithology : Black shale and sandstone alternation with interbedded thin conglomerate beds.
   Fossils : Brachithyrina thailandica Hamada, Fusella cf. convoluta (Phillips), Punctospirifer sp., Kitakamithyris buravasi Ham, "Linoproductus" cf. umariensis (Reed), etc.
   Age : Upper ? Carboniferous.

2. West coast of Ko Klang (WTT-8).
   Lithology : Black sandstone and shale in alternation.
   Fossils : "Linoproductus" cf. umariensis (Reed), etc.
   Age : Upper ? Carboniferous.

3. Khuan Din So, highway 5, 16 km. from Phatthalung (CP-1,2).
   Lithology : Gray massive brittle mudstone with small rounded pebbles of quartzite. Gray shale beds are intercalated.

Fossils : Fenestellid bryozoa, brachiopod fragements including linoproductid, pelecypod from pebbly rock ; undetermined brachiopod from shale.
Age : Upper Carboniferous ?

4. Khao Wang Yuan, south of Thung Song (CP-21).
Lithology : Gray pebbly sandstone and greenish gray, black, brown shale in alternation.
Fossils : "Posidonomya", crinoid stem joints and calyx, blastoid, trilobite fragments from shale.
Age : Devonian or Carboniferous.

Permian :

The Rat Buri limestone series includes the Permian fusulinid and brachiopod-limestones in this district. At Ko Muk the fossiliferous gray limestone lies on the Upper ? Carboniferous alternation of sandstone and shale. An abundant amount of brachiopods, tetracorals, cephalopods, and bryozoa were collected from this limestone. This fauna includes a lot of large dictyoclostid brachiopod and a few Leptodus species. No fusulinid was found at all. We can say nothing on the precise geological age of this fauna until the palaeontological study on these materials is over, but it looks like Lower Permian. The lower part of the limestone exposed at Khao Chiak, between Trang and Phatthalung, is composed of finely laminated and thinly bedded fine-grained gray - white limestone. This lithology is rather peculiar for the Rat Buri limestone series. Only the indeterminable pelecypod, gastropod, calcareous algae and bryozoa were detected in it. Ko Phe Tra and Khao Huai Han were entirely constructed by the typical Rat Buri limestone series. From the east coast of the former locality we found many fusulinids and corals in the limestone, and its geological age was determined as Middle Permian.

## Description of Fossil Localities

1. Ko Muk (WKM-2-10).
Lithology : Bedded gray limestone with cherty nodules in some parts.
Fossils : Many bryozoa, tetracorals, brachiopods, cephalopods, etc.
Age : Lower ? Permian.

2. East coast of Ko Phe Tra (WTT-4-6).

Lithology : Gray massive limestone and reddish gray brecciated limestone.
Fossils : Parafusulina ? Pseudodoliolina, Miselina, Verbeekina, Michelinia, tetracorals, ammonoid, calcareous algae.
Age: Middle Permian.

3. Behind the Ratthaphung Amphoe Office, Changwat Songkhla (WTT-18).
Lithology : Pinkish gray limestone.
Fossils : Fusulinids were once obtained.
Age : Permian.

4. Khao Chiak quarry, between Trang and Phatthalung (CP-3).
Lithology : Gray, white, brown fine-grained limestone ; finely laminated and thinly bedded.
Fossils : Small gastropods, pelecypods, brachiopods, bryozoa and calcareous algae.
Age : Permian ?

5. Khao Huai Han, north of Trang (CP-6,7).
Lithology : Gray limestone, partly recrystallized ; lower part is unfossiliferous and rather fine-grained and bedded as the limestone at Khao Chiak quarry.
Fossils : Primitive Parafusulina, bryozoa, brachiopods, gastropods, tetracorals, crinoid stem joints, calcareous algae, etc.
Age : Lower - Middle Permian.

Quaternary Tin Deposits :

At the north of Khao Sung, near Khlong Muan, there are several tin mines working on the gravel and sand layers which were originated from the younger granite of Khao Sung. Cassiterite is unevenly contained, but generally speaking, the placer becomes more rich as close to the granite exposure. The maximum size of cassiterite grain attains about 3 cm. in diametre as well as in length. Thickness of the deposits extremely variable at places. The basement of the placer is composed of biotite-sericite-chlorite-quartz schists with crystalline limestone lenses. The schist series seems to be produced from the Kanchanaburi series by the contact metamorphism of the younger granite of Khao Sung. The limestone outcropped near the Khlong Muan railway station is white and coarsely recrystallized. Several thin dykes of tourmaline-bearing granite intrude into the schist series of the basement.

The dark brown tourmaline is common in the boulder derived from Khao Sung granite mass.

Granitic Rocks :

The younger granite is fairly widely exposed at the axial parts of the anticlinoria. At Khao To Nam near Rhatthaphung and at the Khao Shong Botanic Garden some waterfalls are hunging on these granite mountains. Tourmaline is common in the pegmatite veins. In the porphyritic granite at the quarry of Khao Ban Dai Nang, Songkhla, purple or green fluorite is found as thin veinlets. Around the Muang Khwa area, near Phatthalung the cassiterite-bearing younger granite is distributed and poor thin placers are scattered in the river gravel beds. A beautiful Tha Phae waterfall of Khao Cha Om at Ban Na is on the younger granite. This granite is composed of fine-grained biotite granite and medium- or coarse-grained biotite granite with slightly orientated feldspars. The feldspar crystals in the porphyritic granite have an appearance of "dents de cheval" and attain 2.8 x 4.5 x 6.5 cm. in the maximum size. Small pink zircon and magnetite grains are contained in the river sand near the waterfall.

## VIII. Stratigraphy and Geologic Structure of the Langkawi Islands

Teiichi Kobayashi
Toshio Kimura
Hisayoshi Igo

The Langkawi Islands are situated in extreme northwest Malaya and consist of two sizable main islands and many small dependent islands, such as Pulau Langkawi, P. Dayang Bunting, P. Tuba, P. Langgon, P. Timun, P. Singa Besar and several others (Text fig. 7). Recently, geology of this area has been worked out by Mr. C. R. Jones of the Geological Survey of Malaysia (Malaya). The Cambrian, Ordovician, Silurian, Carboniferous and Permian rocks are distributed in these islands and intruded by granite. Jones classified the following four lithologic units as follow in descending order.

Chuping formation ..... Permian limestone
Singa formation ..... Carboniferous-Permian detritus
Setul formation ..... Ordovician-Silurian limestone and intercalated detritus
Machinchang formation .. Cambrian detritus.

A geological survey and fossil collection in this area were done in the period from December 15, 1963 to January 5, 1964 with the cooperation of Mr. C. R. Jones, M. W.D. Procter and other field assistants of the Geological Survey of Malaysia (Malaya).

## 1. Stratigraphic Summary (Fig. 7)

Machinchang formation:- This formation is the lowest lithologic unit in this area and exposed in northwestern corner of the Pulau Langkawi and P. Rebak. It consists of well-bedded quartzite, siltstone, shale and flaggy rocks. According to Jones this formation attains more than 4,500 feet in thickness. The similar rocks are also distributed in Tarutau island which is located to the north of Pulau Langkawi. Kobayashi (1957) described the fossils which were collected from Tarutau by Mr. Saman Buravas of the Royal Department of Mineral Resources, Thailand. They are Apheorthis (?) sp., Pagodia thaiensis Kobayashi, Thailandium solum Kobayashi, "Eosaukia" buravasi Kobayashi, Saukiella tarutaoensis Kobayashi, Coreanocephalus planulatus Kobayashi and others.

The occurrence of saukid trilobites suggests that the formation is the Upper Cambrian (Kobayashi, op. cit.). The fragmental cephalons of similar trilobites were also found in the Machinchang formation in Pulau Langkawi by C. R. Jones.

Setul formation:-This formation crops out in the western sea shore of Pulau Langkawi, P. Langgon, P. Tanjong Tembus Dendong, P. Timun, P. Dayang Bunting and others. This shows characteristic sharp-edged topography because of its styliolitic limestone. It consists mainly of bedded gray limestone including dolomitized facies. Two detrital bands are intercalated in the upper part. Jones estimated that the total thickness of the Setul is more than 7,500 feet, and he subdivided into the following five members in Pulau Langgon where the Setul is typically exposed. (See Fig. 7)

Bedded gray limestone, occasionally cephalopods...ca.1,000 feet thick.
Upper detrital band, near the base Monograptus clingani and Styliolina.....ca. 750 feet thick.

Banded gray styliolitic limestone, occasionally Ormoceras near the base .....ca. 400 feet thick.
Lower detrital band, Monograptus spp. Diplograptus spp., Climacograptus sp., Dimophograptus sp. near the base cherty and Dalmanitina Malayensis .....
.....ca. 90 feet thick.
Banded styliolitic limestone including cephalopods and gastropods .....ca.500+ feet thick.

Our field observations agree with his established sequence of this formation, provided some reservations concerning the stratigraphic position of the limestone member which overlies the upper detrital band. We could not observe actual contact between two members, but their boundary may be a fault so far as field observation could be gathered. Therefore, there are high posibilities that the limestone member in question is a repeated fault block of the lower limestone member.

Jones found many fossils from the various levels of the lower banded styliolitic limestone and Kobayashi (1959) discriminated the following fossils, such as, Hormotoma (?) spp. indet., Helicotoma jonesi Kobayashi, Helicotoma (?) costata Kobayashi, Palaeomphalus giganteus Kobayashi, Lesueurilla zonata Kobayashi, Lesueurilla (?) sp. indet., Malayaspira rugosa Kobayashi, Malayaspira (?) sp. indet., Endoceras (?) sp. indet., Ormoceras langkawiense Kobayashi, Discoceras (Hardmanoceras ?) chrysanthimum Kobayashi, and Discoceras (Hardmanoceras ?) laeviventrum Kobayashi.

The lower detrital band is also richly fossiliferous and yields Dalmanitina malayensis Kobayashi, and poorly preserved fossils such as plectambonid indet., Megalomphala (?) sp., Stenopareia (?) sp., hyolithid inet., Cystedean sp., Climacograptus sp., and others. This shale is immediately overlain by black graptolite shale in which Jones found Monograptus clingani Carruthers, M. sp., Dimorphograptus sp., Climacograptus cfr. rectangularis M'Coy sp., Orthograptus sp., and Gyptograptus sp. Therefore this detrital band is probably the Lower Silurian or Llandoverian.

