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THESIS submitted for the DEGREE of MASTER OF SCIENCE.

THE GEOLOGY OF THE LUNDU-SEMATON - TANJONG DATU AREA OF THE FIRST DIVISION OF SARAWAK

by

A. W. ALLEN, B.Sc., A.M.I.M.M.

November, 1951.

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LIST OF FIGURES AND MAPS.

The Geology of the Lundu - Sematan - Tanjong Datu area of the 1st. Division of Sarawak.

Introduction.

This thesis describes the geology of the western part of the 1st. Division of Sarawak and attempts to give a classification of the rocks of the area. This work is based on a geological reconnaissance carried out from December 1949 to June 1951 for the British Aluminium Co. Ltd., In view of the differences which exist between geological wotk in a tropical climate and that of a temperate climate it has been thought that some of the difficulties attendant on this work should be pointed out in this introduction.

The first really serious drawback encountered is the absence of good topographical maps for this area. The state of the topographical survey is such that only primary triangulation points have been established and a compass and chain survey of the rivers and paths south of Sematan exist. For the large area north of Sematan which includes a forest reserve of more or less 100 square miles, only a rough coastal survey exists. The location of the principal peaks in the high country forming the Sarawak - Indonesian border is known from the Dutch Military reconnaissance maps. The method of

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work used in these unmapped areas was to start from a known position on the coast and to drive measured traverses to the west and plot the geology and topog graphy on them. Subsidiary traverses were driven north and south until the upper valley of the Samunsam river was reached. A compass survey of this river was then made and it was established as a base line and traverses driven east and west from it. In January, 1951, mosaics based on air photographs made by the Royal Air Force in June, 1950 were made available and simplified operations considerably.

The second major difficulty encountered was due to the blanket of weathered products and alluvium which obscures exposures and to the presence of detached and transported boulders which are general over the country ranging from 100' to 1,100' above mean sea level. One has to be very careful in distinguishing between a genuine outcrop and a large boulder embedded in the weathered deposits. An extensive programme of pitting has aided the mapping fairly considerably as the weathered rock gives many clues as to the actual nature of the fresh bedrock. It is estimated that in the 450 square miles of country traversed, exposures occur at an average of one for every eight square miles. This does not take the excellent coastal outcrops which are seen along the coast from Tanjong Datu to Kuala Samunsam into account.

Finally, in this thesis, a fair amount of space has been devoted to describing the physiography of the country, as many features play an important part in unravelling the Post - Pleistocene history of the area.

Acknowledgements.

My thanks are due firstly to the Directors of the British Aluminium Co. Ltd., for permission to use material collected during the course of the survey for the purposes of this thesis.

I am also indebted to Dr. F. W. Roe of the Geological Survey Dept. Sarawak, for considerable help in placing facilities for making thin sections and their microscopical examinations at my disposal and to G. E. Wilford who discussed results obtained.

Finally my sincere thanks are due to Miss A. Dent for typing this thesis and to Captain R. A. Wilson 2nd.10th Ghurkha Rifles for reading the proofs and correcting the English.

Glossary of Malay and Dyak terms which appear in this thesis and their abbreviations.

Malay words are succeeded by (M); Dyak words by (D).

Malay or Dyak.		Abbreviation.	English.
Bukit	(M)	Bt.	Hill
Batang	(D)	Btg.	Main river channel.
Danau	(D)	D.	Lake
Gunong	(M)	G.	Mountain
Ilir	(D)	Ilir	Downstream
Kuala	(M)	K.	River mouth
Kampong	(M)	Kg.	Village.
Loba	(M)	L	Creek joining two rivers.
Lubok	(M)	Lbk.	Deep pool in river
Loagan	(M)	Lg.	(a) Abandoned reach of river (b) Ox bow lake.
Muara	(D)	M.	River mouth.
Munggu	(D)	Mgu.	Low hill.
Nangah	(D)	N.	River mouth.
Pulau	(M)	P.	Island.
Pangkalan	(D)	Pang.	Landing stage.
Pengkalan	(M)	Peng	″ ″
Rumah	(M)	R.	Longhouse.
Sungai	(M)	S.	River.
Tanjong	(M)	Tg.	Cape or headland.
Telok	(M)	Tk.	Bay
Trusan	(M)	Tr.	Channel.

PART I

GENERAL.

SECTION 1.

Location of Area.

The area under survey lies in the Western part of the 1st Division of Sarawak and is bounded to the east by the Batang Kayan as far as the confluence with the Sungai Pasir. This latter river forms the southern boundary as far as the Indonesian frontier which forms the western boundary as far as Tanjong Datu. The area lies wholly within the Lundu administrative district.

SECTION 2.

History and review of previous work in the area.

Prior to 1925 no work had been done in this district. In 1925 a party of geologists and mining engineers under the direction of Dr. F. H. Krol and including Dr. H. Ehrat and O. W. Memelink, all of the Netherlands East Indies Geological and Mining Department made a survey of the Western Residency of Borneo and included parts of the Kuching and Lundu districts of Sarawak in their survey. Their results were published in 1939 by C. P. A. Zeylmans van Emmichoven (who took over the survey in 1932) and R. W. van Bemmelen. van Bemmelen whose paper deals with our particular area states in his introduction that he has never visited Bormeo in a professional capacity and that his paper is based on the examination of 2,500 specimens and that his map was constructed by interpolating boundaries between specimen localities. He states that consequently his map is of little value. The specimen location map accompanying his paper shows that very few of the specimens described were collected from Sarawak and these chiefly from Tg. Datu and the coastal districts of Lundu. van Bemmelen's map is shown in Fig. 1.

During the late war, Japanese geologists carried out a survey at Sematan and in the Tanjong Serabang area, directed according to local information towards the location of bauxite and haematite. As a result of naval action, the geologists and their results failed to reach Japan and consequently nothing is known of their work except that both of their objectives were partially successful.

In 1947 and 1948, H. C. Parker under the direction of Dr. W. S. McCann made two rapid reconnaisaances for the British Aluminium Co. Ltd., between Lundu and Sedemak and in the Sematan area.

In 1949, Dr. F. W. Roe in a coastal survey discovered bauxite at Sematan (Ref. 3) as a result of which the author of this thesis was detailed by the British Aluminium Co. Ltd., to carry out a survey in the area. The results of this survey are dealt with at length in this thesis and were summarized and published by A. W. Allen in the Annual Report of the Geological Survey Dept. Sarawak for 1950.

In view of the non-discovery of any fossil evidence as to age, reference must be made to N. Wing Easton's survey of the Sambas or so-called Chinese districts of Western Borneo and C. P. A. Zeylmans van E Emmichoven's work in the eastern part of West Borneo, both of which help to provide basis for the dating of the rocks in our area.

References to the area are made by R. W. van Bemmelen in 'The Geology of Indonesia' and by Professor K. B. H. Umbgrove in 'The Structural History of the East Indies'.

PART II
PHYSICAL and HUMAN GEOGRAPHY

SECTION 1.

Topography.

Three mountainous areas exist. The country in the north consists of the mountainous peninsula of

Tanjong Datu (culminating in Gunong Melanau, 1,900 ft. above mean sea level), to the East of the high 'massif' between Lundu and Sematan (G. Perigi, 2,950 ft.) and to the West the area is bounded by the high Pueh range (G. Kanyi 5,150 ft.) which has over 11 peaks higher than 4,200 ft.

A range of high hills connects the Pueh range with the Tg. Datu range but is pierced by an ancient marine channel to the north of G. Chermai. This range will be known as the Gunong Puting range.

In the Sebako valley three isolated hills are conspicuous. They are G. Angus, G. Tamin Menari and G. Tamin Tungku.

Between the middle reaches of the S. Samumsam and the sea, a low series of hills nowhere higher than 350 ft. above mean sea level occur. These will be known as the Bedaun Hills.

Between G. Puting and the S. Samunsam a few isolated hills rising to about 100 ft. above mean sea level are found.

To the west of Sematan low hilly country covers $\frac{3}{4}$ of a square mile. This is known as Munggu Belian.

To the south of the Pueh range a low pass to be known as the Sadjingan gap separates this range from another range of high hills known as the Aruk Range.

The remainder of the country is low lying and generally swampy except in the vicinity of hills where it is extensively cultivated.

The principal rivers are (a) to the east, the Batang Kayan which rises on the Matang Range and flows out to sea north of Lundu. Its principal tributaries are the Sungai Pasir (with its attendant tributary the S. Jangkar) and the S. Sembayang.
(b) in the area between Lundu and Sematan, the Sebako and Serayan rivers, which coalesce just north of G. Angus to flow out to sea at Sematan.

The principal tributaries of the S. Serayan from north to south are the S. Salarat and the Sepali.

Those of the S. Sebako from north to south are the S. Sebat, S. Tembaga, S. Teput and S. Sematan.

To the north of the Pueh Range the S. Samunsam is the principal stream. Until recently its source was unknown but has recently been established as being the northern slopes of G. Pueh.

Numerous small rivers, e.g., the S. Siruh Besar, S. Pueh, S. Blinsah and S. Bedaun flow directly into the sea between Sematan and Kuala Samunsam but these are not important.

SECTION 2.

Vegetation.

Old or primary jungle is predominant on the high mountains and hilly country and is general in the country between Pueh and Tanjong Datu. Moss forest occurs on the higher peaks of the Pueh Range. Where cultivation does not take place in the low lying country between Pueh and Lundu, scrub jungle or swamp jungle depending on the nature of the ground is the general rule.

Along the sandy raised beaches fringing the coast between Siar and Pueh, light open jerami forest consisting of stunted trees and well developed casuarina groves are general where the country is not swampy.

SECTION 3.

Climate and Rainfall.

The climate is monsoonal, the dry season occurring between March and November, the north-eastern monsoon striking the coast during the remaining months is responsible for a rainfall of between 260 to 300 inches. During the dry season the temperature averages 85°F. and 78°F. during the wet season.

SECTION 4.

Human Geography.

The area is sparsely inhabited, the bulk of the population being Land Dyaks. Three tribes of these people live in the district, each speaking its own language and having its own customs. Along the slopes of the foot-hills of the Pueh Range and the western foot-hills of the Lundu mountains, Selakau Dyaks farm the hilly country. Their principal villages or long-houses are Pueh, Sebako, Serayan, Sebiris, Rukam, Jangkar and Biawak. Larah Dyaks occupy the country flanking the Aruk Ramge and Kandai, whereas Jagoi Dyaks inhabit the middle reaches of the Batang Kayan. The principal villages of the former are Kandai, Sungai Pasir and Bedaun; of the latter Selampit, Rasau, and Stungkor.

Sea Dyaks are found along the lower reaches of Batang Kayan. They form part of the large and wide-spread tribe of Sebuyau Dyaks; the other great branch of the Sea Dyaks i.e., Iban Dyaks are represented by a long-house at Sampadi.

Malays inhabit the coast at Melanau, Serabang Sematan and between Tg. Pandan and Lundu where they cultivate coconuts and rubber. They are excellent fishermen in addition. They live inland at Sebat.

Chinese traders are concentrated at Lundu and Sematan, where they form rich and powerful communities.

Chinese farmers are found in the Selarat-Serayan - Tembaga area where their principal crops are rubber, pepper, rice and vegetables.

The district is administered from Landu by a British District Officer, who works with the advice of two native officers.

Dyak and Malay headmen are responsible to the District Officer for their villages and the Chinese appoint two officials known as Capitan China, who reside at Lundu and Sematam and who are responsible to the District Officer for Chinese affairs.

PART III
PHYSIOGRAPHY

SECTION 1.

General.

The area under investigation is a part of the old Sunda (Soenda) continent, a large part of which now lies submerged beneath the South China and Java Seas. This district and the Schwaner mountains of West Borneo form the most deeply eroded part of this old continent.

van Bemmelen classifies

the Soenda continent into five zones and places the Sematan area together with its northern continuation into the Natuna islands in zone α or the Natuna zone.

Zone β or the Anambas zone consists of the Anambas islands and the Schwaner mountains of Borneo. Zone γ or the Karimata zone is shown as consisting of the east coast of Malaya, the Karimata islands and the southern part of West Borneo, although the east coast of Malaya has far more affinity to zone δ or the Tin Belt than to the southern part of Borneo. Zone ϵ the Karimundjawa zone comprises parts of Sumatra and Java.

In our area three clearly defined and one ill defined mountain systems occur. They are, in order of age,

(4) A pre-Permian and Carboniferous system which is represented by regionally metamorphosed rocks which are so deeply weathered and altered by later orogenies that no clear picture as to trends and structure can be obtained.

(3) A post-Permian, probably early Triassic system trending N-S and reflected in the G. Aruk mountains, the Pueh and Lundu ranges (these latter have been subsequently intruded by Cretaceous granites), the Gunong Puting mountains and the northern part of the Bedaun hills.

(2) A late Jurassic-early Cretaceous system trending NW-SE and forming the Tanjong Datu mountains.

(1) A Tertiary system characterized by severe faulting and gentle folding forming the Bedaun hills, the southern part of the G. Puting hills and the hills to the east of Lundu in the Sampadi area. The structures referable to these movements trend NE-SW.

These four systems are shown in Fig. 2

The low-lying country consists of a plain covered by recent marine sediments. In the immediate vicinity of rivers these marine deposits are overlain by fluviatile sediments. It will be shown subsequently that the whole area lay below water to a height of 1,100 ft. above present sea level, the higher peaks standing out as islands.

The principal features of the coast line are those of a recently emerged coast line, the evidence for which will be detailed in a later section.