The succeeding banded styliolitic limestone includes dolomitized facies and sporadically yields Ormoceras and other orthoceratids and trilobites near the base.

The upper detrital band consists of quartzite, black shale, yellowish shale and red to purple shale. According to Jones, Monograptus clingani Carruthers and Styliolina clavulus Barrande were found from the basal black to gray shale. A rich fauna comprising trilobites, ostracods, Posidonia-like pelecypods and brachiopods is found from red to purple shale in the upper

part.

The bedded gray limestone including dolomitic parts overlies the upper detrital band without any hiatus. This formation is very poor in fossils, but it yields poorly preserved cephalopods and stromatoporoids.

The lower banded styliolitic limestone is also exposed in Pulau Langkawi and other islands and displays further lower divisions. The lower and upper detrital bands also crop out in other islands, but fossils are very poorly preserved or almost completely destroyed by the thermal effect of the intruded granite.

Concerning the geological age of the lower bedded limestone of the Setul formation, Kobayashi determined the Discoceras limestone at the Middle Ordovician Llandeilian and the Armenoceras limestone (Thung Song limestone s. str.) at Caradocian or Black River of North America. The lower detrital band may be Llandovery rian, as suggested by the graptolites and Dalmanitina malayensis. The exact age of the succeeding limestone is as yet obscure, although Dalmanitina-like trilobites were found in the basal part. Any further discussion on the geological age of this member is deferred until their palaeontological study will be finished. Incidentally, Igo has succeeded to separate many well-preserved conodonts from the limestone with the aid of Toshio Koike of the Tokyo University of Education.

The upper detrital band is divided into the Styliolina-bearing gray thin bedded shale, quartzitic sandstone and variegated fossiliferous shale in Pulau Langgon. According to our observations the upper detrital band seems not so thick as estimated by C. R. Jones. The geological age of this band is an interesting problem. A rich fauna comprising trilobites, ostracods, brachiopods, pelecypods and others was procured from red shale in the upper part. An intensive study on the collection will decide the age of this part. As the preliminary presumption it is noted that the Styliolina bearing black to grey shale may be not older than Middle Silurian and the variegate shale may fall in the range from Middle Silurian to Devonian.

As already mentioned, the stratigraphic position of the upper limestone is obscure, because we could not observe any actual contact between the limestone and the upper detrital band. It is probable that there is a fault between them.

Singa formation:- It is distributed in the central zone of Pulau Langkawi, P. Singa Besar and adjacent small islands. The formation mainly composed of black fucoid-bearing shale including pebbly facies and shows slumping structure. Thick

bedded quartzite is interbedded with black shale. None of the fossils obtained from this formation is a good age-determiner. Jones' collection from Pulau Panjang however, contains Marginirugus ? , spiriferid, Dielasma sp., Worthenia aff. orientalis (Roemaer). Therefore this fossil bed is considered Carboniferous. In this area this formation is overlain by the Middle Permian limestone with slight disconformity. Therefore it is quite possible that the upper part of the formation is Lower Permian. A further investigation is needed to solve this chronological problem.

Chuping formation:- This formation consists of white to dark gray limestone. It is distributed in the western half of Pulau Dayang Bunting and scattered in neighbouring small isles and in the central part of Pulau Langkawi as patches. The limestone is intruded by granite and appears saccharoidal at many places. Fossiliferous limestone crops out in Pulau Jong where fusulinids, bryozoans, brachiopods and corals have been collected. Sakagami (1964) has described four species of bryozoans, viz. Cyclotrypa alexanderi Sakagami, Fistulipora hupehensis (Yanh), Polypora aff. timorensis Bassler and Polypora gigantes Waagen and Pichl. He thought that the fauna is Middle Permian.

We found Pseudofusulina, Parafusulina, Yatsengia and other fusulinids and corals. Stratigraphic relation between the Singa and Chuping formations is very interesting. The basal part of the Chuping formation is decalcified sandy limestone including angular impure dolomite and is followed by massive impure dolomite.

## 2. Description of fossil localities (Fig. 7)

Pulau Langgon and P. Tembus Dendang

Loc. 15-1. Red Shale, fossiliferous; trilobites, brachiopods, ostracods, Posidonia-like pelecypods and others; Setul formation; upper Siluraian or Devonian.

Loc. 16-1. Limestone, gray, compact, thickly bedded; Trilobites, Styliolina (?) and tiny orthoceratids; Lower Silurian (?); Setul formation.

Loc. 16-2. Shale, black, thin bedded, pyritiferous, carbonaceous; Monograptus, Climacograptus and others; Setul formation; Lower Silurian

Loc. 16-3. Limestone, intercalating this black shale, dark gray, partly cherty, thin-bedded, trilobites fragments. Setul formation; Upper Ordovician (?)

Loc. 16-4. Shale, black, cherty, thin-bedded, Dalmanitina malayensis Kobayashi and ill-preserved brachiopods.
Loc. 16-5. Limestone, gray, dolomitic, thickly bedded, Endoceras (?); Setul formation; Lower or Middle Silurian.
Loc. 16-8. Limestone, dark gray, dolomitic, partly cherty, bedded; gastropods and cephalopods (most of the Kobayashi's (1959) described specimens came from this locality); Setul formation; Middle Ordovician.
Loc. 16-9. Limestone, dark gray, dolomitic, bedded; Archaeoscyphia-like sponges and brachiopods; Setul formation; Middle Ordovician.
Loc. 16-10. Limestone, dark gray, dolomitic, bedded, partly silicified; Tetradium-like corals; Setul formation; Middle Ordovician.
Loc. 18-1. Limestone, dark gray, thin-bedded, dolomitic, thin intercalation of shale; conodonts (?); Setul formation; Upper (?) Ordovician.
Loc. 18-2. Limestone, same as the Loc. 18-1; conodonts (?); Setul formation; Upper (?) Ordovician.
Loc. 18-3. Limestone, dark gray, dolomitic, thin-bedded, trilobite.
Loc. 22-2. Limestone, same with the locality 22-1; Armenoceras chediforme; Setul formation; Middle Ordovician.

Pulau Singa Besar

Loc. 25-1. Alternation of sandstone and black sahle, including pebbles, partly pyritiferous, spiriferids, productids; Singa formation; Carboniferous.
Loc. 26-3. Limestone, gray, thickly bedded; bryozoa, Sinopora Michelinia and brcahiopods; Chuping formation; Middle Permian.
Loc. 26-4. Limestone, gray, thickly bedded, Squamularia sp.; Chuping formation; Middle Permian.

Pulau Merah

Loc. 26-2. Limestone, gray, thin-bedded, fragmentary corals and calcareous algae; Chuping formation; Middle Permian.
Loc. 26-1. Limestone, gray, thin-bedded, calcareous algae and fragmental brachiopods; Chuping formation; Middle Permian.

Pulau Singa Kechil

Loc. 27-1. Limestone, gray, bedded, concretionary chert, partly dolomitic, foraminifera (?); Chuping formation; Middle Permian.

Pulau Tepok

Loc. 27-2. Shale, black, intercalating thin sandstone laminae, fucoid, partly pyritiferous; Singa formation; Carboniferous.

Pulau Jong

Loc. 1-1. Limestone, gray, chert concretions and interbedded chert layers, fossiliferous; bryozoa (Sakagami's described specimens came from this locality), Parafusulina, Pseudofusulina, Sinopora dendroidea, Wentzelella (?), brachiopods, fish teeth; Chuping formation; Middle Permian.

Pulau Langkawi

Loc. 16-6. Limestone, dark gray, thickly bedded, dolomitic; Lytospira rectangularis and other gastropods; Setul formation; Middle Ordovician.

Loc. 16-7. Limestone, dark gray, thickly bedded, dolomitic, Armenoceras chediforme; Setul formation; Middle Ordovician.

Loc. 16-11. Limestone, pale gray, crushed; Verbeekina, Neoschwagerina (?) and others; Chuping formation; Middle Permian.

Loc. 17-1. Sandstone, intercalating thin shale, buff to yellow; pygidium and free cheeks of saukid trilobites; Machinchang formation; Upper Cambrian.

Loc. 17-2. Sandstone, hard, buff, quartzitic, medium-grained, fossils unknown; Machinchang formation; Upper Cambrian.

Loc. 17-3. Sandstone, buff, quartzitic; lower part of the Machinchang formation; Upper Cambrian.

Loc. 18-8. Limestone, dark gray, interbedded dolomite layers; small gastropods; Setul formation; Middle Ordovicaian.

Loc. 18-9. Limestone, same with the locality 18-8, small gastropods; Setul formation; Middle Ordovician.

Loc. 18-10. Limestone, dark gray, dolomitic; conodonts (?); near the base of the Setul formation; Middle or Lower Ordovician.

Loc. 19-7. Limestone, dark gray, dolomitic, thin-bedded; gastropods; Setul formation; Middle Ordovician.
Loc. 19-8. Limestone, dark gray, highly dolomitic; Bryozoa; Setul formation; Middle Ordovician.
Loc. 20-1. Limestone, dark gray, highly dolomitic; bryozoa; Middle Ordovician.
Loc. 20-2. Limestone, same with the locality 20-1.
Loc. 20-3. Limestone, same with the locality 20-1; Armenoceras chediforme; Setul formation; Middle Ordovician.
Loc. 20-6. Limestone, dark gray, thin-bedded, crinoids, brachiopods, gastropods, trilobite pygidium; Setul formation; Middle Ordovician.
Loc. 22-1. Limestone, dark gray, dolomitic, thin-bedded, tiny brachiopods; Setul formation; Middle Ordovicaian.

Loc. 18-4. Limestone, thickly bedded, dolomitic; conodonts (?) Setul formation; Upper (?) Ordovician.
Loc. 18-5. Limestone, pink to red, hematitic, fragmental gastropods, trilobites and others; Setul formation; Middle (?) Ordovician.
Loc. 18-6. Limestone, dark gray, dolomitic, styliolitic; orthoceratid; Setul formation; Middle Ordovician.
Loc. 18-7. Limestone, black to dark gray, rather pure, Ormoceras (?); Setul formation; Middle Ordovician.
Loc. 19-1. Limestone, black, thin-bedded, dolomitic part in alternation; conodonts (?); Setul formation; Lower or Middle Silurian.
Loc. 19-2. Limestone, dark gray, same as the locality 19-1; Endoceras (?); Setul formation; Lower or Middle Silurian.
Loc. 19-3. Limestone, including sphaeroidal dolomite; Endoceras (?); Setul formation; Lower or Middle Silurian.
Loc. 19-4. Shale, gray to dark gray, thin bedded, Styliolina sp., fragmental graptolites; Setul formation; Middle (?) Silurian.
Loc. 19-5. Sandstone, dark buff, quartzite, thickly bedded, fossils unknown; Setul formation; Middle (?) Silurian.
Loc. 19-6. Limestone, dark gray, highly dolomitic, conodonts; Setul formation; Ordovician (?).
Loc. 20-4. Limestone, dark gray, dolomitic, gastropods, Armenoceras; Setul formation; Middle Ordovician.
Loc. 21-1. Shale, black, carbonaceous, partly cherty, Monograptus and other graptolites; Setul formation; Lower Silurian.

Loc. 21-2. Limestone, dark gray, dolomitic, bedded, gastropods, orthoceratid; Setul formation; Middle Ordovician.
Loc. 21-3. Limestone, same with the locality 21-2, orthoceratid; Setul formation; Middle Ordovician.

## 3. Geologic structures of the northeastern and southern parts of the Langkawi Islands

Toshio Kimura

### Great fault between the Ordovician and the Permo-Carboniferous formations

The Ordovician and Silurian Setul formation is distributed in the northeastern and eastern parts, and the Permo-Carboniferous Singa and the Permian Chuping formations are in the central part of the Langkawi Islands. The boundary between the two groups appears to be bent remarkably with eastward convexity as already reported by Jones. Along the boundary, faults and shear zones are found at some localities (Fig. 8).

At Loc. 29-5, the southern extremity of the Pulau Dayang Bunting, the Ordovician limestone is thrust upon the Carboniferous hornfelsic slate. The fault plane strikes in the direction of N10°E and dips 15° toward east, with striations in the dip direction. Minor faults with some minor drag folds in the slate on the lower side show that this fault is a thrust fault. The Ordovician limestone on the upper side of the thrust presents remarkable closed folds, some of which are recumbent. About 800 m northwest of Loc. 29-5, where the fault runs along the hill side, the fault is bent strikingly with westward convexity. This feature is due to the low angle of the fault.

On the other hand at the northern extremity of the Pulau Dayang Bunting (Loc. 03-1), Permian marble is thrust upon the Ordovician limestone. The fault plane strikes in the direction of N40°E and dips to the west. However, number of minor thrust faults and minor closed folds within the Ordovician limestone on the lower side of the fault trend in the direction of N30°-25°E. Therefore, the general trend of the fault may be in this direction. This is also parallel to the general trend of the boundary between the Permian and the Ordovician formation. The Permian marble along the thrust fault is traversed by numerous shear joints parallel to the thrust fault has only vertical joints.

Minor folds and minor thrust faults develop at Loc. 28-1

about 800 m south of Loc. 03-1. The structures and the trends are quite similar to those at Loc. 03-1. Another thrust fault appears to run to the west of Loc. 28-1 within the Ordovician formation.

The minor structures and the trend of the fault at Loc. 03-1 are quite similar to those at Loc. 29-5. But the dip direction is opposite with each other. These two thrust faults are probably conjugate thrust faults formed under a maximum principal stress in the direction of N70°W-S70°E. The thrust fault along which the Ordovician formation is thrust upon the Carboniferous formation may be the main thrust fault and the thrust at Loc. 03-1 may be the counter thrust.

Permian sheared limestone occurrs at Loc. 16-11 in the northern part of the Langkawi main island. Many minor thrust faults are found in the limestone. They strike N60°W and dip 35° to the north. A large thrust fault may exist on the north side of the sheared Permian limestone and the Ordovician limestone is thrust upon it.

A thrust fault, with similar strike to the thrust at Loc. 16-11 but with opposite dip direction, is seen at Loc. 21-1. There the thrust strikes N30°W and dips 25° to the west. The Ordovician limestone is thrust upon the Silurian detritus strata along the fault. The thrust may be the counter thrust of that at Loc. 16-11.

According to the observations mentioned above, the boundary between the Ordovician and the Permo-Carboniferous formation is large faults, along which or apart from which counter thrusts occur. The thrust has a trend of N60°W in the northern part and of N20°E in the southern part. It is possible that the two parts were formed in different stages. However, minor faults in the direction of N20°E do not develop in the northeastern Langkawi Islands, and minor thrusts in the direction of N60°W do not in the southern Langkawis. Therefore, it is not probable that these deformations in these two directions were formed in different stage from each other. So it is highly probable that these deformations were formed originally at one stage. However, it is not clear now whether these two deformation patterns in two directions were formed together originally under only one regional stress, or whether later rotational movement of the one part against the other part produced these two different patterns. Occurrence of granite mass on the concave side of the faults may suggest that they were produced originally under one regional stress which is differentiated into two local stresses. At Loc. 19-4 in the northeastern Langkawis, the Ordovician formation show minor folds in the trend of N50°E with about 10 m half wave length.

The Cambrian formation at Loc. 27-3 in the southern Langkawis also show similar folds in nearly the same direction. These features may disapprove the rotation hypothesis.

Geologic structure of the northeastern part of the Langkawi Islands.

Folds with NE axis and Chevron folds Minor folds, which have about 10 m half wave length and trends in the direction of N50°E plunging gently to the NE, prevail in the upper detrital band of the Setul formation at Loc. 19-4 (Fig. 9). Some folds among them, especially immediately beneath the thick quartzite bed, have axis which bent remarkably(Fig. 9a) for instance from N80°E to N30°E. In the sandstone and shale beds there occur also N55°E joints and N35-40°W joints. These joints do not vary the trend, while the NE folds occasionally vary the direction of fold axis. Therefore these joints are not the cross or transverse joints related to the formation of the minor folding in the NE direction. Chevron folds (Fig. 10a) of cleavage planes along the joints are remarkable in the shale beds. These chevron folds as well as the joints clearly cut the NE folds.

Knick folds Graptolite shale and black siliceous shale of lower detrital band of the Setul formation at Loc. 16-2 and Loc. 21-1 sometimes show minor folding with half wave length of 50-100 cm. The folds has rather short wave length and the beds show frequently the angularly bent outline along the fold axis. Closed folds are frequently seen (Fig. 10b).

There are two sets of folds in different direction from each other; folds with axis in the N30°E direction and those in the N30°-60°W. These two sets of folds are usually accompanied by flexure joints with proper direction parallel to the fold axis. They seem to be formed simultaneously, because they cut each other. On the stereographic net (Fig. 10c), the fold axis or the flexure joints are arranged in general as if they were formed under maximum principal stress in the N70°W direction and nearly vertical medium stress. On the other hand, a conjugate fold at the same locality (Fig. 10d) seems to be formed under a maximum principal stress in the N55°W direction and nearly vertical minimum stress. But this is an exceptional case.

Faults at Loc. 18-1 to the south of Loc. 16-2 strike in the NW direction and show left lateral strike-slip movements. The directions of faults as well as those of the slips quite agree with the fold analysis. These faults were also formed under a maximum principal stress in the N50°-70°W direction.

These two directions of the knick folds are nearly the same with those of joints and chevron folds which cut the N50°E folds at Loc. 19-4. The chevron folds appear to be formed by strike-slip movements. Moreover, in the southernmost part of Loc. 19-4, similar folds to the knick folds occur in the black shale, and the left lateral strike-slip fault in the N20°W direction also occur (Fig. 9a). The knick type folding at Loc. 16-2 and Loc. 21-2 was probably formed simultaneously with the chevron folding and they are younger than the N50°E folding at Loc. 19-4.

Broad folds in the NW direction The Ordovician limestone in the northeastern part of the Langkawi Islands gently inclined to the northeast in general. However, small antclines occur in the neighbourhoods of Loc. 18-2K, Loc. 22-1 and Loc. 19-8. Anticlinal structure is also presumed at the neighbourhood of Loc. 19-5, because the inclination of the strata to the opposite directions were observed. These anticlines are all broad folds with NW axis and half wave length of about 100 m.

NW normal faults are predominant in the limestone formation. Some of these faults occur along the gentle flexures in the limestone formation. These faults are probably related to the broad NW folds.

These NW folds and faults are nearly parallel to the NW great thrust fault in the northeastern Langkawi Islands. They are probably produced by the movement related to the great thrust fault. At Loc. 21-1, the black shale with the knick type folds are cut by a N30°W thrust, a counter thrust of the main great thrust. The thrusting and folding related to the great thrust are probably later than the knick folding.

Geologic structure of the southern Langkawi Islands.

The Carboniferous detritus formation and the Permian limestone, which are intruded by granite, are generally distributed in the central part of the southern Langkawi Islands. The Permian limestone, some part of which are metamorphosed into marble, is distributed along the great thrust fault in the eastern part. The Carboniferous detritus formation is distributed to the west and the south of the Permian. The Carboniferous formation strikes N30°-10°E, parallel to the great thrust fault, to the west of the Permian and N-W or E-W to the south. The Carboniferous formation as well as the Permian appears to form a broad syncline parallel to the great thrust fault.

The Cambrian formation is distributed to the west of the Carboniferous formation. At Loc. 27-3, N60°E folds, with

about 10 m half wave length, and joints cutting them are found. The features quite resemble to those in the Silurian at Loc. 19-4 in the northeastern Langkawis. Slaty cleavage is prevalent in the Cambrian formation. The slaty cleavage and the structural features mentioned above cannot be seen in the Carboniferous to the east of the Cambrian.

The Ordovician limestone to the east of the great thrust fualt have somewhere intercalations of hornfels or biotite schist, which show minor folds as will be mentioned later.

Joint system in the Carboniferous formation In the Carboniferous formation, especially in the slate, occurs a remarkable joint system (Fig. 10e,f). Predominant joints are of N60°E. N10°E and N70°W. The three sets of joints are clearly observed at Loc. 25-1, Loc. 25-2, Loc. 27-3K, Loc. 27-4 and so on. Among them, those of N60°E and N10°E are conspicuous. Feather joints filled with calcite occur along the joints of two directions at Loc. 25-2, Loc. 27-3K and Loc. 27-4. The feather joints appear to show that the maximum principal axis of stress was nearly parallel to the strike of the great thrust fault and to the major fold axis of the Permo-Carboniferous strata and that minimum one is nearly perpendicular to them during the formation of the conjugate joints. The movement, which formed the great thrust fault and major fold, appears to be related to the conjugate joints, even though all of them were not formed exactly at only one stage.