Severe erosion of the coast line is occurring to the immediate west of Kuala Sematan.

It is proposed to discuss the physiography in greater detail as it presents features which have a considerable bearing on interpreting the sequence of events during Late Tertiary and Quarternary times.

SECTION 2.

Coast Lihe.

The coast can be divided into four sections.

(a) A rocky coast line with prominent headlands and bays fringed by raised beaches backed by cliffs stretching from Tanjong Datu to Tg. Limoh.

(b) A wide bay fringed by wide beaches and three raised beaches stretchimg from Tg. Limoh to Tg. Batu. Seawards, off-shore bars are common.

(c) A coast characterized by four small bays separated by rocky headlands stretching from Tg. Batu to Tg. Pelandok. The small bays are fringed by raised beaches, the headlands being formed by igneous and metamorphic rocks.

(d) A long flat coast line stretching from Tg. Pelandok to the mouth of the Batang Kayan.

They will be described in that order:-

(a) Coast line from Tg. Datu to Tg. Limoh.

This coast in contrast to that south of Tg. Limoh, consists of hard crystalline rocks of igneous or metamorphic origin with the result that coastal erosion is not so marked as in areas further south.

From Tg. Datu to the northern end of Telok Labuhan the coast is made up of granite cligfs which are covered by vegetation and where small bays and inlets are developed, these cliffs are fringed to the seaward side by raised beaches which are covered by massive blocks and boulders dislodged from the cliffs.

Telok Labuhan is a well developed bay fringed 200 yards inland by quartzite and slate cliffs, the narrow 'coastal ' plain containing two raised beaches.

Tg. Labuhan which forms the southern limit of the bay is of interest as it has a sea cave developed 2 ft. above maximum high water level. This headland shows a characteristic feature which is developed in all the principal capes from here to Tg. Pelandok. The headland consists of a rounded hill joined to the mainland by a low valley filled by marine alluvium and flanked to the ~~east~~ west by the steep slopes of Gunong Melanau. The distribution of Recent sediments shows that not long ago the seaward part of the headland was an island and has only recently been joined to the mainland as a result of Recent uplift of the land surface. This is seen to an even better degree at Tg. Serabang and Tg. Limoh and the process can be seen in operation at the latter headland where a small island ,P. Kerengga, is attached to the mainland at low tides and becomes an island at high tide.

Telok Jinsiang, which lies to the south of Tg. Labuhan shows a similar pattern of raised beaches flanked by cliffs as exhibited by Telok Labuhan. A small headland Tg. Jinsiang in the centre of the bay is formed by the outcrop of a large quartz vein.

From Tg. Stimeh to Tg. Melanau the coast consists of cliffs with well developed wave swept platforms and storm beaches.

Between Tg. Melanau and Tg. Serabang a change in the geology is noted; Triassic conglomerates passing southwards into Permian and Carboniferous actinolite quartzites. This junction is obscured by recent sands and a bay is formed here with two raised beaches flanking it.

Tanjong Serabang shows similar features to Tg. Labuhan in as much that it consists of an island which has recently been joined to the mainland.

It is of further interest in that to the west of the old marine channel a raised beach occurs 250 ft. above sea level flanking G. Serabang to the east. The eastern face of the mountain actually forms an old cliff face with screes banked up against it. A diagram of this headland showing these features is shown. At Telok Serabang just to the north of Tanjong Nyawang a remarkable distribution of recent sediments is found in the shallow

Photograph showing ancient marine channel to the west of Tanjong Limoh. A similar feature is in process of formation to the east of the headland.

bay. This will be discussed in the section on present day sediments.

From Tanjong Nyawang to Kuala Samunsam the principal features are similar to those developed between Tg. Labuhan and Tg. Pinang.

These are the development of cliffs along bays or inlets fringed by raised beaches. The headlands are fringed by pronounced wave swept platforms. At Tanjong Badak a sea cave with a blow hole occurs 15 ft. above high water mark.

Just north of Kuala Samunsam a large fault is responsible for the abrupt termination of the cliffs and it is this line of fracture which has caused the River Samunsam to flow out to sea at this point.

Tanjong Limoh shows similar features to Tg. Serabang except that the 250 ft. raised beach is not present here and the presence of three former islands can be proved. The marine channel is well in evidence. In addition a small island just off the coast is in the process of being added to the mainland. During low tides it is connected by a strip of sand to the mainland and at high water resumes its existence as an island. Old inhabitants of Kg. Serabang say that about 40 years ago a deep channel existed between the

Photograph showing Tanjong Limoh and Pulau Kerengga at low tide: at low tide attachwd to the mainland and an island at high tide.

island and the mainland and that it occupied a considerably smaller area than at present.

About half a mile out to sea from Kuala Sungai China an island with a pronounced raised beach at 75 ft. above sea level on its western side is connected to the mainland by a shallow stretch of sand which is however covered by water at both low and high tides.

There is therefore on this coast ample evidence to show that the land has recently risen in relation to sea level. The evidence in support of this is summarized below:-

(1) The occurrence of raised beaches fringing cliffs along bays and inlets.

(2) The presence of ancient islands which have since been joined to the mainland. Stages of this joining can be seen as follows:-

(i) Pulau Datu at the mouth of the S. China, which is still separate from the mainland.

(ii) Pulau Kerengga off Tg. Limoh, which is an island at high tides and a peninsula at low tides.

(iii) Tg. Labuhan, Tg. Serabang and Tg. Limoh which were islands and are now part of the mainland. In all cases the headland is separated from the mainland by a valley filled with marine sediments.

(3) The presence of sea caves at Tg. Labuhan and Tg. Badak, the former just above high water level, the latter 15 ft. above the same level.

(4) The presence of a raised beach 250 ft. above sea level on the eastern flanks of G. Serabang and at 75 ft. on P. Datu and Tg. S. China. This is part of the evidence for flooding, on a much larger scale, of the area and can be recognised in other areas. It will be discussed in connection with wider phenomena of this nature in a subsequent section.

(b) Coast line from Tg. Limoh to Tg. Batu.

The second main section of coast line stretches from Tg. Limoh to Tg. Batu and is approximately 16 miles long. One rocky headland interrupts a sequence of long wide beaches through which numerous small rivers flow out to sea. At Sematan the beach is interrupted by the half-mile wide mouth of the Sematan river.

Evidence for recent emergence of the shore line can be seen in the presence of three beautifully preserved raised beaches separated from each other by marshes and running parallel to the shore. Off-shore bars are extensively developed along this coast.

Between Sungai Kelong and Kuala Sematan extensive erosion of the coast is going on. In 1947

Photograph showing damage caused to the shore to the west of Kuala Sematan by severe marine erosion.

and 1950 the Royal Air Force photographed this area for topographical purposes and Major E. W. Lawrence, then Superintendent of Lands and Surveys for the 1st Division, estimated that 60 ft. of the coast had been washed away. A triangulation peg (N 61) put in in 1932 by Mr D. L. Leach, Director of Lands and Surveys, now lies about 200 ft. out to sea. Some photographs are included to show the extent of the erosion.

The mouth of the Sematan river is a drowned valley as are two streams which originally developed along the depression between two raised beaches to the east of Kuala Sematan, and whose mouths have been deflected to the south by deposition and silting which is taking place on the eastern banks of the Sematan river.

The cause of the erosion on the west bank is a subsidiary current which swings in a S.E. direction from S. Kelong and erodes the coast on the west bank. The current is checked by a fairly fast flow from the Sematan river with the consequence that deposition of the material eroded from the west bank occurs on the eastern bank forcing the main channel of the Sematan river to the west and deviating the mouth of the Pugoh river to the south. These features are shown in the adjoining sketch.

Between Kuala Sematan and Tg. Batu, off-shore bars are developed to a considerable extent.

(c) Coast line from Tg. Batu to Tanjong Pelandok.

Tanjong Batu is a headland built out of quartzite and exhibiting exactly the same features as Tg. Limoh, i.e., the headland has recently been attached to the mainland as a result of uplift, the headland proper being separated from the mainland by a valley filled with marine alluvium.

The coast is essentially the same in detail as the coast from Tg. Limoh to Tg. Batu consisting of bays fringed by three raised beaches. Outcrops of igneous rock and quartzite are responsible for forming headlands at Tg. Pandan (granite intruded into gabbro), Tg. Hashim (quartzite) and Tg. Pelandok (gabbro).

(d) Coast from Tg. Pelandok to the mouth of the Batang Kayan.

From Tg. Pelandok to the mouth of the Batang Kayan the coast is flat with sandy beaches fringing fluviatile muds and is in fact part of the delta formed by the Batang Kayan.

SECTION 3.

Alluvial Plains.

Three alluvial plains occur. To the east the large and extensive flood plain of the Batang Kayan-Sungar Pasir system; in the centre of the flood plain of the Sebako-Serayan system which merges to the north-west with a coastal plain; and to the north of Pueh C. the flood plain of the Samunsam river.

The main point of interest about these plains is that they are covered by marine sediments covered by a veneer of river sediments in the immediate vicinity of the main rivers and these latter are generally restricted by a fairly narrow margin on either side of the valleys with the exception of the Batang Kayan where the fluvial deposits are more extensive.

Half a mile to the west of Sematan an old weathered pre-Tertiary land surface outcrops through the marine sands.

SECTION 4.

River Valleys and Drainage.

The Batang Kayan River

(a) When this river enters our district it flows along a geological boundary separating Tertiary sand-stone to the east and Mesozoic and late Palaeozoic rocks to the west. It has formed an extensive flood plain and flows almost at base lwvel, meandering widely.

It is in the process of forming an extensive delta and although the river is deep and wide, it is useless for navigation purposes as an extensive series of bars has developed across its principal mouth. Its largest tributary, the Sungai Pasir shows similar old-age features developed on a smaller scale.

(b) Valleys of the Sebako and Serayan Rivers.

These two rivers rise on Gunong Kanyi and Gumomg Lundu respectively and in the upper part of their courses are separated from each other by a low ridge with twoculminations at G. Tamin Menari and G. Angus. These rivers and their principal tributaries have exceedingly fast headwaters, the Sebako river forming a 200 ft. waterfall, and they together with their tributaries in their upper reaches have carved themselves narrow gorges filled with huge boulders, with precipitous sides in the mountains. These gorges make the foothills of the mountains almost inaccesible in places. On entering the low-lying country the velocity of the streams is checked and extensive alluvial fans occur, some being 80 ft. high. These low hills form a detached feature all along the Pueh range from Sebako to Pueh.

The Sebako river is deviated to the east near Sebat by a pre-Quarternary low ridge between Siruh and

Sematan, and joins the Serayan river just N. of C. Angus and flows into the sea at Sematan.

(c) The Samunsam ~~Valley~~ River.

This river drains the country to the north of the Pueh range, cuts across the strike of the sandstone hills flanking the mountains to the north ahd in this part of its course, the valley has cut through to basal quartzite and schist which underlie the sandstones. It also forms a series of alluvial fans on entering low-lying country. The river then flows between Upper Palaeozoic rocks (Permian and Carboniferous) to the west and soft Tertiary grit, sandstones and conglomerates to the east through a wide flood plain across which it meanders extensively flowing in a north-westerly direction. About three miles to the north of an E-W line through Gunong Chermai the river is deflected to the east by Mesozoic slates and quartzite and flows out to sea along a valley based on a large fault which throws older hard actinolite quartzites in the south against younger Mesozoic metamorphosed sediments in the north.

SECTION 5.

High Country.

The principal features of interest in the high ground lies in the preservation of erosional features due to marine action.

Before describing these features it should be pointed out that the topographical survey of the area is still very incomplete, that no accurate maps of the area exist and that consequently the heights given below are estimated.

These erosional features are seen at the following localities.

1,000 ft. above mean sea level.

G. Gebong and G. Sebuloh.

Marine etched boulders and patches of marine alluvium overlying a deeply weathered surface.

Gunong Pueh. A marine bench.

Gunong Puting. A marine bench fringed to the west by a peneplaned surface.

Gunong Melanau. A marine beach.

Gunong Panggi. A marine beach.