Cleavage in the Carboniferous strata Sliding deposits frequently occur in the Carboniferous strata. In some cases, fracture similar to the slaty cleavage occur. Folds produced by the sliding may be, at a glance, taken for those of shear fold. For example at Loc. 27-3K, fractures occur parallel to the axial plane of minor folds, and slightly displaced the thin sandstone bed (Fig. 10g). However, the cleavage clearly cut the slumped sandstone block at Loc. 01-2.. The mechanism and age of the formation of the cleavage are nor clear now.

Deformation of hornfels or biotite schist of the Ordovician in the eastern part At Loc. 28-8 and Loc. 03-2, hornfels or biotite schist intercalated in the Ordovician limestone show folding.

Minor folds, similar to the knick folding in the northeastern Langkawi Islands, occur in the biotite schist. The folds, however, has the wave length of 10 cm or so and there is no closed one. The features are different from those in the northeastern Langkawis. Flexure joints occur along the fold axis which run in the N30-45°E. Some folds is accompanied by conjugate faults which show the maximum principal stress in the N50°W direction. The direction of the maximum principal stress is nearly the same that of the great thrust fault.

Folds in the N10°E direction with about 10 m half wave length occur at Loc. 28-8. Minor folds with 5 cm half wave length in the same direction accompany them. It is highly probable that they are also formed under the same stress with those of the great thrust fault.

Summary

Many kinds of geologic structures were observed as mentioned already in the northeastern and southern parts of the Langkawi Islands. They were not formed at only one stage and under only one stress system. In summary, the following succession of deformation will be suggested.

(1) The NE minor folds at Loc. 19-4 and Loc. 27-3 under the NW principal stress.

(2) The knick folds at Loc. 16-2 and Loc. 21-1, and the chevron folds and N55°E & N35°-40°W joints at Loc. 19-4 under about N70°W principal stress.

——————— ( granite intrusion ? ) ———————

(3) a. The great thrust and counter thrust under the N30°E local stress in the northeastern part.
The broad folds and normal faults in the NW trend.
(They were not formed under exactly the same stress with the great thrust.)

b. The great thrust and counter thrusts under about N70°W local stress in the southern tangkawis.
The broad syncline of the Permo-Carboniferous strata.
The minor folds at Loc. 28-8 and Loc. 03-2.
The joints of the Carboniferous strata. (They were not formed under exactly the same stress with the great thrust.)

## IX. Stratigraphy of Northwestern Malays

Hisayoshi Igo
Takashi Hamada

The Paleozoic and Mesozoic rocks are distributed in Perlis and Kedah, northwestern Malaya. Many fossil localities have been known by the classical work of Newton (1925, 1926)

and several others. Our field observations and fossil collections were made in this area during February 11 to 16 with the cooperation of Mr. C. R. Jones and two Malayan field assistants of the Geological Survey of Malaysia (Malaya).

Generally speaking, the geology of this area is very similar with those of the Langkawi Islands and extreme-southern Thailand. However, stratigraphic relationship among the different formations is rather obscure because of rather extensive distribution of the Alluvial deposits and thick jungle.

The Ordovician-Silurian Setul formation equivalents of the Permo-Carboniferous Singa formation, Permian Chuping formation and Permo-Triassic (?) and Middle to Upper Triassic unnamed formations are distributed and they form large anticlinorium and synclinorium. Mesozoic granite intruded these sediments in southern part of this area.

We observed many previously known fossil localities which discovered C. R. Jones, B. C. Coutier and other Malayan geologists. Moreover, stratigraphic observations were done as far as possible.

## 1. Stratigraphical Summary

The Setul formation:-This formation is subdivided into lower Thung Song limestone and upper detrital member. The Thung Song limestone distributed in the mountain ridge consisting Thailand and Malayan national border. This limestone is well bedded, black to dark gray and including dolomitized facies. Kobayashi (1958, 1959) described Malayspira rugosa Kobayashi, Ormoceras langkawiense Kobayashi, Armenoceras chediforme Kobayashi, Actinoceras perlisense Kobayashi and A. sp. This cephalopod and gastropodal limestone is apparently direct extension of the Thung Song limestone in Peninsular Thailand and the Langkawi Islands. No graptolite shale have been found in this area.

The overlying detrital member mainly consists of red purple and partly gray shales and less common quartzite. This member can be correlated to the upper detrital band in the Langkawi Islands, but it is fairly thick than that of Langkawi. Fossils have been found various levels but their stratigraphic positions are still obscure. Posidonia-like large pelecypods are most common throughout associated with trilobites, brachiopods and fragmental crinoid stems. The geological age of this detrital member represents rather long time span and should be Silurian to Devonian. We are fortunate to find several reliable fossils from this member, thus the detailed chronology of this member will be presented in the near future.

The Singa formation or its equivalent:-We did not have any

opportunity to observe intensively this formation. The formation crops out beneath the Permian limestone hills and also distributed in the lower land of this area. Lithology of this formation slightly differs from the typical Singa formation in the Langkawi Islands and it is occasionally difficult to distinguish from the detrital member of the Setul formation. It mainly consists of gray shale but red to purple in some strongly weathered surface and intercalated quartzitic sandstone. No fossils have been found in this formation of this area.

The Chuping formation:-This formation is distributed in southern Perlis and Kedah as the resisting hills surrounded by alluvial deposits. It mainly consists of pale gray to black massive or bedded limestone. The stratigraphic relation between this limestone and underlying detrital sediments are conformable in this area. The following succession can be seen in Bukit Temian, Perlis in descending order, namely:-

| | |
|---|---|
| Limestone, pale gray massively bedded .... | more than 20 m thick. |
| Shale, gray calcareous, thin-bedded ..... | 0.5 m thick. |
| Limestone, gray, algal, lenticular, brachiopods (Cancrinella cancrini De Verneuil) very aboundant..... | 0.5 m thick |
| Shale, gray, partly sandy, thin-bedded ... | more than 20 m thick. |

This sequence seems to be conformable relation between Permo-Carboniferous detrital and Permian limestone. Thin intercalation of limestone and shale represents the passage beds and may indicate sea-level fluctuations.

Fusulinids are rather rare throughout but calcareous algae, corals and brachiopods are abundant in the certain localities and levels. Previously, Newton (1926) described Fusulina granumavenae, Doliolina cfr. lepida and other fossils from Mata Ayer, northern Perlis. Thus the formation is lower Middle Permian and may extend to upper Middle Permian.

The Triassic and Permo-Triassic rocks:-Unnamed and unclassified Permo-Triassic and Triassic rocks are rather widely distributed in Kedah and southern Perlis. They are mainly rhythmic alternations of red and gray shales and somewhat tuffaceous shale, and quartzitic sandstone. Conglomerate is occasionaly intercalated with sandstone. Thin layers of chert is also interbedded with these sediments.

As will be mentioned later Kobayashi (1964) described Halobia and other fossile from these sediments and cited Coutier's observation of the stratigraphy of this area. According to him, they can be subdivided into the following three lithologic units, namely:-

3. The rhythmic sediments of the eastern side composed of shale, banded shale and siltstone, quartzite, graywacke and conglomerate... mostly upper Triassic, partly middle Triassic.

2. Banded chert belt immediately east of Pokok Sena ..... Permian or Permo-Triassic.

1. Red and gray shales with subsidery quartzite west of Pokok Sena ..... Carboniferous or Permo-Carboniferous.

His lower red and gray shales are continuous lithofacies of the Setul and other upper Paleozoic formations C. R. Jones and we found large specimens of "Posidonia", well-preserved Proetus-like trilobites and brachiopods. However, classification of these shales and overlying chert-bearing sediments and rhythmic sediments is rather difficult in the field.

Kobayashi (op. cit.) described the following fossils from the scattered localities, such as Entrochus (?) sp., "Rhynchonella" malayensis Kobayashi, Posidonia sp., aff. P. siamensis (Reed), P. kedahensis Kobayashi, P. cfr. japonica Kobayashi and Hukasawa, Halobia charlyana Mojsisovics, H. talauana Wanner, H. subquardrata, Kobayashi, H. aotii Kobayashi and Ichikawa, H. parallela Kobayashi, H. comata Bittner, Daonella indica Bittner and Pecten (Chlamys) courtieri Kobayashi. Kobayashi's view concerning the chlonology of these sediments agrees with Coutier's view.

## Despeription of Fossil Localities

PE-1; Gunoug Klein quarry, northwest of Alor Star. Limestone, pale gray, slightly crystalized, algal; brachiopods, pelecypods, bryozoans, formainifera (Tetrataxis and other endothyroid), coral (Yatsengia) and others; Middle Permian.

PE-2; Immediately west of the Gunoug Klein quarry. Raised beach shell beds, Anadara, Meretrix, Telescopium, Cyrena and others; Alluvium.

PE-3; Bukit Penang, east of the Alor Star Air Port. Shale, white to pale green, thin-bedded; Posidonia sp., aff. P. siamensis (Reed); Permo-Carboniferous.

PE-4; Bukit Tunjung quarry, 16 miles north of Alor Star. Shale, pale gray, thin-bedded with intercalation of black shale and quartzite; Posidonia sp., crinoid stems; Permo-Carboniferous (?).

PE-5; Bukit Kechil quarry near Kodiang Station.
Limestone, pale gray, organic, thickly bedded, overlying Permo-Carboniferous shale, algae, formainifera (Tetrataxis and Climacammina ?); Middle Permian.

PE-6; Bukit Kodiang quarry, 24 miles north of Alor Star.
Limestone, partly styliolitic, pale gray, occasionally cherty, including limestone conglomerate and gray algal biomicrite; algae, formainifers, brachiopod fragments; Middle Permian.

PE-7; Hutan Haji, road side cutting of 3 miles south of Kangar.
Shale, pale purple, thin-bedded; Posidonia sp., Permo-Carboniferous(?).

PE-8; South of PE-7, road side cutting.
Shale, red pale gray, thin intercalation of cherty layers; Trilobites (Proetus sp.), Posidonia sp., brachiopods; Silurian or Devonian.

PE-9; Bukit Lagi quarry, Kangar.
Limestone, dark gray, bedded, dolomitic; Thung Song limestone; Helicotoma, Actinoceras; Middle Ordovician.

PE-11; Batau Pahat, along the road side cutting.
Limestone, black to dark gray, bedded, dolomitic, styliolitic; Armenoceras, Malayspira; Middle Ordovician.

PE-12; Bukit Temian, northeast of Beseri.
Limestone, pale gray, massive to thickly bedded, overlying passage beds of limestone and shale; algae and Cancrinella cancrini from the passage beds; Middle Permian.

PE-14; Bukit Wang Pisang, 9 miles north of Kangar.
Limestone, gray, pseudoolitic, algal; Pseudofusulina, Waagenophyllum (?), brachiopods, gastropods; Middle Permian.

PE-15; Gua Getri, 10 miles north of Kangar, along the highway cutting.
Shale, gray to bluish green, thin-bedded with thin intercalation of quartzite; fragmental plants; Permo-Carboniferous (?)

PE-16; Gua Getri, along the highway cutting slightly north of PE-15. Limestone, pale gray, partly pink, dolomitic, hematitic, styliolitic; Endoceras (?); Upper Ordovician or Lower Silurian.

PE-17; Thye Shan Tin Mine, Kampong Wang Mu, 13 miles north of Kangar. Limestone, massive to thickly bedded, dolomitic, dark gray; bryozoans, conodonts; Middle Ordovician.

PE-18; Mata Ayer, 4 miles east of Padang Besar; Newton's locality. Limstone, pale gray, partly pinkish, siliceous; formainifera and brachiopods; Middle Permian.

PE-19; 10.8 miles east of Alor Star along the highway from Alor Star to Pokok Sena.
Shale, gray, soft, thin paper fissility, partly pebbly; Posidonia (?) sp.; Triassic.

PE-20; 17.5 miles east of Alor Star along the highway from Alor Star.
Alternation of chert and shale; Radioralia; Permo-Triasic (?).

PE-21; 22.5 miles east of Alor Star along the highway.
Shale, purple to pale gray, bedded; Halobia sp.; Upper Triassic.

PE-27; 29.5 miles east of Alor Star along the highway.
Alternation of sandstone (Graywacke) and shale, micaceous; Halobia sp.; Upper Triassic.

PE-28; 30 miles east of Alor Star along the highway.
Rhythmic thin alternation of sandstone and shale with intercaltion of coarse conglomerate; Halobia sp.; Triassic.

PE-29; 31 miles east of Alor Star along the highway.
Shale, pale gray, thin-bedded; Halobia sp.; Upper Triassic.

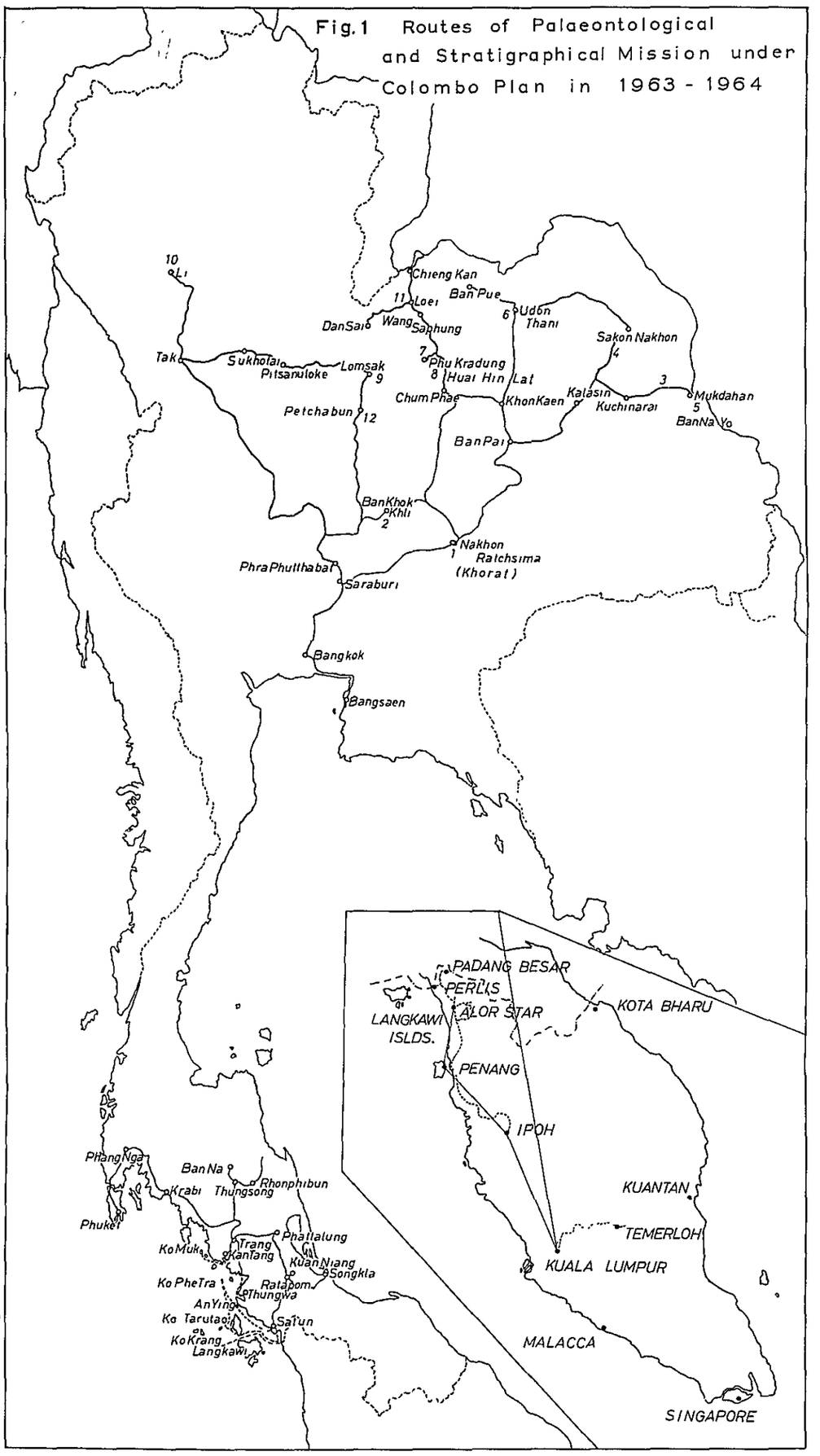


Fig. 1 Routes of Palaeontological and Stratigraphical Mission under Colombo Plan in 1963 - 1964
10
Li
Chieng Kan
Ban Pue
11
Loei
6
Udon Thani
Dan Sai
Wang Saphung
Sakon Nakhon
4
Tak
Sukhotai
Lomsak
Pitsanuloke
9
7
Phu Kradung
8
Huai Hin Lat
3
Chum Phae
Khon Kaen
Kalasin
Kuchinarai
Mukdahan
5
Petchabun
12
Ban Na Yo
Ban Pai
Ban Khok Pkhli
2
Nakhon Ratchsima (Khorat)
1
Phra Phutthabat
Saraburi
Bangkok
Bangsaen
PADANG BESAR
PERLIS
ALOR STAR
KOTA BHARU
LANGKAWI ISLDS.
PENANG
IPOH
KUANTAN
TEMERLOH
KUALA LUMPUR
MALACCA
SINGAPORE
Phang Nga
Ban Na
Rhonphibun
Krabi
Thungsong
Phuket
Phatalung
Trang
Ko Muk
Kantang
Kuan Niang
Songkla
Ko Phe Tra
Ratapoom
Thungwa
An Ying
Ko Tarutao
Satun
Ko Krang
Langkawi

Fig. 2b Geologic Sketch along the Creek of Huai Hin Lat (J. Iwai)