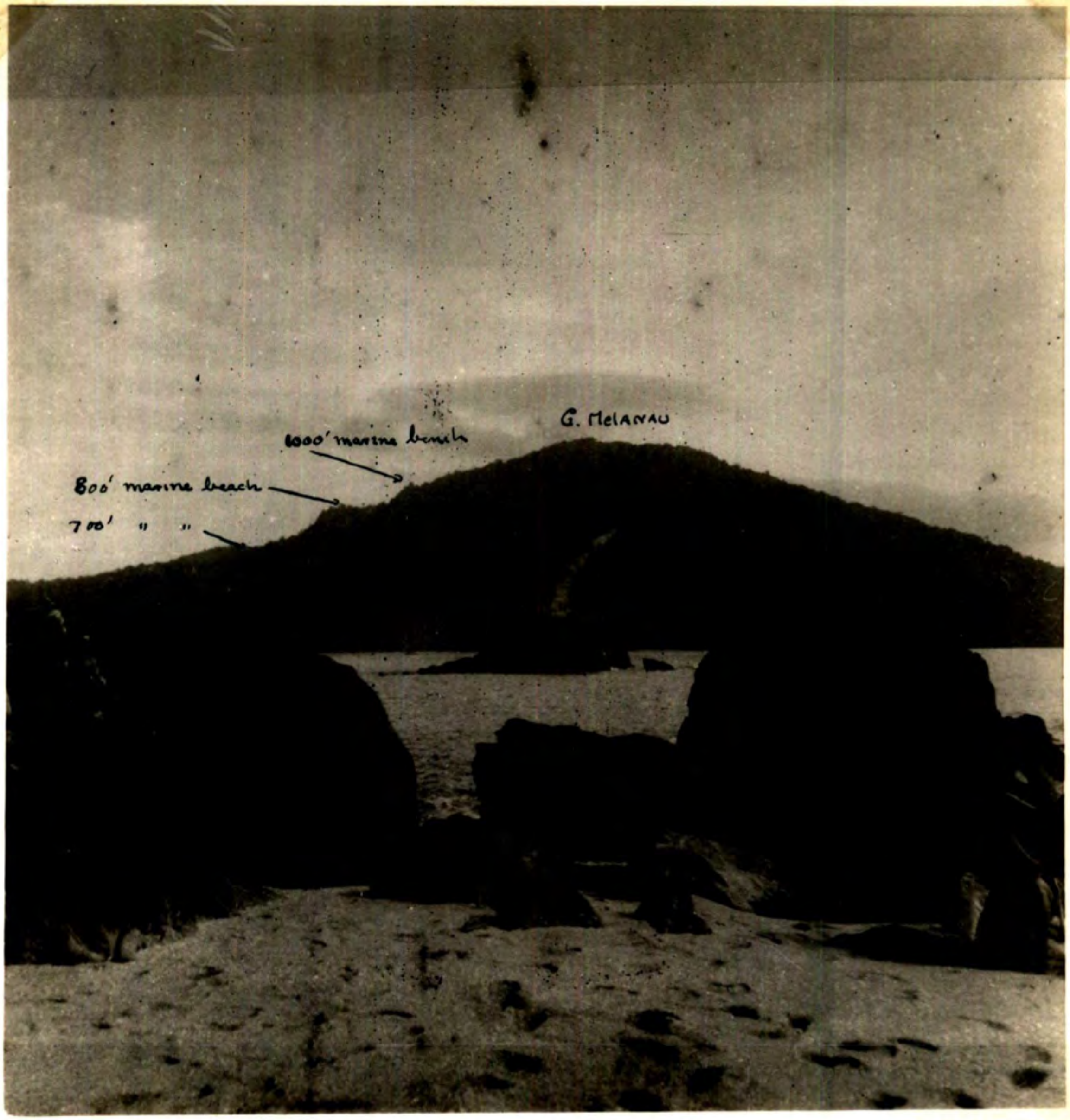
800 ft. above sea level.

Gunong Melanau. A marine beach accompanied by an old wave eroded beach covered by wave etched boulders overlying sand which in turn overlies a weathered surface.

700 ft. above mean sea level.

Gunong Melanau. A wave eroded platform with boulders and patches of sand fringed by a cliff face banked up by considerable screes.

Gunong Panggi. As for Gunong Melanau. The cliff is



Photograph showing erosion features due to marine action on Gunong Melanau. The rocks in the foreground are Permian and Carboniferous actinolite quartzites.

on a smaller scale.

Gunong Puting. A marine beach.

Gunong Gebong and Gunong Sebuloh.

Beautifully preserved old beaches with pockets of corted sand on the upper slopes of these beaches fringed by high and well preserved bare cliff faces against which screes of wave etched boulders are banked up. These cliffs are particularly well developed on the northern face of Gunong Gebong. The cliff tops are overlain by a deeply weathered surface in which over 16 ft. of bauxite has been found.

350 to 250 ft. above mean sea level.

G. Melanau, G. Panggi, G. Sungei China.

Cliffs fringed with wave eroded beaches on their eastern flanks.

G. Serabang.

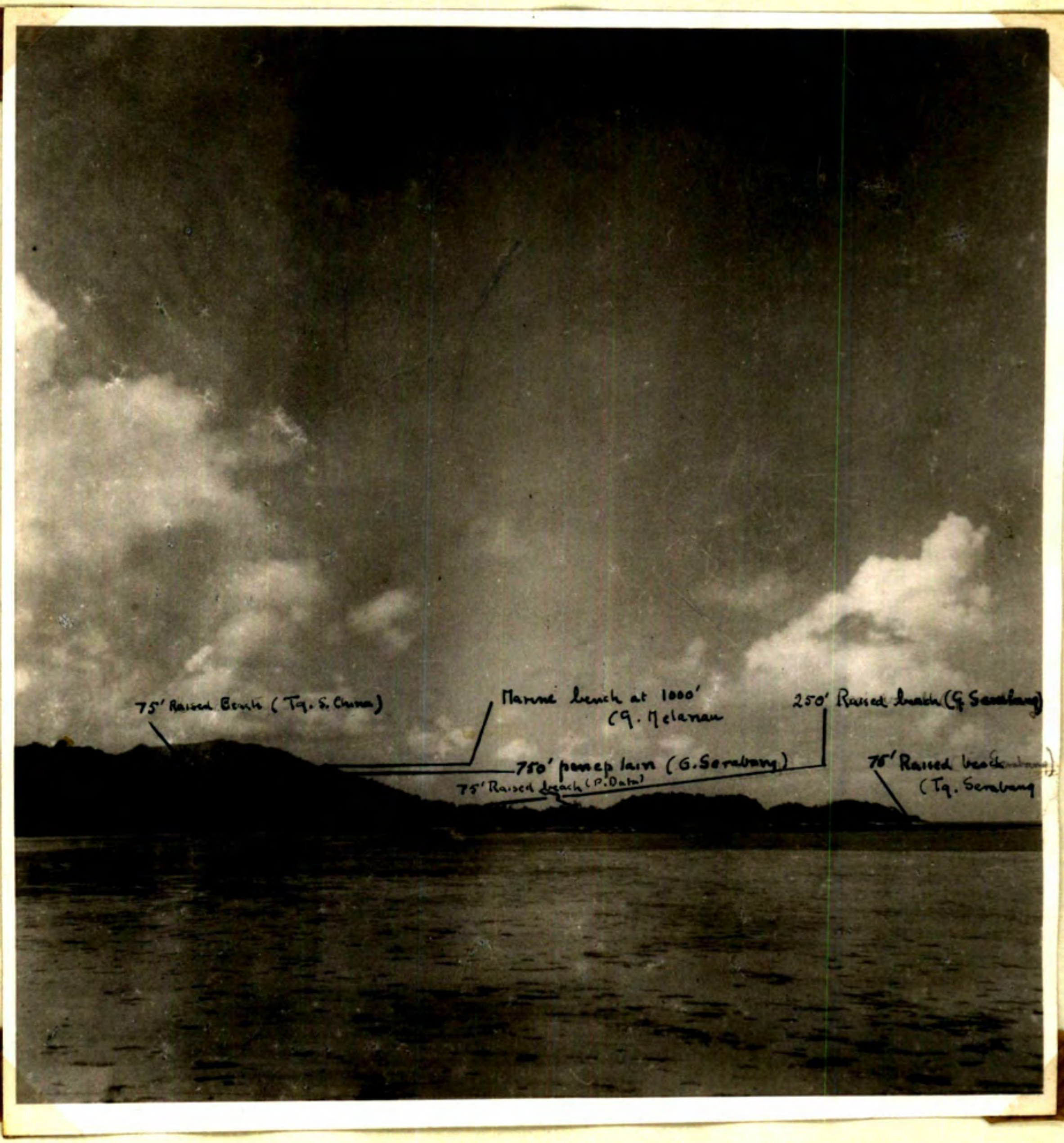
A high raised beach covered with transported boulders and pebbles of bauxite, actinolite quartzite and slate, fringed to the west by a magnificent cliff face banked up by screes.

Gunong Pueh, Gunong Sebat and Mgu Semabeng.

Cliffs with banked up screes and boulder and sand strewn beaches.

Gunong Gebong and Gunong Sebuloh.

Low cliffs, screes and boulder strewn beaches.



Photograph showing some of the principle features due to marine erosion in the tanjong Datu area.

Gunong Angus.

A 70 ft. cliff developed on the southern face, fringed by a gently sloping beach to the south. The cliff is preserved on the other faces of the hill but the beaches are rudimentary and suggest that deep water flanked this hill when the cliffs were in the process of formation.

Gunong Tamin Menari.

Cliff faces fringed by rudimentary beaches at a similar height to those of G. Angus.

At Pulau Datu and along the southern Tg. Datu hills a beach is developed at about 75 ft. above mean sea level. This is represented by numerous old sand dunes flanking the western slopes of G. Gebong and G. Tamin Tungku and in west Paloh in Indonesia van Bemmelen reports similar raised beaches eight miles inland from the sea.

Associated with these levels of erosion old residual peneplaned or partially peneplaned land surfaces can be recognised. They occur at three levels and are generally a few feet higher than the corresponding marine erosion levels. The highest is at about 1,050 ft. to 1,100 ft. above mean sea level and is seen on Gunong Puting, Gunong Panggi (where the peneplanation is incomplete) and in the Sampadi hills to the east of the Batang Kayan.

On the flat surface of G. Panggi low hillocks rising about 20 ft. above the general level are separated by wide alluvium filled valleys in which beds of pebbles are found which are foreign to the area. These rounded and water worn pebbles of biotite quartzite and hornblende granite can be matched in the Gunong Puting and Gunong Batoe areas. (G. Panggi consists of slates). On Gunong Puting the weathered zone is deep whereas on Gunong Panggi it is shallow.

The next peneplaned surface is seen on the top of Gunong Serabang whcih according to the Admiralty chart is 750 ft. above sea level. It is a level weathered surface. It is also found outside our area on Bt. Meroyong and Bt. Snibong both of which occur to the south east of Lundu. The lowest level occurs at various levels ranging from 350 ft. on G. Tamin Menari to 250 ft. on P. Talang Talang.

The flat surface on G. Angus at 329 ft. above mean sea level is not part of the peneplaned surface as it consists of a wave swept rock platform.

It has been pointed out that on G. Gebong, three marine erosion levels are found. Thisn mountain contains a large deposit of bauxite whose tenor can be directly related to these levels and therefore provides striking confirmation of the rise of the old land surface. These are found to be as follows:-

Erosion level	Thickness of bauxite	% Al_2O_3	% SiO_2
Above 700 ft. level	16'	(63.0) ~~63.2~~	1.06
Below 700 ft. and above 300 ft.	9'	54	4.8
Below 300 ft.	6'	49	7.21

Since this ore has been derived from gabbro these figures can give an approximate estimate of the age of the levels. The gabbro contains approximately 15% Al_2O_3 and 54% silica. The silica content in stagnant water (analysis carried out at the Company's laboratory in Singapore) in pits on this site was 2.8 parts per million. To produce 16 ft. of ore averaging 63% Al_2O_3 requires that - 65 ft. of gabbro should have been decomposed. 54% of this is silica and to be removed at a concentration of 2.8 parts per million would require - 12.5×10^6 feet of water and at an average rainfall of 150 inches a year, this would require 1,000,000 years which according to Professor Arthur Holmes corresponds to the beginning of the Pleistocene which is when the old Sunda continent sank beneath the waves according to van Bemmelen (Ref. No. 7)

Similar arguments give ages of 460,000 and

260,000 years for the middle and lower erosion levels respectively. It is assumed that the formation of bauxite commenced as the sea retreated from the area and that a uniform rainfall has occurred throughout this time. The values given for the Al_2O_3 and SiO_2 contents for bauxite associated with the three levels are average for a large number of analyses from pits sunk on 200 ft. squares over the whole site.

Further evidence of relative uplift of the land surface is seen in the very deeply incised valleys of the headwaters of the rivers rising on the Pueh and Lundu mountains with their precipitous sides and boulder filled courses which have been referred to in the section on rivers.

This does not complete the evidence relating to recent land and sea movements as the distribution of marine sediments has to be taken into consideration. The interpretation of these results therefore will be left over until the unconsolidated sediments have been described.

PART IV

GEOLOGY.

SECTION 1.

Location of Exposures.

Unconsolidated deposits of marine and fluviatile origin cover all the low country with few exceptions to a height of about 50 ft. above mean sea level.

Unmetamorphosed sedimentary rocks chiefly grits, sandstones, conglomerates and breccias occur in the area north of Pueh and south of Tg. Limoh to t the Samunsam river and across the Indonesian frontier between G. Pueh and G. Puting. Breccias also form an outlier between Tg. Batu and G. Sebong.

Sandstones and grits form the mountains to the east of the Sampadi river.

Mudstones flanking gabbro are found in the vicinity of G. Angus, G. Tamin Menari and G. Tamin Tungku where they have been found in pits.

Slates and quartzites of flysch facies with coal in their upper horizons occur in the Tg. Datu peninsulafrom Telok Labuhan, G. Melanau, K. Temajok in the north to K. Samunsam and G. Chermai in the south. These rocks are affected by the Tg. Datu granite, only slightly in the G. Chermai area and increasing in intensity to the north.

Massive actinolite quartzites occur at Tg. Serabang, Tg. Sungai China, Tg. Limoh and in a few low hills just wouth of K. Samunsam and west of Tg. Limoh.

Biotite and actinolite quartzites occur

in the G. Puting, G. Jernang, G. Chermai area and biotite quartzites occur along the eastern foot-hills of the Pueh range as far south as Sebako. They also occur in the western foot-hills of the Lundu mountains between Selarat and Titi-akar, in the valley between G. Selarat and G. Gebong and at Tg. Batu and Tg. Hashim.

Crystalline schists are found in the Biawak, G. Nibong, G.Kallau area and in Ulu Samunsam. They are inferred at Sematan and in low hills to the east of G. Puting.

They also occur although altered subsequently to hornfelses to the south of Kuala Temajok on the Indonesian side of Tg. Datu.

Old hornblende and pyroxene granites are exposed at Tg. Pelandok, Tg. Pandan, G. Batoe (in Indonesia) and near Bt. Gebong.

Basic igneous rocks and amphibolites occur extensively at Tg. Pelandok, Tg. Pandan, Ulu Blungi Kechil, G. Angus, G. Tamin Menari and G. Tamin Tungku.

Younger biotite granodiorites and granites together with aplitic varieties form the Pueh mountains, the Lundu mountains and the northern part of the Tanjong Datu mountains. They also form a small stock in Ulu Samunsam.

SECTION 2.

Order of superposition.

The succession of sedimentary rocks and altered rocks is as follows in descending order.

6. Crystalline schists

unconformity.

5. Biotite and actinolite quartzites with thin intercalated indurated shales.

unconformity.

4. Conglomerates, slates, quartzites and coal measures

unconformity.

3. Sandstones, breccias, grits and mudstones.

unconformity.

2. Recent marine unconsolidated sediments.

1. Fluviatile alluvium.

The relations of the intrusions to each other is clear from the field evidence. There are two series of granites and an old basic series of gabbros and diorites.

The gabbros and diorites are intruded into the biotite quartzites and are of the same age as the hornblende and pyroxene granites of Tg. Pandan, Tg. Pelandok, Bt. Gebong and G. Batu. They may be slightly younger.

These hornblende granites are affected by the Tg. Datu, Pueh and Lundu granites and granodiorites and are consequently older than the latter.

The complete order of superposition as seen in the field is as follows:-

7. Crystalline schists.

unconformity.

6. Biotite and actinolite quartzites.

5. Intrusion of gabbro, diorite and hornblende and pyroxene granites.

4. Conglomerates, slates, quartzites, and coal measures.

3. Intrusion of biotite granites and granodiorites.

2. Breccias, grits, conglomerates, sandstones, mudstones and shales.

unconformity.

1. Quarternary marine and fluviatile alluvium.

In spite of extremely careful search no fossils have been found in this area at all except in Recent sediments and the ages given for these rocks in subsequent chapters are based on lithological comparisons with areas in Central and West Borneo described by C. P. A. Zeylmans van Emmichovena and Wing Easton respectively.

The rocks will be described in the following order:-

Crystalline schists.

Biotite and actinolite quartzites.

Conglomerates, slates, quartzites, coal measures.

Unmetamorphosed sedimentary rocks.

Unconsolidated sediments.

Igneous rocks.

SECTION 3.

Description of Rocks.

(a) Introduction. and metamorphism.

Before dealing with the petrological and stratigraphical description of the rocks in this area, an account of the various metamorphic phases and their relations to each other will be described.

In this area it has been possible to recognise four separate metamorphic phases.

They are:-

a. A regional metamorphism affecting rocks in the Biawak, Ulu Bentarang, Ulu Samunsam, G. Puting, Tanjong Datu, and Sematan areas.

b. An older dynamic metamorphism whose resultant structures trend along N-S axes and which was accompanied by intrusion of gabbro, diorite and pyroxene and hornblende granite thus introducing a thermal element into the metamorphism.

c. A younger dynamic metamorphism whose resultant structures trend generally N. 53°W - S. 53°E. and particularly well seen at Tanjong Datu.

d. A thermal metamorphism due to the intrusion of the Pueh, Lundu and Tanjong Datu granites.

Their relationship to each other is clearly seen in the field and in thin sections of the rocks and these are summarized below:-

The regional metamorphosed rocks is characterized by a clearly defined schistosity. In the Biawak area the gradual alteration of schist to hornfels can be traced towards the Pueh intrusion as it can be to the S. of Kuala Temajok near the Tg. Datu granite. van Bemmelen in his paper describes the alteration of actinolite into pyroxene in actinolite schist as a result of the action of the granite.

Specimen No. 35 (Geol. Survey No.S.687) from G. Nibong is a biotite muscovite schist in which the muscovite flakes are elongated in parallel bands whereas the biotite occurs as large porphyroblasts and is obviously of later origin than the muscovite. The biotite is younger than the muscovite and is due to the thermal metamorphism caused by the Pueh intrusion.

The regional metamorphism is therefore older than the thermal metamorphism due to the Pueh granodiorite.

The biotite quartzite into which the Pueh granite is intruded overlies the schists and shows not the slightest trace of regional metamorphism. Thin indurated shale bands interbedded with the quartzite show that the latter is folded along N-S axes. This folding can be recognised in Tanjong Limoh and Tanjong Serabang in actinolite quartzites where a false or second cleavage trending approximately N.53°W - S.53°E. is superimposed on this folding.

The two dynamic metamorphisms are therefore younger than the regional metamorphism and the N-S dynamic metamorphism is older than the N.53°W - S.53°E. one. This last metamorphism is found to affect the following igneous intrusions; Gabbro and diorite at Gunong Angus and Tamin Menari and hornblende granite at G. Batoe. It does not affect the Tanjong Datu, Pueh or Lundu granites. At G. Tamin Menari, sheared gabbro is altered into an amphibole plagioclase rock with gradual destruction of all cataclastic textures due to this metamorphism as the granodiorite is approached. The slates at Tanjong Datu have suffered recrystallization and destruction of cataclastic textures as the granite is approached.

The Tanjong Datu granite and the Pueh granodiorite, (and in view of petrological similarity the Lundu granodiorite as well) are later than the younger dynamic metamorphism.

The Gunong Batoe granite is severely affected by this metamorphism and hence must be older. It is intruded into basic rocks of igneous composition and biotite and actinolite quartzites and hence must be younger than the quartzites.

The extremely hap-hazard distribution of gabbro, diorite, pyroxene and hornblende granites in the intrusions at Tg. Pelandok, Tg. Pandan and G. Angus suggest that these rocks were intruded during a period of orogenic stress (Harker 1932 p. 330).

Therefore the metamorphic phases can be classified as follows in decreasing order of age.

(4) Regional metamorphism.

(3) A dynamic-cum-thermal metamorphism.

(2) Dynamic metamorphism.

(1) Thermal metamorphism

Nos. 4, 3 and 2 affect rocks in the Schwaner mountains, Kembajang mountains and the Mengkiang area of W. Borneo where Zeylmans van Emmichoven has shown that (4) is pre-Permian and Carboniferous, (3) is post-Permian and pre-Upper Triassic and (2) is post Upper Triassic. He bases these age determinations on fossil collections. From field relations it can be shown that (1) is pre-Tertiary and post Upper Triassic.

(b) Regionally metamorphosed rocks.

Crystalline schists.

Location.

These rocks are exposed in the Biawak-Sungai Pasir- G. Kaliau - Bt. Nibong area where they have been deeply weathered; in Ulu Samunsam; in Ulu Benterang; in Indonesia, and in the South of the S. Temajok on the west coast of Tg. Datu. Residual schistosity in laterites and bauxites to the east of G. Puting and to the west of Sematan at Munggu Belian, suggests that schists form the bed rock in both these areas.

Description.

(a) Biawak area.

From Sungai Pasir to Biawak and across the Indonesian frontier to Soengai Radja and north of Biawak to Bt. Nibong a series of schists occur which are severely affected by weathering and it is hard to find specimens in a fresh enough state of preservation to enable an accurate picture to be drawn. In general chlorite-quartz schists occur to the east of Biawak, quartz-mica schists to the west of Biawak and in the frontier area hornblende schists and staurolite mica schists are known. As these rocks are traced towards the Pueh range considerable alteration has taken place and hornfels have been formed. Biotite-cordierite-quartz hornfels and andalusite biotite hornfels have been noted.

In the following section, the results of a microscopic examination of these rocks are set out and descriptions of specimens from the Geological Museum Collection at Bandoeng from the Indonesian side of the frontier are quoted from van Bemmelen's paper (Ref.2). A full set of specimenscollected by the author of this thesis has been presented to the Geological Survey in

Kuching and the specimen numbers are prefixed by the letter S. The specimens from Bandoeng are prefixed by the letter P. Numbers without a prefix refer to slides in the author's collection.

Details.

No.	Locality and rock	Description.
35 (S 687)	Bt. Nibong, 800 ft. N.E. of Kg. Pasir. Muscovite biotite schist showing alteration due to later contact metamorphism.	Hand specimen is a greyish schistose rock with plates of mica. The thin section shows the rock to consist of fine angular crystalline quartz with elongated laths of muscovite and porphyroblasts of biotite, Iron oxides occur as accessory.
36 (S 688)	200 yds west of Biawak in a tributary of the S. Biawak.	Hand specimen is a greyish green medium to fine grained schistose rock with visible bands of quar quartz. Under the microscope the rock shows laths of hornblende, recrystallized quartz; plagioclase grains and iron oxides.
37 (S 689)	Gunong Kaliau. Muscovite quartz gneiss.	Fine grained reddish schistose rock with visible mica Thin section shows grains of muscovite concentrated into bands alternating with bands of quartz. Red brown limonite is distributed throughout.
59 (s 711)	2 miles east of Biawak. Graphitic quartz schist.	Hand specimen is a markedly schistose fine grained rock. Thin sections shows rock to be composed of quartz grains with finely disseminated graphitic material.

No.	Locality and Rock.	Description.
38 (S 710)	Bt. Pantak Kechil to the east of Kg. Biawak. Chlorite quartz schist.	Hand specimen is a dark blue fine grained schistose rock with flakes of a micaceous mineral. Thin section shows the rock to consist dominantly of a dark grey micaceous mineral of very low birefringence identified as penninite and fine grains of quartz. A quartz chlorite vein crosses the section and the chlorite shows incipient weathering to limonite
20 P	Gunong Kaliau	van Bemmelen describes this specimen as a staurolite muscovite biotite quartz schist. Biotite porphyroblasts are extensively weathered to limonite giving the rock a brown colour.
5, 6, 7 P	S. Aping near S. Radja	van Bemmelen describes these specimens as actinolite schists in which the actinolite shows stages in the alteration to pyroxene as a result of metamorphism by the Pueh graniodiorite

In addition to the above specimens, dark muscovite biotite quartz schist has been identified from three small hills N. of S.Pasir (Specimens 150, 151 and 152); purple muscovite-biotite-felspar schist (160) from a small stream to the south of Biawak; plagioclase muscovite quartz schist 900 ft. north of Bt. Nibong near Biawak; greenish black hornblende quartz schist from G. Kaliau and weathered quartz schist containing kaolin from which the presence of felspar is deduced from the same locality.

From the flanks of G. Nibong a biotite cordierite quartz hornfels (166) appears to be the thermally metamorphosed equivalent of these schists.

Degree of metamorphism.

From the few specimens found the direction of increasing metamorphism is undoubtedly from east to west, chlorite quartz schists occurring in the Sungai Pasir area, mica quartz schists between S. Pasir and Biawak and the higher grades represented on G. Kaliau by staurolite-and hornblende mica felspar schists.

It would appear that these rocks prior to metamorphism were siliceous shales mudstones and sandstones incorporating a fair quantity of argillaceous matter. and occasionally calcareous and magnesian compounds.

(b) Ulu Samunsam and Ulu Bentarang.

In the headwaters of the Sungai Benterang in Indonesia muscovite quartz schist, muscovite-biotite-quartz schist and actinolite schist have been found. Similar rocks have been discovered in Ulu Samunsam where the river has cut through the overlying sandstones and quartzites into the basement schists.

(c) Tanjong Datu.

To the south of Kuala Temajok biotite-cordierite hornfels is found which when traced to the south shows a poorly defined schistosity as the grade of thermal metamorphism decreases. This would suggest that the hornfels is derived from schist.

(d) Sematan and small hills to the east of G. Puting.

At Sematan schist is inferred to be the bed-rock underlying the bauxite deposit at Mgu Belian, the reason for this assumption being that 45 ft. and more below the surface a marked schistosity becomes apparent in the boulders of semi-consolidated kaolinitic bauxite. The presence of kaolin in quantity suggests a felspathic or muscovite schist.

In the small hills lying to the east of G. Puting, a similar schistosity in laterites although at only 8 ft. depth, suggests that schists form the bed-rock here.

Regional distribution of these schists in Borneo.

These crystalline schists are found generally throughout Borneo where they form the basement rocks of the island.

Age of the crystalline schists.

No direct evidence as to the age of these rocks has been found in the Sematan area.

In the Kembajang and Middle Mengkiang area of Central Borneo, Zeylmans van Emmichoven has shown that they are pre-Permain and Carboniferous.

He bases this on the discovery of Fusulina and other Permain and Carbonferous fossils found by Krekeler in 1932 and 1933 (Ref. 9 and 10) determined by Zeylmans van Emmichoven and verified by Tan Sin Hok in limestones and marbles intercalated with cherts, quartzites and shales which overlie the schists.

In eastern Borneo in the Telen area M. G. Rutten discovered Devonian fossils in similar schists. They were Clathrodiction cf. spatiosum Boehnke and Haliolites porosus Goldfuss. These are LowereDevonian in age.

It would appear then that the schists were deposited during early Devonian times and the regional metamorphism is probably Devonian or early Carboniferous in age.

(c) Quartzites.

These rocks are more widely distributed in our area. They are found flanking the Lundu 'massif' to the North, West, and South, flanking the Pueh range to the East and form the Gunong Puting range from, but excluding, G. Tampe to G. Chermai. They also outcrop at Tg. Limoh and in hills 1 mile to the west thereof and are exposed at Tg. S. China and Tg. Serabang.