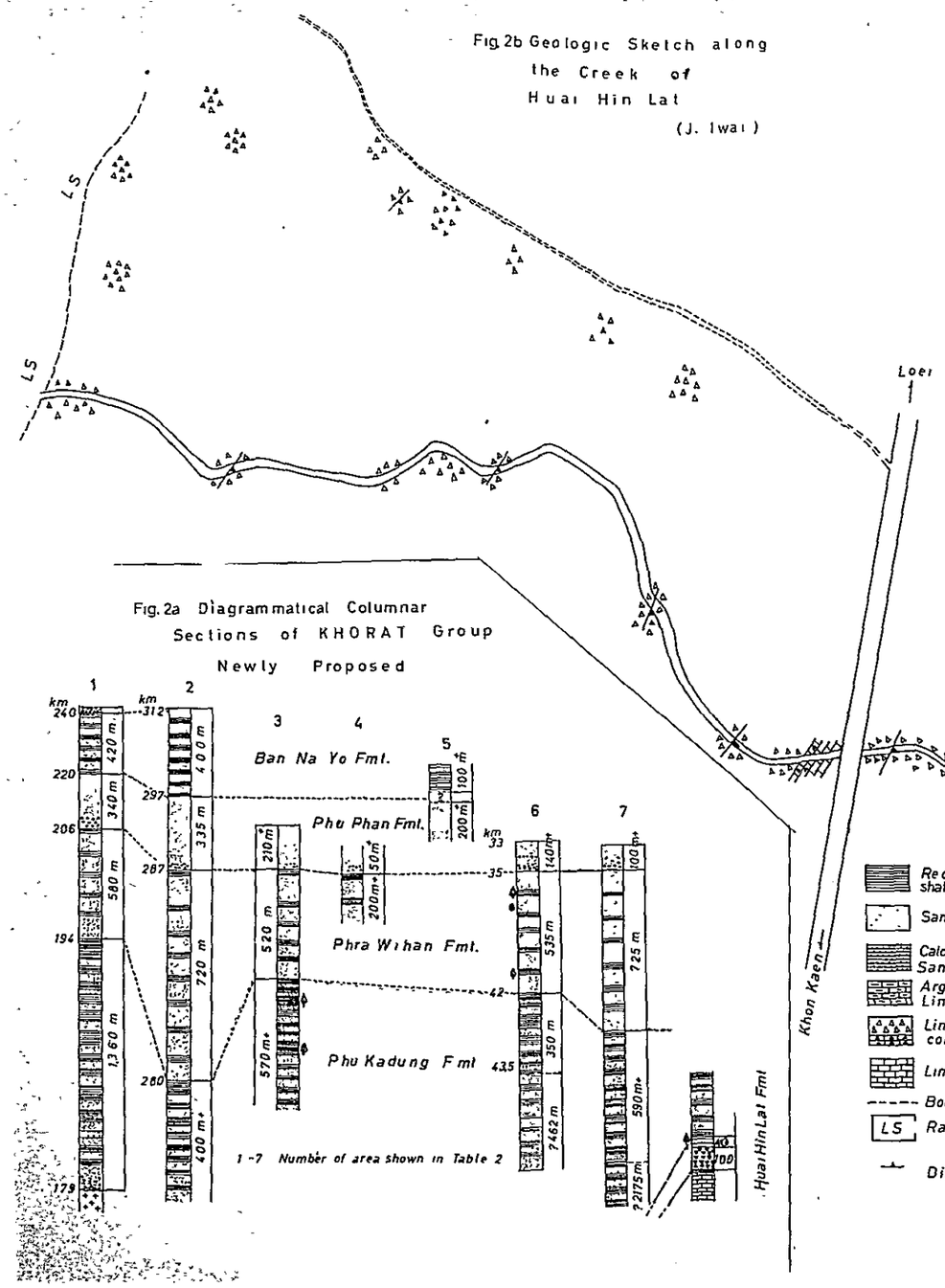
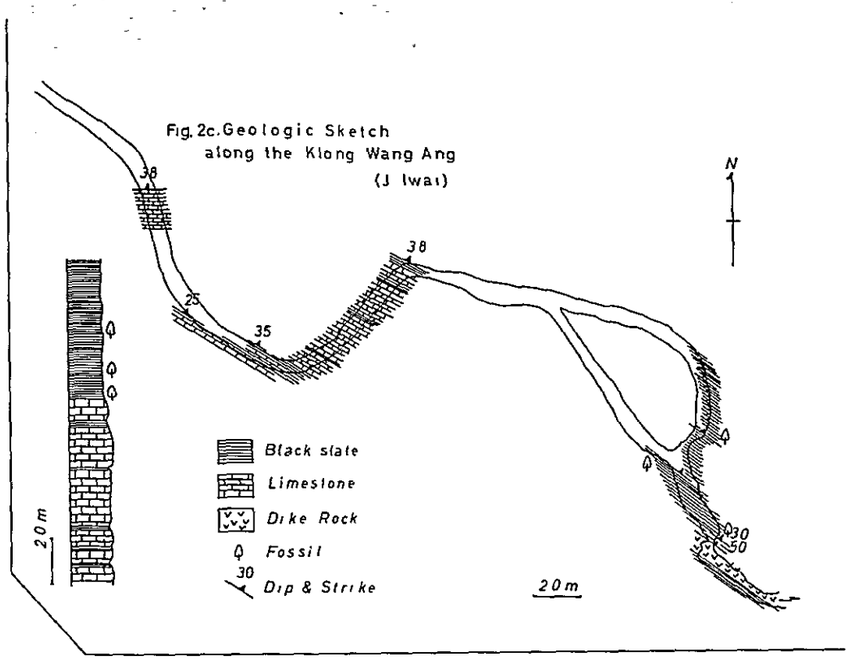
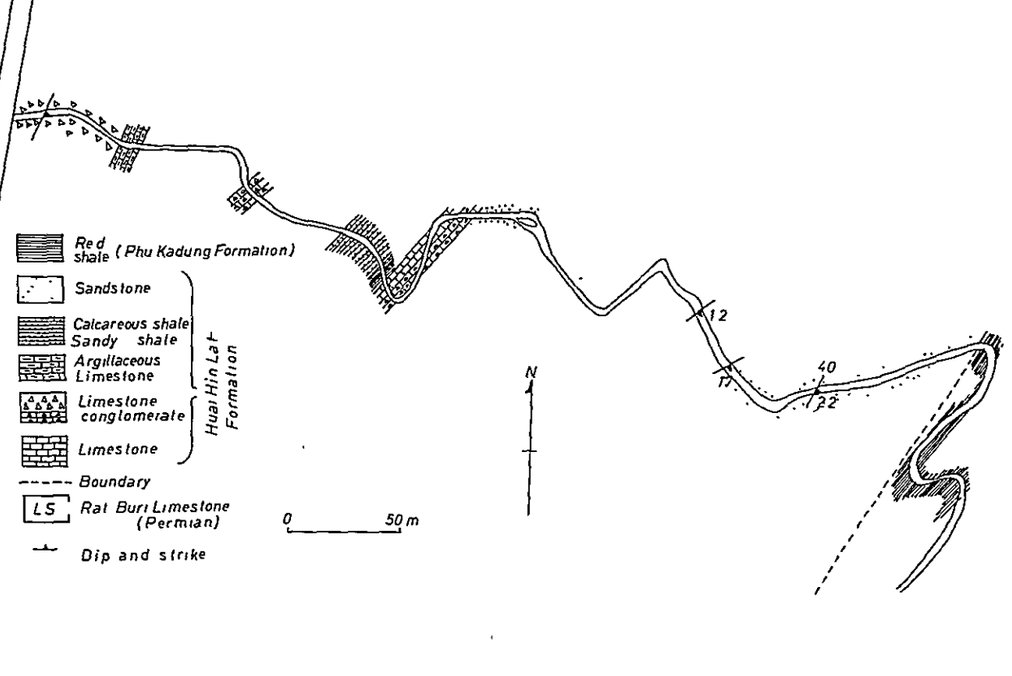



Fig. 2a Diagrammatical Columnar Sections of KHORAT Group Newly Proposed




Fig. 2c. Geologic Sketch along the Klong Wang Ang (J Iwai)



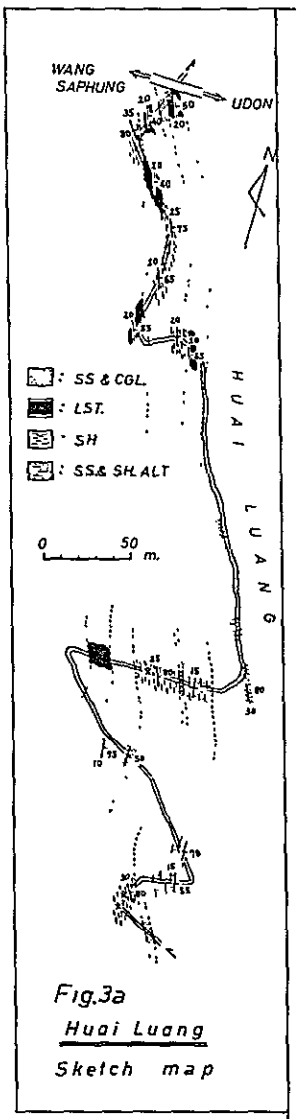



Fig.3a
Huai Luang
Sketch map

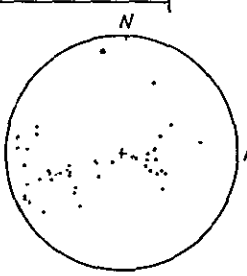



Fig.3b
Bedding planes
their poles on Schmidt's net

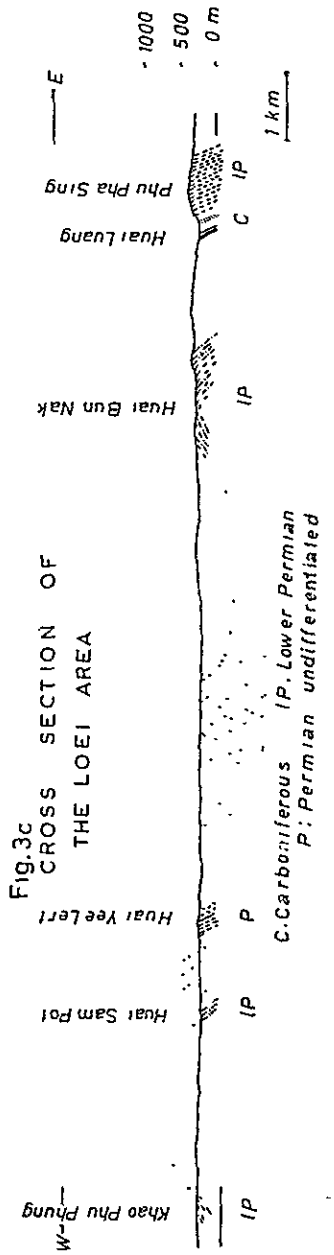



Fig.3c
CROSS SECTION OF THE LOEI AREA

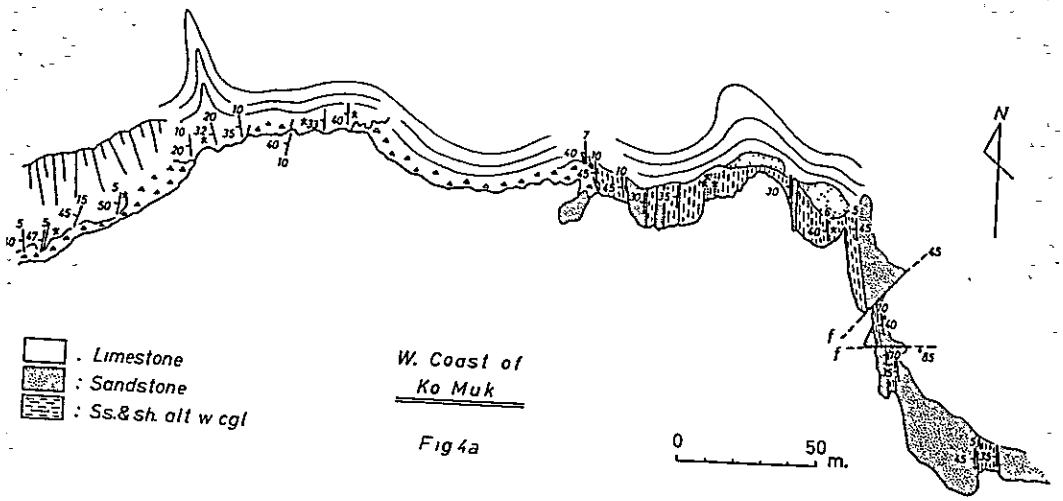



Fig 4a

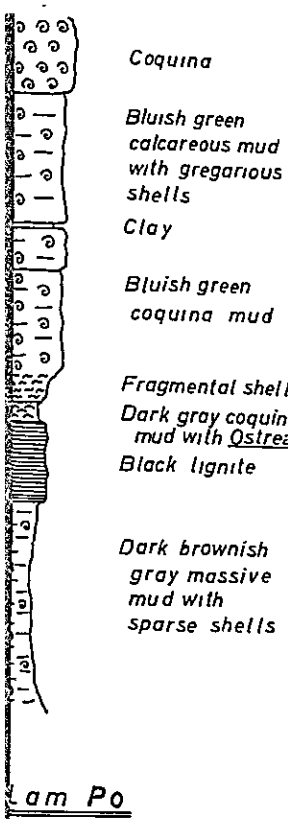



Fig. 4b

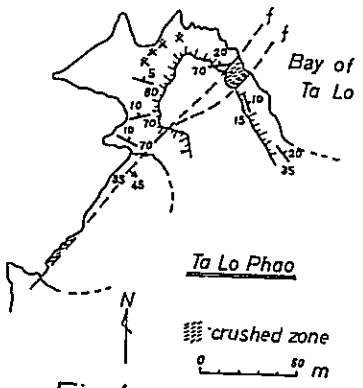
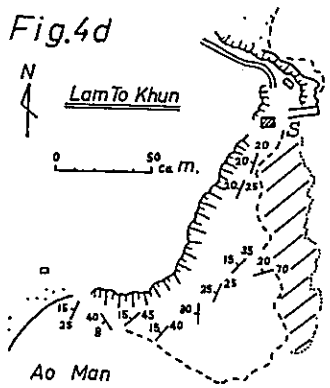