They are in general fine to medium grained massive rocks with intercalated thin indurated shales, the presence of the latter enabling the structure to be determined in places. The presence of actinolite in any quantity gives the rocks a darkish green colour.

Microscopically these rocks consist of medium to fine grained recrystallized quartz with biotite or actinolite. Schistose conglomerates form the base of the series in Ulu Samunsam where an exposure of this conglomerate occurs followed up-stream by outcrops of mica schist. This occurrence is $1\frac{3}{4}$ miles up-stream from the ford of the Pueh-Sambas track over the S. Samunsam.

In outcrops which are not too close to the Pueh Lundu and Tg. Datu intrusions, a false cleavage is superimposed on the folding which these rocks have undergone, the former forming an angle of $\pm 50^{\circ}$ with the latter.

These rocks are extensively pierced by quartz veins, generally carrying haematite in the northern exposures and in the Selarat-Seddmak-Tg. Batu- Tg.Hashim areas, fluorspar, pyrites, arsenopyrites and stibnite.

i Details of exposures.

(1) Northern Area, North of Kuala Samunsam.

No.	Locality and Rock.	Description.
13 (S.665)	Small cape 400 yds. N. of Tg. Serabang. Actinolite quartzite.	A hard sheared and intensely slicken-sided fine grained green rock with an angular fracture.

No.	Locality and Rock.	Description.
13 (S.665)	Actinolite quartzite.	Thin section shows rock to be essentially composed of actinolite in laths needles and grains in a fine grained ground mass of brecciated quartz which has partly recrystallized. Calcite and pyrites are accessory. Section shows poorly developed banding due to grain size and wisps of a fine vrownish material possibly limonite.
14 (S.666)	Southern end of Telok Melanau Actinolite quartzite.	Hand specimen as above. Section shows brecciated fragments of quartz which has undergone partial recrystallization in a ground mass of very fine acicular actinolite with a little chlorite. Iron oxides occur as accessories
15 (S.667)	Near S. Melanau Actinolite quartzite.	Hand specimen as above except that greenish colour is not so pronounced. Thin section shows brecciated partly recrystallized quartz grains in a ground mass of laths and needles of actinolite. Iron oxides and calcite are accessory.
16 (S.668)	50 yds. north of specimen 15. Actinolite quartzite.	Description as for S.667, except that the propostion of quartz is greater than that of actinolite.

Slides Nos. 17 & 18 (S.669 & 670) show exactly similar composition.

ii. Gunong Puting range and Ulu Samunsam.

Exposures on these mountains are few and far between. The weathered rock has been identified in pits sunk along this range.

No.	Locality and Rock.	Description.
1 (S.651)	Munggu Jernang. Actinolite quartzite.	Hand specimen is a dark fine grained rock with barely visible crystals of quartz. The microscope shows fine grained quartz showing weak undulose extinction, with actinolite and iron oxide disseminated throughout.
3 (S.653)	Summit of Mgu Jernang. Biotite quartzite.	Hand specimen is a fine grained grey rock with visible crystals of quartz. The thin section shows fine angular grains with biotite flakes disseminated throughout.
4 (S.654)	30 yds. N.35°W of summit of Mgu Jernang. Banded quartzite.	Hand specimen as No. 3. Section shows cryptocrystalline quartz with small irregular quartz veins. A very fine opaque material is disseminated throughout and condensed occasionally into streaks with a marked parallelism. This is probably graphite.
2 (S.652)	Gunong Puting 400 ft. 35°E of S. from summit.	Hand specimen is dark grey fine grained rock.

No.	Locality and Rock	Description.
2 (S.652) contd.	Biotite quartzite.	Thin section shows fine angular quartz grains in a crypto-crystalline siliceous matrix and longish biotite flakes disseminated throughout
5 (S.655)	Günong Puting 600 ft. 35°W of N. from summit in headwaters of the Ayer Putch.	As for slide No. 2 (S.652)
10 (S.660)	Ulu Samunsam, $1\frac{3}{4}$ miles upstream from ford of Pueh-Sambas track over the S. Samunsam. Conglomeratic actinolite quartzite.	Hand specimen is a markedly banded rock with elongated and fractured pebbles. The thin section shows fine recrystallized quartz with finely divided actinolite and patchy grey staining. Areas of recrystallized quartz represent altered pebbles.
13 (S.663)	5,700 ft. due East of junction of Pueh Sambas track with the Samunsam river and exposed in the S. Pakeh.	Hand specimen in a fine grained grey quartzite rock This section shows recrystallized quartz with actinolite laths.

Specimens from G. Puting and Munggu Jernang are pierced by veins containing quartz, tourmaline and epidote.

Specimen No.10 (S.660) from its field relations appears to be the base of the quartzite series in this area as it is followed a few yards upstream by mica schist. Exposures are so rare in this area that it is impossible to get a clear picture of the succession.

It should be pointed out that actinolite reaches its greatest distribution in these rocks in the Tanjong Serabang area and progressively decreases towards the south. It has not been found to occur in quartzite south of the Samunsam river.

iii. Eastern foothills of the Pueh range.

Biotite quartzites are exposed in a narrow band from S. Tekerong to the Sebako river. They are best seen in the headwaters of the S. Sebat Besar, the S. Sebat Kechil, the S. Tembagu and the S. Teput. They are intruded by biotite granodiorite and the contact where seen is razor sharp. (e.g., specimen No.39 (S.691). These rocks are remarkably constant in composition being medium grained grey biotite quartzites.

Localities of the specimens described below run from North to South.

No.	Locality and Rock.	Description.
40 (S.692)	Bukit Tegorak between Pueh and Sebat.	Hand specimen is a grey fine grained quartzitic rock. The microscope shows it to consist predominantly of micro-crystalline quartz with patches of coarser grained quartz, and fine flakes of biotite disseminated evenly throughout the slide.

No.	Locality and Rock.	Description.
39 (S. 691)	Ulu Sebat Kechil Foothills of G. Sebat in S. bank of the stream. Biotite quartzite in contact with granodiorite.	Grey medium grained quartzite rock. Thin section shows well developed crystalline quartz and flakes of biotite. Some of the larger quartz crystals contain inclusions of biotite and iron oxides. The granodiorite contains andesine, quartz and biotite and the contact is very sharp.
66 (S. 718)	Headwaters of S. Sebat Besar 100 ft. b from granite contact Muscovite chlorite pyroxene quartzite.	Hand specimen is a dark fine grained quartzite rock with visible pyrites crystals disseminated through the rock. The slide under the microscope shows recrystallized quartz with a little muscovite chlorite , pyroxene and pyrites.
64 (S.716)	23,000 ft. south of junction of EPL track with Pueh river. Specimen is from a thin indurated shale band. Biotite muscovite cordierite quartz hornfels.	Hand specimen is a very dark fine grained poorly laminate mica. The thin section shows the rock to consist of anhedral cordierite enclosed quartz in some cases large flakes of biotite, muscovite and recrystallized quartz. Iron oxide also occurs.

All these rocks show the effects of a high grade of thermal metamorphism. Indurated shale bands are common and where they have been examined under the microscope, have the constitutionand texture of a low grade hornfels in that the lamination is poorly preserved and not entirely destroyed.

iv. Quartzites in the Lundu 'massif'.

These rocks are entirely similar to those described from the Pueh range except that they are of wider distribution. They occur from Selarat to Sedemak in the south and in the valley between G. Selarat and G. Gebong then run northwards to Tg. Batu and are exposed again between Tg. Hashim and Tg. Pelandok where thin hornfels bands are common. The quartz is in various stages of recrystallization netween Selarat and Sedemak and completely recrystallized in the other localities. Specimen 43 (S.695) is described in detail below and is typical of 10 other quartzites examined.

No.	Locality and Rock.	Description.
43 (S.695)	Near Survey peg 1,123 Kg. Sebiris Banded biotite quartzite.	Fine grained very dark grey quartzite. The microscope shows the rock to consist of fine quartz grains with biotite laths exhibiting a marked parallel elongation. The quartz is partially recrystallised.
67 (S.719)	Bukit Tagun, near Serayan. A thin indurated shale band.	The rock in hand specimen is a fine grained siliceous dark grey compact rock. Under the microscope it shows patches of recrystallized quartz in a fine grained matrix of biotite, muscovite and iron oxides.

From the valley between G.mSelarat and G. Gebong eight specimens of completely recrystallized biotite quartzite were examined.

From Tg. Batu three specimens of partially recrystallized biotite quartzite were identified under the microscope and four specimens from Tg. Hashim. From the latter locality andalusite quartz hornfels, biotite cordierite quartz hornfels, and one specimen of chiastolite biotite quartz hornfels were identified.

These rocks appear to have been laid down as thick sandstones with a small proportion of argillaceous matter intercalated with thin siliceous shales. In the area north of Pueh cchloritic and calcareous sandstones would appear to be the parent rock.

v. Age of Quartzites

No fossils have been found in these rocks. An exactly similar stratigraphical scheme for the older rocks has been described by Zeylmans van Emmichoven from the Kembajang mountains and the Middle Mengkiang area where an intercolated limestone facies has yielded fossils, notably Fusulina, which demonstrate that these rocks are of Permian and Carboniferous age. In view of the stratigraphical and metamorphic resemblances between the Sematan and Kembajang Mts. areas, these rocks will be classified into the Permian and Carboniferous.

(d) Slatey conglomerates, slates, quartzites, with coal measures.

These rocks are exposed between G. Chermai and

G. Melanau in Tanjong Datu, along the coast of which, magnificent exposures occur. They are found in Indonesia near the S. Chamar Boelan from where they have been described by van Bemmelen as possibly Cretaceous in age. During a visit to this area, the author found that these rocks bore a very close resemblance to the basal slatey conglomerates of Tg. Serabang (which van Bemmelen classifies into the Permian and Carboniferous systems.) In view of their close resemblance the rocks of S. Chamar Boelan will be considered to be the equivalent to those at Tg. Serabang for the purpose of this thesis.

From north to south these rocks are affected by a decreasing grade of thermal metamorphism. In the Gunong Chermai area they are represented by dark blue graphitic phyllites and further north by siliceous graphitic slates and quartzites till eventually near Tg. Datu granite they are homogenous tough quartzites with a total destruction of all cataclastic textures and structures. About 400 ft. from the granite these rocks have a pronounced gneissic banding. These rocks are not known South of the Samunsam river and at Kuala Samunsam they are faulted up against actinolite quartzites by a large fault down throwing to the North. From its trend this fault is believed to be Tertiary in age.

Coal measures occur in the upper horizons of this series in the Ulu Sungei China area where there have unfortunately been considerably affected by thermal metamorphism.

North of Tg. Pinang the succession is as follows:-

3 Alternating slates and quartzites.

2.Siliceous slates -200

1.Siliceous slatey conglomerate -600

To the south of Tanjong Nyawang the succession is as follows:-

5. Coal measures.

4. Cleaved carbonaceous slates, mudstones and quartzites.

3. Interbedded siliceous slates and quartzites.

2. Siliceous slates.

1. Siliceous conglomerates.

The degree of folding and faulting makes any estimate of the thickness of these strata merely an erratic guess.

The slates are generally true slates in that the fissility in members where recrystallization of quartz is not general is due to the development of flakey minerals chiefly chlorite and sericite. A second cleavage due to the development of numerous parallel planes of slickensiding in the fine grained rocks is responsible for the major part of the fissility. As the Tg. Datu granodiorite is approached, recrystallisation of the rock has led to a total destruction of the fissility.

Extensive new mineral development has occurred along the fracture planes in slates exposed in pits sunk on G. Panggi, chiefly chlorite, sericite and carbonaceous matter, presumably graphite. Small veins of quartz, calcite and pyroxene have been intruded along some of the fracture planes, the minerals in these veins showing no sign of strain and appear to be younger therefore than the dynamic metamorphism. The rocks seen in pits at G. Panggi are highly imbricated.

The basal slatey conglomerates overlie green actinolite quartzites at Tanjong Serabang with pronounced unconformity, the junction at the southern end of Talok Serabang being a faulted one in which it is estimated that 200 ft. of the conglomerate have been faulted out. The conglomerates consist of large fractured boulders of quartzite elongated in a direction 50°W of N.- 50°E of S. in a fine slatey siliceous groundmass.

At Soengai Chamar Boelan the lowest beds of the basal conglomerate were not seen.

The slates which overlie the conglomerates are uniform fine grained dark rocks, intensely slicken sided along close parallel planes giving the rock a characteristic appearance. The intercalated quartzites and slates appear to be developed to a tremendous thickness but this apparent effect may be due to the repeated isoclinal folding.

The quartzite beds are highly fractured and range from grey to yellow medium to fine grained rocks.

The average thickness for over 300 counted and measured beds of quartzite was 1.7 inches, the intervening slates averaged 1.8 inches. These beds ranged in thickness from ¼ inch to over 3 ft.6 inches.

The cleaved carbonaceous mudstones were exposed in four pits on G. Panggi and as stated before, the fracture planes contain chlorite and carbonaceous matter developed along them. They tend, unlike the slates, to have an angular fracture.

The coal bearing strata lie to the south of Gunong Panggi and between this mountain and the hills in Ulu Sungei China. They are not exposed to any extent and a thin coal was seen in a pit sunk on the most northerly of the S. China hills and another coal occurs in the left hand branch of the S. China. Numerous bits of iron slag in this area suggest that previously coal was worked here possibly in conjunction with the iron deposits at Likoe in Paloh round about 1820, when the Sultan of Sambas issued a licence to a Chinese "kongsi" to work the iron.

<u>Details</u>.

An extensive collection has been made of rocks from this area. They will be described in two parts. (a) Area N. of Tanjong Serabang and (b) area S. of Tg. Serabang.

(a) Area north of Tg. Serabang.

(1) Slatey conglomerates.

These are exposed on Tg. Pinang which is 300 yds. north of the headman's house at Kg. Melanau and consist of large pebbles and boulders of quartzite and actinolite quartzite sporadically distributed in siliceous slate.

The pebbles and boulders are lenticular in shape and are severely crushed and fractured.

The slatey part of the rock is represented by the following three specimens:-

No.	Locality and Rock.	Description.
21 (S.673)	350 yds. north of headman's house in Kg. Melanan. Biotite sericite slate.	Grey fine grained slicken sided slate in H.S. Thin section shows biotite bordered quartz stringers in a very fine grained groundmass of sericite and microcrystalline quartz. The sericite flakes show marked orientation.
20 (S.672)	50 yds. south of Tg. Pinang. Muscovite-biotite quartz slate.	Hand specimen is a dark grey to bluish black fine grained fissile rock. Under the microscope it consists of fime angular quartz grains set in a matrix of biotite, muscovite and cryptocrystalline quartz. A marked banding is due to the parallelism of biotite flakes and graphitic material.

No.	Locality and Rock.	Description.
22 (S.674)	Tg. Melanau Graphitic biotite sericite slate.	Greyish black slate in hand specimen. Description of thin section as for No. 21 except t that graphitic material is more prominent.

The boulders in the conglomerate are represented by Specimen 93 (S.745) which is an actinolite quartzite and specimens 23 (S.675) and 25 (S.677).

No.	Locality and Rock.	Description.
23 (S.675)	Location as for 22. Biotite sericite quartzite.	Hand specimen is a dark medium to fine grained siliceous rock speckled with pyrites. The microscope shows the rock to consist of fine grained quartz with a little sericite and biotite in a cryptocrystalline matrix of quartz. Graphitic streaks occur and pyrites is common.
25 (S.677)	Tg. Pinang	Hand specimen as above. Thin section shows fine angula quartz grains with shreds and aggregates of a brown pleochrois ferro magnesian mineral probably biotite in a siliceous matrix. A few crystals of plagioclase and zircon were noted and iron oxides occur in patches throughout.

Slates.

These are well exposed on Tanjong Stimeh where they are fissile, indurated, dark, highly slickensided, fine grained rocks. They are represented by Specimen 102 (S.1204) and 106 (S.1208).

No.	Locality and Rock.	Description.
102 (S.1204)	Tg. Stimeh. Slate with secondary biotite.	Dark grey fissile very fine grained rock. Thin section shows the rock to consist of very fine partially recrystallized quartz and fine biotite flakes. Second or false sleavage is well developed in the section and biotite flakes can be seen lying across the folding thus indicating that the biotite is later than the dynamic metamorphism.
106 (S.1208)	Tg. Stimeh.	Hand specimen is a dark grey fissile fine grained rock containing quartz veins. The thin section shows the rock to consist of fine grained partially recrystallized quartz with flakes of biotite along fissile planes and secondary plates of biotite, developed as well.

These two slides show mica in two generations and regeneration of quartz and commencement of destruction of the planes of fissility and cleavage.

Alternating thin slates and quartzites.

The quartzites show extreme crushing and fracturing The fissility in the slates becomes less marked and in the area of S. of Tanjong Labuhan, they already begin to resemble dark compact quartzites.

No.	Locality and Rock.	Description.
87 (S.749)	Quartzite bed from Telok Jinsiang. Quartzite.	The hand specimen is a grey fine grained rock cut by a quartz calcite vein carrying pyrites. Under the microscope the rock consists of recrystallized quartz and the vein contains quartz, calcite chlorite, pyroxene and pyrites.
104	Slate bed from Telok Jinsiang. Biotite slate.	Hand specimen is a fine grained rock with fissility less pronounced than the previously described slates. Thin section consists of partially recrystallized quartz and biotite in a ground mass of quartz and fine biotite flakes.

At Tg. Labuhan, a magnificent exposure of a thrust fault occurs. At this locality the slates and quartzites have formed a generally homogenous and compact rock. Reconstitution of the rock as a result of the close proximity of the Tg. Datu granite has destroyed most of the cataclastic and crushing structures due to the thrust. Garnet makes its appearance here. (Sp.108 or S.1210)

No.	Locality and Rock.	Description.
S.1214.	N. end of Tg. Labuhan.	Hand specimen is a greyish green medium grained crystalline rock with some fracture at surface showing crystals of pyrites. In thin section the rock consists of crystals of quartz and felspar (albite) in a matrix of fine crystallized quartz and biotite flakes

No.	Locality and Rock	Description.
S 1210.	Tg. Labuhan Garnet quartzite.	Hand specimen is a hard grey green fine grained rock. The thin section shows fine grained quartz, garnet and diopside.

In the immediate vicinity of the Tg. Datu granite these rocks assume a pronounced gneissic banding.

No.	Locality and Rock.	Description.
100 (S.1202)	40 yds. S.E of granite contact. Kuala Labuhan.	Hand specimen is a mottled grey fine grained fissile rock with pronounced banding. Thin section shows bands of cryptocrystalline quartz alternating with bands of microcrystalline chlorites and granules of iron oxide are distributed throughout the section.
111 (S.1213)	40 yds. S. of Kuala Labuhan. Cordierite-biotite quartz gneiss.	Hand specimen is a rock with alternate fine and medium grained bands. The thin section shows that the rock is composed of bands of cordierite porphydroblasts in a fine grained quartz matrix and biotite.

(b) Area south of Tanjong Serabang.

Slatey conglomerates.

This exposure forms the southern limb of a fold, the core of which exposes the older actinolite quartzites of Tanjong Serabang. As a result of a parallel system of step faults at Tanjong Nyawang, these conglomerates are thrown up against slates to the north which in turn are faulted up against actinolite quartzites.

The slatey conglomerate shows exactly similar microscopic features as that to the north of Tanjong Serabang. The pebbles and boulders are represented by specimens 28 (S.680) and 30 (S.682) which are identical.

No.	Locality and Rock.	Description.
30 (S.682)	Boulder component of slatey conglomerate at Tg. Nyawang. Calcareous muscovite quartzite.	Hand specimen is a grey medium grained rock with abundant visible quartz. Under the microscope it consists of angular quartz grains in a siliceous matrix which contains calcite, muscovite and iron oxide.
28 (S.680)	As previous.	

The slatey component is represented by specimens 26 (S.678) which is a fissile siliceous slate and 29 (S.681) which is a black fissile siliceous slate.

No.	Locality and Roak.	Description.
29 (S.681)	Slatey component of slatey conglomerate at Tg. Nyawang. Biotite sericite quartz slate.	Hand specimen is a greyish black slate, the thin section of which shows quartz bordered by biotite in a fine grained matrix of sericite and quartz. The sericite shows a pronounced parallel orientation.
26 (S.678)	Slatey compnnent of slatey conglomerate at Tanjong Nyawang. S iliceous sericite slate.	Hand specimen is a soft light green siliceous rock. Microsection shows fine angular grains in a crystalline groundmass of quartz and sericite.

The siliceous slates as a result of the faulting mentioned above and the normal succession are exposed on both sides of the slatey conglomerates. To the south they are faulted down against actinolite quartzite at Kuala Sungai China. To the south of the actinolite quartzite here, carbonaceous slates are thrown down against the quartzites by a very considerable fault down throwing to the south.

The slates in the north of the fault at Tg. Nyawang are represented by (S.679)

No.	Locality and Rock.	Description.
27 (S.679)	North of fault at Tg. Nyawang. Biotite sericite slate.	In hand specimen the rock is a black fine grained fissile slate. In thin section it shows microcrystalline quartz with pyrites finely disseminated throughout. A marked fine banding is present and abundant sericite flakes oriented parallel to this banding are noted. Fine quartz stringers with wisps of biotite are also present. Bands of a black substance which is presumably graphite also occur.

The alternating slates and quartzites are not exposed along the coast but were penetrated in pits sunk in the hills to the south of the southern tributary of the S. China. No specimens were taken from here as they were poorly preserved.

The alternating carbonaceous shales and quartzites are well exposed on the coast between Tg. Batok and Tg. Badak and Tg.Batok. At Tanjong Badak and to the south a zone of disturbance occurs in which numerous small faults trending N.W. - S. E. are penetrated by large quartz veins carrying haematite, these veins and faults being crossed by a system of barren younger faults trending S.W. - N.E. which displace the older faults and are associated with the large Samunsam fault.

The carbonaceous slates are represented by specimen 31 (S.683) which in hand specimen appears to be a black slate and under the microscope is a graphitic fissile mudstone, the fissility being due to a pronounced false cleavage. Specimen 32 (S.684) is a metamorphosed siliceous grit in which large fractured angular quartz grains showing undulose extinctionoccur in a fine siliceous groundmass.

On the northern slopes of G. Chermai and in a few pits sunk on low hills to the north-west and north-east thereof pits penetrated graphitic bluish black phyllitic mudstones and in a small river flowing off G. Chermai a comglomerate sandstone in which the pebbles are severely fractured is found.

This rock under the microscope was found to consist of quartz grains, muscovite and biotite fragments in a very fine matrix of siliceous nature. The pebbles were quartzite containing biotite. The crystals of quartz showed considerable fracturing and undulose extinction. This rock is presumably the base of the series in this area.

From the aoast to the west of the S. Charman Boelan in Indonesia similar conglomeratic sandstones were found in which the shattered pebbles consisted of biotite and actinolite quartzite and chert. This rock differed from the conglomerate on G. Chermai in that the component pebbles form a higher proportion of the rock. Chlorite and Sericite were identified in the silic-eous groundmass.

These rocks have been severely folded along approximately N.W. - S.E. axes and tend to be overfolded to the S.W. This together with the evidence of the large thrust seen at Tg. Labuhan shows that the tectonic forses responsible for the dynamic metamorphism were directed from the S.E.

The relatively narrow elongated basin in which these rocks have been deposited together with the rapid alternation of quartzite and graphitic slate suggest that the lower and middle members of the series were deposited in a delta which eventually silted up and the carbonaceous sands, silts, muds and the coal measures of the upper series were deposited in fresh water under swampy conditions

Age of these Rocks.

No direct evidence for the age of these rocks has been obtained. However, on the basis of comparison with the Sambas area described by Wing Easton and the Kuching and Central Borneo area described by Zeylmans van Emmichoven these rocks are correlated into the Upper Trias and Jurassic systems. According to the latter, graphitic blue phyllite found near G. Chermai is found in Central Borneo and in the Sadong area of the 1st Division where they are associated with Monotis Sp. and Halobia (determined by Gerth, Krekeler, and von Koenigswald) which proves their Upper Triassic age. Zeylmans van Emmichoven reports that this graphitic phyllite is characteristic of the Upper Trias in Borneo and has never been found outside the system. This would suggest that the rocks of G. Chermai are Upper Triassic in age. Further confirmation of this Upper Triassic age is obtained by comparing the metamorphic phases in this area with those of Central Borneo. In both areas a regional metamorphism and an older and younger dynamic metamorphism are found. The younger which affects these rocks in the Tanjong Datu area has been shown in Central Borneo to be post Upper Triassic and the older one is post Permian and Carboniferous. The older metamorphism does not affect the Tanjong Datu slates etc., hence they must be Upper post Permian in age since the slates are affected by the younger they are most likely to be Upper Triassic in age.

Wing Easton in his description of the geology of the Sambas district proved conclusively that during Jurassic times, the sea which covered that part of Borneo was retreating to the west.

He bases his determination of the Jurassic age of the revelant rocks in the Sepang-Loemar area on the discovery of Protocardia, Exelissa and Perisphinctes Waag (determined by Martin in 1895) and the determination of Protocardia and Exelissa by Vogel (1888-1899). From the S.Naning, between Sepang and Loemar Wing Easton also reported Harpoceras radians Rein. after Hamg.

From the Ban Pin San area, van Dyk reported a new species of Aegoceras determined by Krause and named A.borneense by him. The Dutch geologists suggest that these fossils are Lower Liassic in age.

In Sambas, therefore, the marine Jurassic stretched as far north as Ban Pin San and only as far as Loemar to the East. It is clear that during late Jurassic and possibly during early Cretaceous times a general uplift of our part of Borneo took place.

The strata from the upper horizon of the Tanjong Datu slates etc., are fresh water and deltaic in nature (witness the occurence of coal measures) and it is possible that they may be the equivalent in time of the marine Jurassic strata in Sambas. That being so, this would suggest that the lower part of the series is Upper Triassic in age and that the upper part of the series is Lower Jurassic or Lias. Krause places Wing Easton's strata in the Upper Lias on the grounds of van Dyk's discovery of Aegoceras.

It would appear then that the strata dealt with in this section are of Upper Triassic to Lower Jurassic in age. This being so, it gives at least an Upper Jurassic to Lower Cretaceous age to the Tanjong Datu granodiorite which gives it the same age as the Malayan granites.

UNMETAMORPHOSED CONSOLIDATED ROCKS.

(a) General.