Fig.4c

Fig.4d

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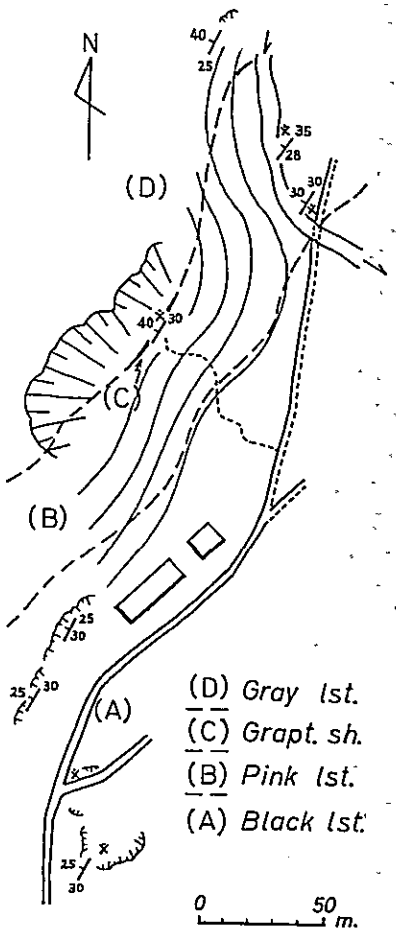
. coral reef flat




Ban Na Fig.4e

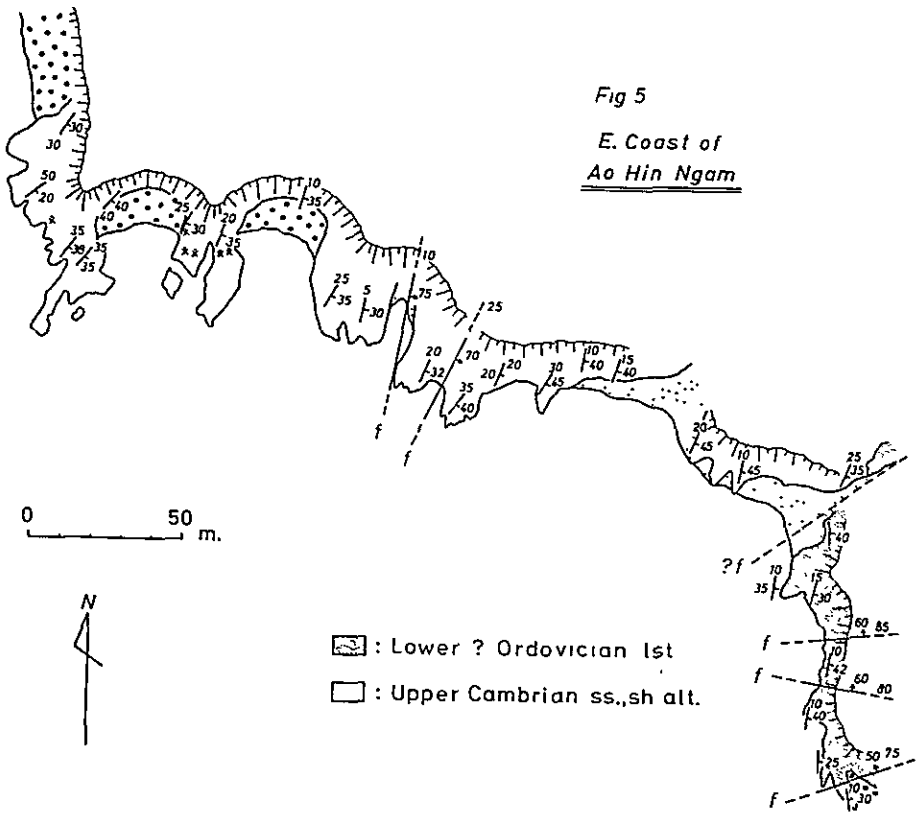



Fig 5

E. Coast of
Ao Hin Ngam

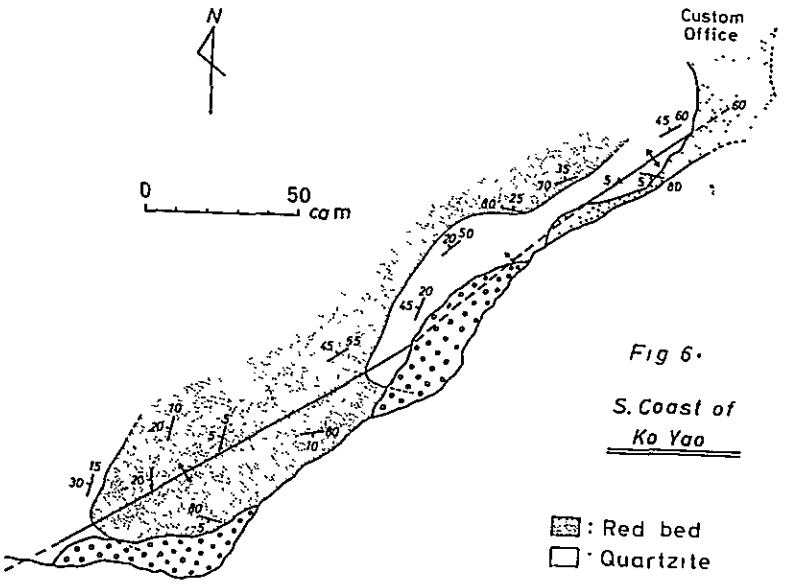



Fig 6.

S. Coast of
Ko Yao

Fig 7. Fossil localities of the Lankawi Islands and Sketch Map of the Setul Formation

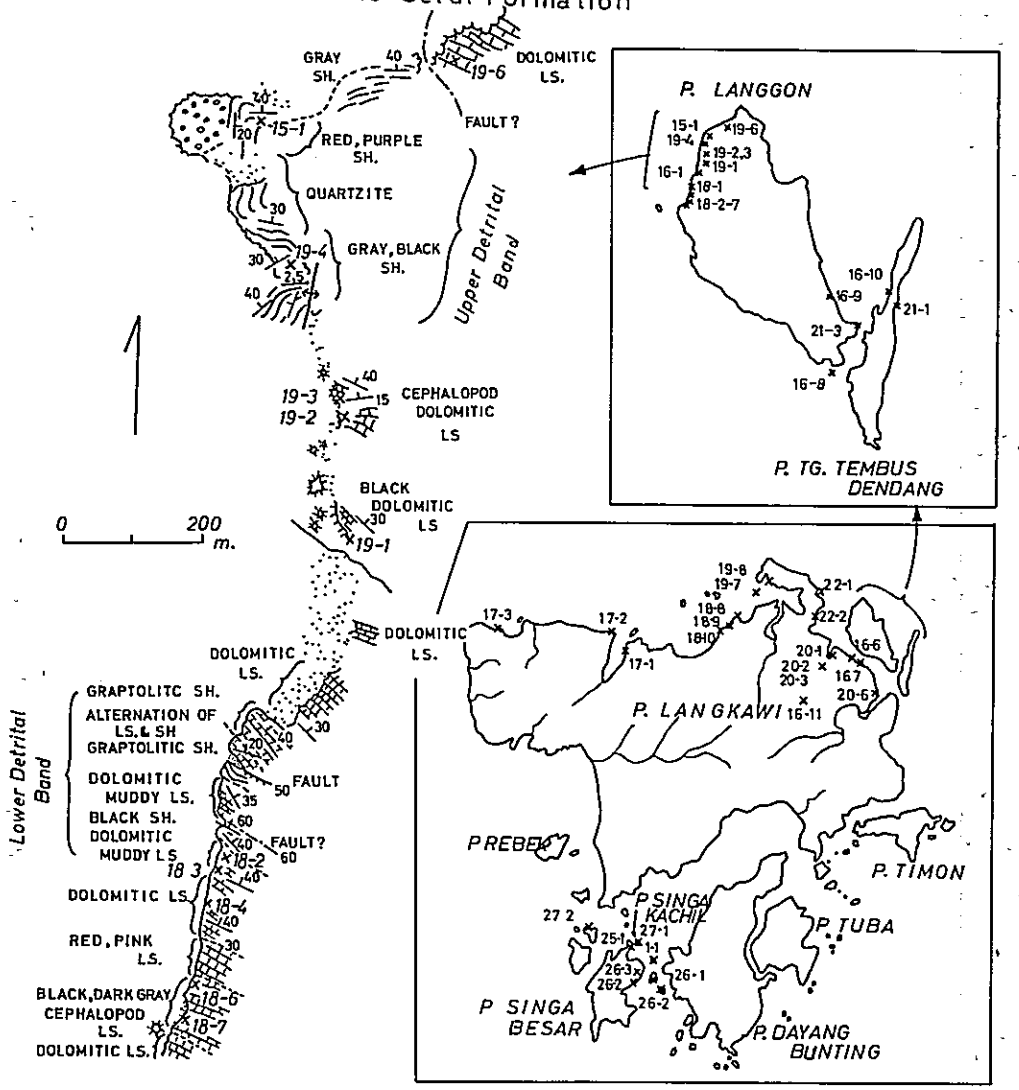
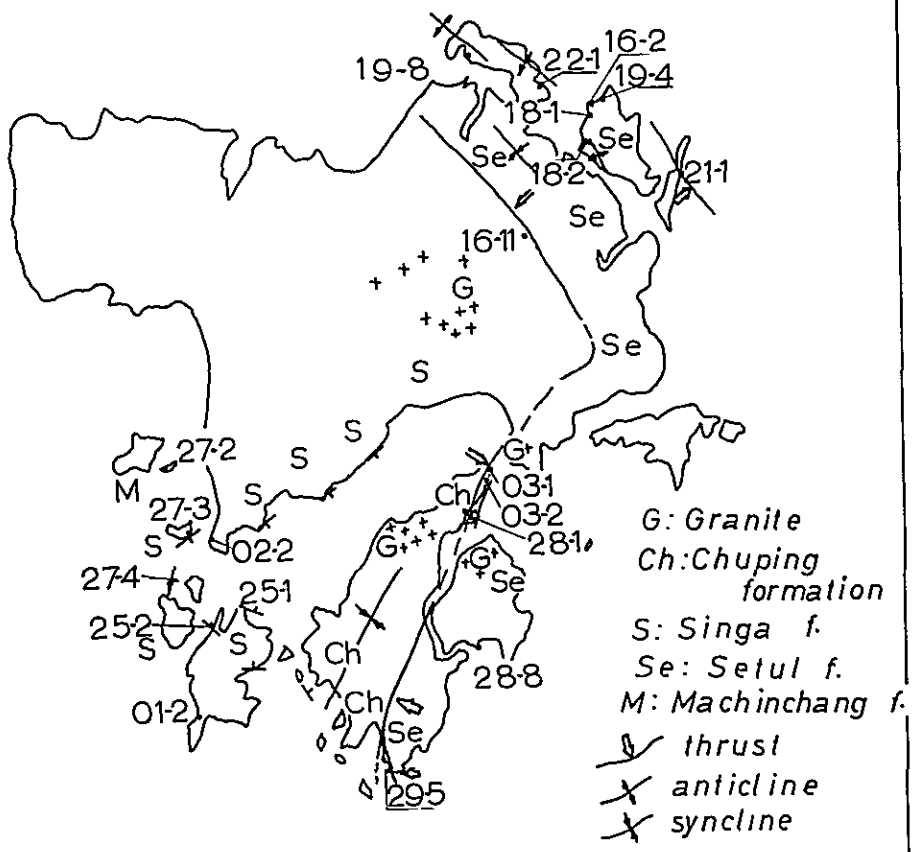