These rocks occur in three areas and in two facies. They occur in a sandy arenaceous-rudaceous facies in the area North of Pueh as far North as the S. Badaun and West between G. Puting and G. Pueh across into Indonesia and also in the area to the East of the Sungai Sampadi. The rocks of argillaceous facies occur as isolated erosional relics banked up against the intrusion of G. Angus, G. Tamin Menari and G. Tamin Tungku in the Serayan-Sebako valley.

These rocks transgress the Pueh granite on the northern slopes of the mountain and the mudstones transgress amphibolite, gabbro and diorite in the three basic intrusions in the Sebako-Serayan valley without the slightest trace of metamorphism. They are generally only slightly faulted. The arenaceous facies is in general brightly coloured.

It should be mentioned that the last mentioned rocks support a very characteristic and rather stunted flora which makes the mapping of the rocks a fairly simple process as the change in nature of the vegetation on crossing from granite or quartzite to these sandstones is abrupt, spectacular and easily recognizable. In particular a thorny palm known locally as 'Kechatau' and a species of casuarina tree, known locally as 'ambun' are entirely characteristic.

(1) Arenaceous facies.

(a) Area north of Pueh and the Pueh range.

These rocks are well exposed at Tanjong Blinsah and in the headwaters of the S. Bakuching, S. Blimsah, S. Bedaun, the S. Pakeh and the numerous unnamed streams flowing off the eastern slopes of G. Tampe and Gunong Kechatau. In general they are highly coloured felspathic and quartzose grits, conglomerates and sandstones with breccias developed at the base of the series near G. Pueh, G. Puting and in the G. Bedaun area. The conglomerates range from sandstones to grits with angular to egg-shaped pebbles. These beds in the lower series contain pebbles of quartzite and granite in the Pueh area, quartzite in the G. Tampe area and fragments of actinolite quartzite in the G. Bedaun area occasionally give the rock a green colour. In the higher beds the conglomerates are lenticular and have a very restricted distribution.

The grits consist of angular fragments of quartzite and silica, which in many specimens has been replaced by reddish iron oxides in a finer groundmass of silica. Felspar is found in some specimens. These grits show considerable false bedding and are massive in nature . They vary iin colour from yellow to red and purplish varieties have been found in pits sunk on G. Pantak in the divide between S. Pakeh and the S. Bakuching. A few transported carbonaceous plant remains have been found in these rocks.

The sandstones show a similar composition to the grits namely, a mosaic of quartzite gragments, vein quartz and occasionally a little muscovite, the quartz grains showing frequent replacement by iron oxide, the beds showing false bedding well developed. Pyrites are common in these sandstones and sometimes reach a fairly high concentration. They occur as small rounded grains which on exposure to the air weather rapidly to limonite and when these grains of weathered pyrites are concentrated into bands as frequently happens they give the rock a dark brown streaky appearance which is characteristic.

Shaley sandstones occur consisting of small angular fragments of quartz grains in a fine shaley groundmass. In two specimens examined from G. Kechatau fragments of biotite quartzite were found. In the latter the groundmass contained a little recognizable chlorite.

Mudstones and shales have not been seen but their presence has been assumed to be responsible for beds of kaolin singularly free from coarse or medium grained quartzose material found in two pits sunk on hills to the north of the Sambas-Pueh track just before it crosses the border.

Details.

Breccias.

Breccias were found on the northern slopes of G. Bedaun, the northern end of Tanjong Blinsah and near G. Tampe.

G. Bedaun.

Two specimens examined from here, Nos. 195 and 196, showed the rock to consist of angular fragments ranging from 1 mm. in diameter to over 12 mm. and consisting of actinolite quartzite 65 %, angular quartzite grains 10 % sericite quartzite 20 %. The remainder of the rock consisted of a siliceous groundmass showing replacement by iron oxide and the quartz grains in the body of the rock and in actinolite quartzite fragment showed partial replacement by irom oxide.

Tg. Blinsah.

The northern end of Tg. Blinsah contains similar breccias (Specimen 115) but the proportion of vein quartz is greater and biotite quartzite and slate make up a high proportion of the rock. A similar replacement of quartz by iron oxide is more pronounced and as a result the rock is a pronounced reddish colour.

Gunong Tampe.

This breccia (Specimen 119) consisted of angular fragments of biotite quartzite, grey actinolite quartzite, fragments of vein quartz with epidote and abundant quartz fragments showing undulose extinction in that order of quantity. The groundmass consists of fine angular fragments of similar composition.

Gunong Pueh and G. Bekumpai including Ulu Bakuching.

Breccias collected from the base of the series here showed a predominance of granodiorite pebbles with biotite quartzite pebbles forming about a quarter of the whole. On G. Bekumpai, however, two specimens were sollected in which biotite quartzite and mica schist formed 80% of the total rock fragments and granodiorite fragments only about 3%. Vein quartz made up about 4%. The groundmass in all cases showed replacement by iron oxide.

These breccias are restricted in their distributionto high ground, flanking well established mountain ranges of pre-Tertiary times. Where the Samunsam how has cut down in the lower foot-hills of the Pueh range the basal beds are grits which overlie quartzites.

The lighter colours characteristic of the series are lacking here, the partial red colour is due to the subsequent replacement of quartz grains chiefly in the groundmass by iron oxides.

Conglomerates, grits and sandstones.

These rock types are general for the formation. They show well developed current or false bedding, are massive in nature and consist generally of the same constituent materials the difference being merely one of grain size.

Over 30 specimens of these rocks were examined of which the following four are representative:-

No.	Locality and Rock.	Description.
14 (S.664)	S. Pakeh 3,700 ft. East of Pueh Sambas ford over S.Samunsam. Ferruginous grit.	Hand specimen is a coarse to medium grained red quartz-ose rock. The thin section shows fine, medium and coarse angular grains of quartz and dark brown iron oxide cemente by yellowish green iron oxide The grains of iron oxide are pseudomorphs after quartz and all stages of the re-placement can be seen in the sedtion.
8.	Gunong Blinsah. Ferruginous sandstone.	Hand specimen shows a yellowish brown medium grained quartzose sandstone consisting in thin section of angular quartz grains and small fragments of quartzite and slatey fragments.
6.	Gunong Pantak between Ulu Baku-ching and Ulu Pakeh. Chloritic sandstone.	Hand specimen is a yellowish sandstone with pyrites grains distributed in small lentic-ular bands. The thin section shows medium grained angular quartz grains and quartzite fragments. The grains are set in a clayey groundmass which contains chlorite in quantity.
17.	From pit sunk in hills forming the divide between S. Samunsam and S. Bentarang, ½ mile west of frontier. Felspathic chloritic grit.	Kaolinitic yellowish brown sandstone showing under the microscope large medium angular grains with patches of kaolin, fragments of un-dulose quartz; quartzite and fine grains of tourma-line and Zircon. The grains are set in a shaley matrix with a little chlorite.

Shale beds have not been seen in situ but are inferred from the presence of thin beds of mottled kaolinite material exposed in pits. They are presumed to be weathered shale beds. They occur between beds of gritty and sandy kaolin.

In all coloured specimens examined, the bright colours were found to be due to replacement of quartz by iron oxideto a greater or less degree and to the occurrence of a ferruginous cement. It is of interest to note that this colouring was rarely seen in basal beds except at the very edges of the deposit. In the Samunsam, Pakeh and Bentarang rivers, the basal grits were yellowish and light coloured generally, the more highly coloured specimens being obtained from headwaters of rivers in the G. Bedaun , G. Blinsah area and in the highish hills forming the Pakeh-Samunsam divide.

The fact that in the exposures where false bedding is seen, the false bedded rocks are underlain by fairly evenly bedded strata, the angularity of the constituent grains and the occurrence of derived and comminuted plant remains and the localized nature of the basal breccias is taken as evidence that the rocks were deposited from water in a basin flanked in the G. Pueh, G. Puting areas and the area north of G. Bedaun (corres-ponding to the area immediately E of Tg. Limoh) by high hills.

The false bedding and the remarkably irregular distribution of the sediments and the poor sorting of the constituent fragment suggest that the rivers feeding the lagoon were subject to sudden flooding, on occasion the subsequent rush of water carrying badly sorted sediment far into the lagoon.

That the colouring is secondary in origin s suggests that after the lagoon had dried up, the climate was hot and arid. That these conditions prevailed over Borneo during Early Tertiary times is proved in addition by evidence from the Sambas, Central Borneo and North Borneo areas where brightly coloured sediments occur at the base of the Tertiary. The first two areas are described by Wing Easton and Zeylmans van Emmichoven respectively. In North Borneo, highly coloured sediments, chiefly sandstones and shales were found at the base of the Tertiary in the Beluran and Kolapis rivers during work carried out there by the author during 1948.

These rocks are gently folded along N.E.-S.W. axes and are severely affected by faults trending along the same direction. Dips are low, rarely exceeding 15° but high dips of 75° have been observed in exposures S. of G. Tampe where they are associated with faults.

(2) Area to the east of the Batang Kayan.

This area falls outside the theatre of this thesis but in view of the fact that van Bemmelen's map shows a blank for this area and a reconnaissance was made by the author in 1950 from Sampadi to G. Meroyong in the south, it would not be out of place to mention that sandstonesand grits occur generally but with a higher argillaceous content than those of Pueh and that conglomerates have not been found in any exposure. In G. Meroyong, the sandstones contain in addition to quartz grains fragments of silicified rocks such as chert, jasper, hornstone and granite. Quartzite fragments were rare and were only noted in two specimens from G. Kuali.

They also show false bedding but this is not so highly developed as in the area north of Pueh. They are only gently folded. At no place is their junction with older rocks seen as the junction is covered by the wide flood plains of the Batang Kayan and S. Sampadi.

(a) Tg. Batu area.

A small outlier of breccia occurs to the N.W. of G. Gebong in the area between Tg. Batu and G. Gebong. It consists of angular fragments of granodiorite, basic gabbro, diorite, vein quartz and quartzite.

(b) Argillaceous facies.

Outcrops of dark fine grained mudstones and shales are found in three areas where they flank intrusions of altered gabbro and diorite on G. Tamin Menari, G. Tamin Tungku and G. Angus.

They are erosion relics of rocks which must have had a much wider distribution.

In general the rocks are siliceous laminated shales and siliceous mudstones and the few specimens examined show nothing of spectacular interest. Specimen 55 (S.707) which is absolutely typical is a dark coloured fine grained banded mudstone showing in thin section micro-crystalline quartz interbedded with an opaque groundmass consisting of fine grained material probably clay, minerals and limonite in addition.

These were probably deposited in a long narrow lake stretching from Sebako to Sematan and are probably contemporaneous with the sandstones, grits, etc., of the Sampadi and G. Bedaun area.

Age of these rocks.

These rocks are later than the Pueh granodiorite in that this intrusion has severely affected the intrusions of diorite and gabbro at G. Tamin Tungku, G. Tamin Menari and G. Angus, but the mudstones are completely unaffected. The granodiorite is believed to be Cretaceous in age. The relatively undisturbed state of these sediments and the lack of metamorphism suggest that they are Tertiary in age.

In discussing the distribution of Tertiary rocks in Central Borneo, and Western Borneo Zeylmans van

Emmichoven and Wing-Easton describe Tertiary rocks of exactly similar facies from that area which the former author names Plateau sandstones and in which lenses of a monotonous grey mudstones and shales occur to which he gives the name 'Silat' shales, the latter being associated with fresh water fauna which were studied by Icke and Martin in 1905, the specimens being collected by Wing Easton in 1899. This fauna is indicative of a Lower Tertiary age.

The close lithological resemblance between these rocks and the rocks described in this section from West Sarawak suggest a Lower Tertiary age for the latter.

In his report of the reconnaissance which he carried out in 1950 in the Sematan area F. W. Roe classified these rocks as being the equivalent of the Bintulu series of Eastern Sarawak. In view of the close resemblance between the rocks developed in this area and those from Central Borneo, It is proposed to reject the term Bintulu as applied by Roe to this area and to adopt Zeylmans van Emmichoven's names i.e., Plateau sandstone group for the arenaceous facies and Silat shales for the argillaceous facies. They are believed to be contemporaneous.

F <u>Conclusions</u>.

In describimg the consolidated rocks of sedimentary origin from this area abd comparing them with rocks developed in Central and Western Borneo where fossils are found associated with them, we can provisionally classify the rocks in Sematan as follows:-

Lower Tertiary.	Plateau sandstone group and Silat shales. Unconformity.
Early Jurassic-Upper Trias.	Coal measures. Carbonaceous slates and quartzites Slates and quartzites. Slates. Slatey conglomerates. Unconformity.
Permian and Carboniferous.	Biotite quartzites and actinolite quartzites with thin indurated shales and hornfels.
Devonian.	Crystalline schists.

G. Unconsolidated deposits.

General considerations.

Marine alluvium occurs extensively in the basin of the Sebako and Serayan rivers where two marine stages separated by a continental stage are recognisable to the west of Sematan. In the Ulu Sungei China, three cycles of erosion occur.

To the east of Sematan, a slightly different series occurs which can be traced coastwise to the north-west as far as Serabang.

Along the main river valleys fluviatile alluvium occurs but is restricted to the vicinity of the main valleys.

Peat occurs in the low lying swampy country between raised beaches N.W. of Sematan and in swampy areas to the west of Sematan and in Ulu Samunsam.

These rocks will be described under the following headings:-

i. Fluviatile deposits

ii. Coastal marine deposits E. of Sematan.

iii. Marine deposits west of Sematan.

iv. Deposits at Tg. Datu.

i. Fluviatile alluvium is centred in three main areas. In the basin of the Batang Kayan where it is widespread. To the west of the river where it overlies marine sands, it is a thick grey black soft mud with abundant organic matter and near Apong it occurs to considerable depth.