Fig. 8

Tectonic Map of the Langkawi Islands



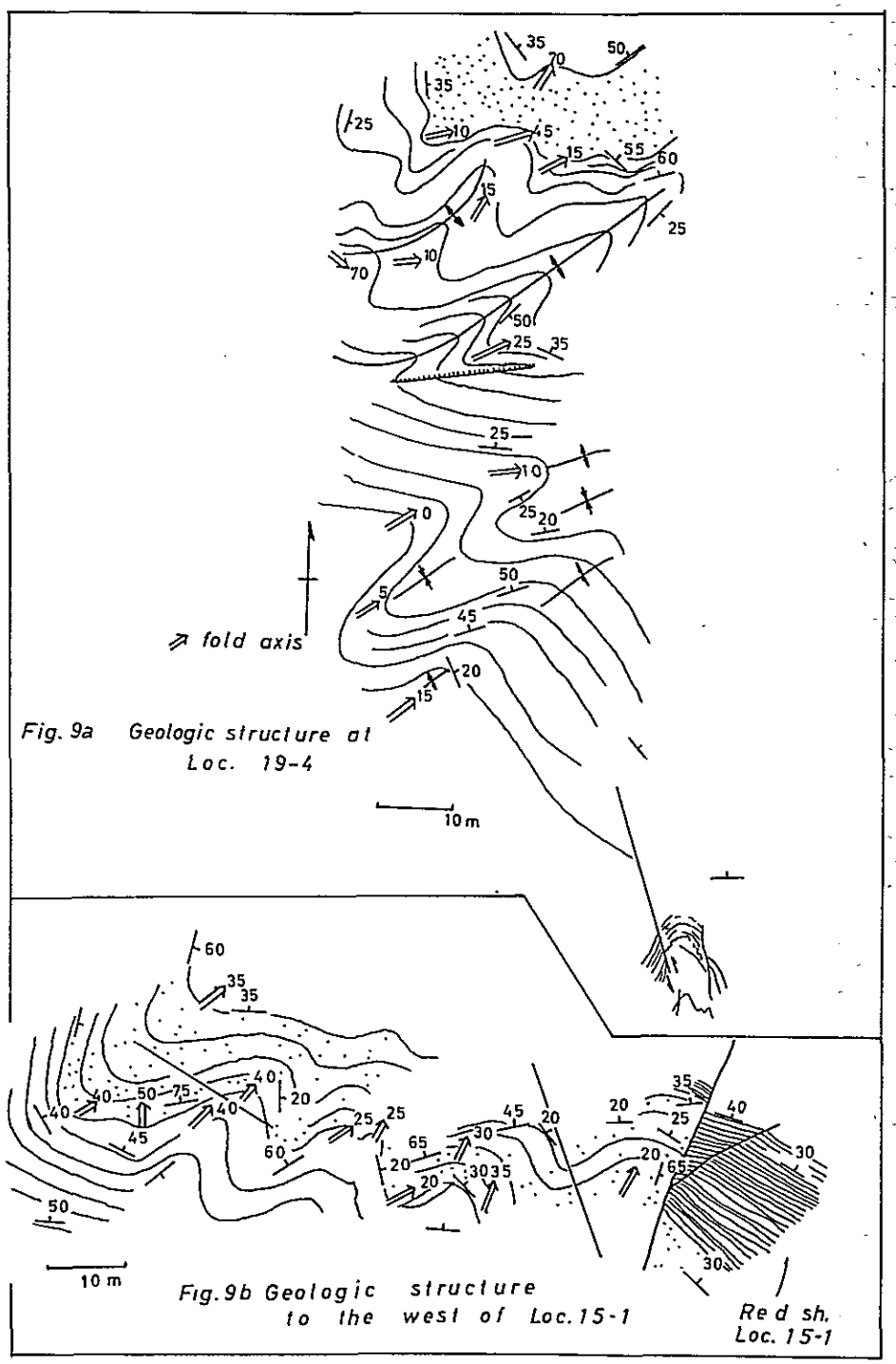



Fig. 9a Geologic structure at Loc. 19-4

Fig. 9b Geologic structure to the west of Loc. 15-1

Fig 10

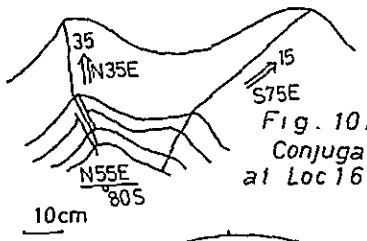



Fig. 10b
Conjugate folds at Loc 16-2

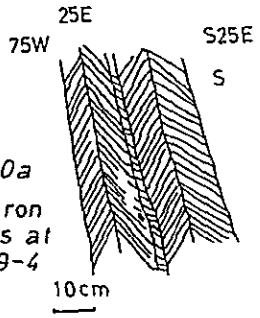



Fig. 10a
Chevron folds at Loc.19-4

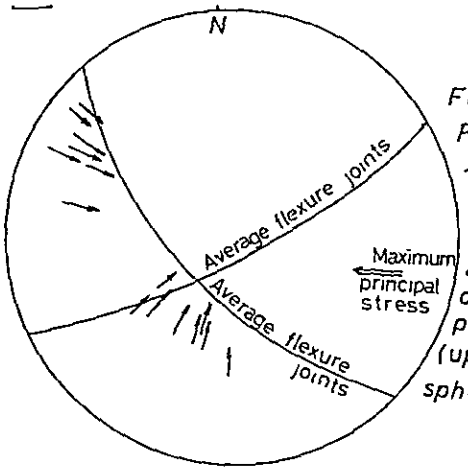
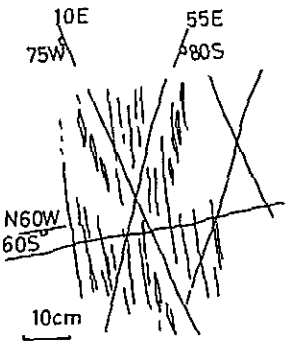



Fig 10c
Flexure joints & fold axis of Knick folds at Loc.16-2 on stereographic net (upper hemisphere)




Joints at Loc.25-2 (Carboniferous)
Fig 10f

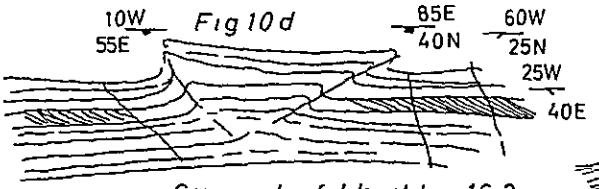
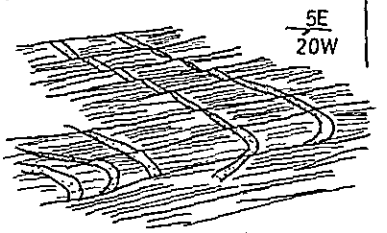
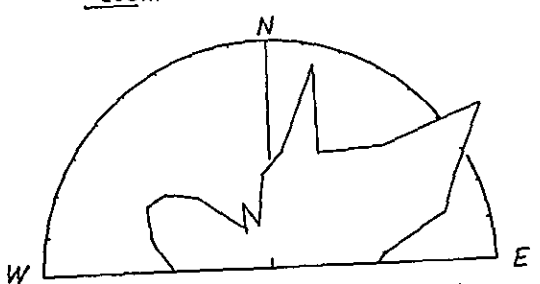



Fig 10d
Conjugate folds at Loc.16-2




Minor displacements along "cleavage" at Loc. 27-3K (Carboniferous)
Fig.10g




Joint patterns of the Carboniferous strata
Fig.10e