In the basin of the Sematan, Sebako and Serayan rivers, the alluvium forms belts rarely more than half a mile wide bordering the main streams. It also consists of a black to greyish black mud with abundant organic matter. Similar deposits cover widespread areas in the lower reaches of the Samunsam river.

Muds of this nature are restricted to the tidal reaches of rivers.

In the upper reaches of the Sebako, Serayan and Samunsam systems, more widespread deposits of coarse grit of granitic or quartzitic derivation cover extensive stretches of country and at the foothills of the Pueh, Lundu and border mountains, extensive alluvial fans of pebbly grit occur. These deposits show a remarkable consistency of constitution as they are mostly derived from granite and quartzite which forms most of the high country.

The streams and rivers flowing off the eastern slopes of the Pueh mountains give an alluvium with the following principal constituents:-

Pebbles: Biotite granodiorite, quartzite, grits, hornfels (in the Samunsam area) pegmatite, vein quartz and granitic laterite.

Grits: In general chiefly made up of 70% to 80% of quartz grains with ferruginous and vein quartz fragments predominant, abundant biotite and muscovite flakes, the latter in smaller quantity, small fragments of quartzite, tourmaline, ilmenite, laterite and bauxite.

The streams flowing off the Landu 'massif' show in addition to the above constituents, the following depending on the locality.

At Perigi, pebbles of gabbro and hornfels in addition to pebbles of granitic and quartzitic composition occur. The gritty portion also contains the following minerals in abundance; pyrites, augite and fluorspar, the latter rarely.

In the Selarat drainage basin, a similar granitic and gabbroic suite occurs but pebbles of bauxite and amphibole schist are noted and fluorspar is more pronounced.

South of Selarat, the detritus is entirely granitic and quartzitic, the fluorspar and pyrites persisting; in addition, abundant manganese quartz, and quartz vein pebbles containing stibnite, arsenopyrite and pyritesn being common. Fragments of manganese quartz are especially common. Gold also has been washed out of these deposits.

In the upper reaches of the Samunsam river, terraces have been noted but these have not been followed up in any detail. They are seen along the Pueh-Sambas track which follows the upper of two terraces for a short distance W. of the river. The terraces both consist of very coarse grit with a very high proportion of pebbles which in addition to hornfels, granite and quartzite, include conglomerate grits and sandstone. A number of pebbles of schistose conglomerates were also observed.

Fluviatile deposits north of Kuala Samunsam will be treated separately.

In the streams flowing off the northern slopes of Gunong Sebuloh between Tanjong Batu and Tanjong Perigi, the pebbles in the fluviatile deposit showed little granite. Their principal comstituents are in decreasing quantity, quartzite, gabbro, diorite, pyroxene granite, aplite, hornfels, vein quartz with abundant stibnite, bauxite and granitic laterite and biotite granite,

The streams between S. Baju Bergantong and Lundu showed pebbles of biotite granodiorite and granitic laterite exclusively in their alluvial deposits.

ii. <u>Marine alluvium to the East and North-West of Sematan</u>.

Coastal sections a few hundred feet to the East of Sematan show the following sections:-

White to greyish white sand.	
Ferruginous sand with comminuted Mollusca	±16 ft.
Loosely cemented and conglomeratic grit	base not seen.

The white to greyish sand is exposed to the west of the Court-house and the Company's bungalow where as it is traced westwards it shows an inceeasing thickness until it abuts against a Quaternary ridge ½ mile to the West of Sematan . In one boring it was shown to be over 40 ft. thick. The sand grains are predominantly quartz (95%), the only other recognisable mineral being muscovite.

These sands form two raised beaches between Pueh and Sematan, both well defined at Sematan and cann be traced for a short distance East of the river. The first one is recognisable slightly to the north of Munggi Belian but is poorly exposed at Siruh and is not seen at Pueh. Between these raised beaches deposits of peat overlie the sand and are marshy.

The ferruginous sand forms a bed which is seen in numerous localities, chiefly at Sematan and Kuala Siruh and Serabang where recent erosion has exposed them. The most recent of the raised beaches which runs N.W. from the Company's Office consists of this sand as well. At Sematan two beds of comminuted Mollusca,3 ft. apart, are exposed in the Sungei Slepeh Kechil and fossils were noted in a well sunk behind the Company's Offices but do not appear to have a widespread occurrence. Fossils from here were collected by N. S. Haile for identification and Dr. L. R. Cox in a letter to Haile stated that the specimens were unidentifiable. The source of iron is the bauxite deposit at Munggu Belian , which continues as a sub-alluvial ridge to the north-west and is recognisable between Simuh and Pueh.

Exposed on the beach just in front of the mosque is an eroded platform of loosely cemented conglomeratic and calcareous grit with comminuted shells. Its relation to the ferruginous grit is uncertain as their outcrops are separated by a belt of sand. They have only been observed at Sematan. In their vicinity is a partially drowned soil bed with rotted stumps of trees.

This drowned forest and severe undercutting of the beach at Sematan show that marine erosion has progressed considerably in the last twenty years. E. W. Lawrence from an examination of recent aerial photographs estimates that 60 ft. of the coast at Kuala Sematan have been eroded away in the last three years.

With these exceptions, the general features of the coast line suggest that uplift of the land surface has been in progress.

Features supporting this statement were summarized in the section on physiography.

iii. Marine deposits to the west of Sematan.

Stretching inland to the west and south of Munggu Belian, an extensive series of marine deposits occur which apart from the top beds of sand near the Lundu mountains bear little resemblance to the deposits exposed on the coast.

Two separate marine stages were found in one boring about 400 ft. to the west of Munggu Belian and 600 ft. to the south of the Sebat track. They are separated by a continental phase represented by a soil bed 20 ft. thick.

It has been shown that during Quarternary times the relative movement of land and sea level since maximum inundation has been in the order of 1,100 ft. as wave etched rocks are exposed at the top of Bukit Gebong which according to the Survey Department stands at 1,087 ft. A.O.D.,

The marine deposits stretch inland along the Serayan and Sebako valleys as far as Sebako village. They are exposed in numerous pits and borings sunk at Perigi, Selarat and near Munggu Belian between the hill and Sebat.

Near the Lundu mountains about 300 ft. to the west of the alluvial boundary, four pits were sunk to a depth of about 25 ft. between Selarat and Perigi. The deposit penetrated is a sandy to silty clay with lenticles of sand, the clay showing incipient weathering to a mottled greyish reddish brown colour, An earlier pit sunk at Selarat showed a faint current bedding with grains of bauxite disseminated along the bedding 'planes', a feature which led to the discovery of a large deposit of bauxite in this area.

Borings near Sematan, about 1,000 ft. W. of Munggu Belian showed the following section:-

Coarse angular gritty sand.
White finer sand with silt.
Sandy clay.
Steel blue clay with occasional pebbles.
Sandy clay.
Pebbly grit.

A bore, about 2,000 ft. W. of Munggu Belian showed a full sequence through a top marine cycle.

The full section is as follows:-

0 - 4	Dirty white sand with rootlets.
4 - 48	Grey fine to medium grained angular quartzose and micaceous sand incorporating about 30% silt.
48 - 50	Silt.
50 - 52	Gritty sand with silt.
52 - 72	Brown peaty soil with abundant sand and rootlets.
72 - 75	Light brown sand and silt.
75 - 78	Silty clay.

The white sand at the top of the section is almost entirely quartzose in nature, a small proportion of clay and the following minerals being noted; white mica; a black mineral, presumably ilmenite or magnetite; biotite and a little shredded hornblende. The biotite is extremely rare but near Selarat it increases in quantity considerably.

The clay underlying these sands is a stiff blue to steel grey deposit with occasional lenticles of sandy clay and as has been proved in borings; the deposit thickens to the west. Over 60 ft. of this clay has been noted in some holes. A few pebbles of rolled and leached quartzite are associated with this clay as well.

The gritty sand at the base of this clay contains a proportion of ferruginous matter and may be the litho-logical equivalent of the ferruginous sands exposed to the east, in that ferruginous matter was derived from the leaching out of iron from laterite at Munggu Belian. They may be equivalent in time.

The bed of earth is 20 ft. in thickness and contains numerous small roots, some of the larger ones of which extend into the underlying sands.

This soil grades rapidly into a light brown gritty sand with a fair amount of silt incorporated, the latter constituent becomes more frequent until within 3 ft., it resembled the sandy clay near Selarat e except that weathering has not yet influenced the deposit. It grades into a silty blue clay.

iv. Deposits at Tanjong Datu.

Fluviatile deposits are extensively exposed in the lower reaches of the Samunsam river where they form a belt of black to greyish soft muds incorporating a high proportion of rolled leached quartzite pebbles and thin beds of dirty grey sand. A thin deposit of this nature also occurs at the mouth of the Sungei China, the Sungei Melanau. These deposits contain a high proportion of pebbles chiefly laterite but amphibole quartzite, grey quartzite and slickensided slates have been observed as well. In the valley of the left hand branch of the Sungei China, pebbles of cinder coal, hardened fireclay and weathered indurated mudstones occur in addition to the above constituents. In the valley of the Sungei Temajok, beds of coarse black sand occur in which ilmenite sometimes form over 80% of the deposit. In the upper valleys of the streams which flow into the Melanau river, extensive sandy pebble beds with boulders of bauxite, laterite, rolled quartzite, biotite, cordierite hornfels and vein quartz with stibnite and tourmaline have been noted. These deposits are extremely extensive in the low ground between Gunong Melanau, Gunong Pangei and Gunong Serabang where they range from 0'6" to over 8' in thickness.

In the hilly country to the south of the 1st ridge, north of Kuala Samunsam a weathered alluvium occurs in which three thin beds of grit consisting of quartz, limonite, rolled laterite, haematite and small rolled pebbles of quartzite occur. The pebbles form about 3% of the total, the remainder of the beds consisting of reddish clay.

The clay separating these three beds of gritty clay consists of reddish clay with normal unconsolidated kaolinitic laterite.

Marine deposits are not extensive. On the west coast of Tanjong Datu south and west of Gunong Melanau, beds of white sand stretch inland for about $\frac{3}{4}$ mile and are well exposed in the banks of the lower reaches of the Sungei Temajok. They form a series of raised beaches as well and incorporate a high proportion of ilmenite.

To the east, raised beaches are seen at Tg. Labuhan, $1\frac{1}{2}$ miles south of Tanjong Datu and Telok Serabang and also flanking the small bays between Tg. Datu and Tg. Limoh.

At Telok Serabang and Telok Melanau, the ferruginous sand also occurs which contains comminuted shells, The origin of the iron is believed to be the same as that for the similar sands near Sematan, i,e,., leaching out of iron from laterite deposits which during Tertiary times must have covered the whole of this area.

North of Tanjong Serabang a partially eroded calcareous bed occurs consisting of comminuted shells and coral incorporating a little sand. This deposit is bedded and has been tilted to the E.N.E. It is overlain by present day sands.

Between the three hills which constitute Tg. Serabang and G. Serabang a low valley running N-S occurs. This is filled with marine sands. The type of valley is a lso a feature of Tg. Limoh and Tg. Batu and has already been discussed in the section on physiography.

H. Igneous Rocks.

i. General.

Two different series of igneous rocks occur in this area of different ages. The younger is a wide-spread series of acid plutonic rocks exposed in the Lundu 'massif', in the Pueh range, in Ulu Samunsam and Tanjong Datu. The older is a series of acid, inter-mediate and basic rocks exposed at Tg. Pelandok, Tg. Pandan, Ulu Blungi, G. Gebong, G. Angus and G. Tamin Menari. Amphibolite, formed as the result of meta-morphism of gabbro is exposed on G. Tamin Menari and

and G. Tamin Tungku. Of similar age to these older rocks is an intrusion of highly sheared, fractured and mylonitized hornblende granite intruded into volcanic rocks and exposed on G. Asoeansang and G. Batoe in west Paloh and described by van Bemmelen in 1939.

The relation between the two series can be studied at Bukit Gebong and G. Tamin Menari. At Bukit Gebong, amphibole plagioclase schist derived from gabbro was found in pits in the south section of the hill and at G. Tamin Menari, gabbro and diorite which is strongly sheared can be traced into an amphibolite in which all traces of cataclastic structure have been obliterated. The gabbro is, therefore, older than the intrusion of granodiorite in the Pueh and Lundu ranges.

The question as to the actual age of these intrusions is a difficult one and will be discussed in a later section of this report. It is the belief of the author that the gabbro and associated rocks are possibly Permian and Carboniferous in age and the younger intrusions of granodiorite belong to a late Mesozoic age, possibly late Jurassic or early Cretaceous. They will be treated in that order.

ii. Gabbro, diorite and pyroxene, and hornblende granite of presumably Permian or Carboniferous age.

As mentioned above, these rocks crop out in a number of areas, namely Tg. Pelandok, Tg. Pandan, Ulu Blungi, Bulit Gebong, G. Angus, G. Tamin Menari and G. Tamin Tungku.

Outcrops are found along the coast between Tg. Batu and Tg. Pelandok and in old cliff faces in Ulu Blungi and G. Gebong. Exposures are widespread in G. Angus and on G. Tamin Menari, chiefly in the shape of detached boulders.

Tanjong Pelandok.

A small intrusion of gabbro diorite and pyroxene granite outcrops at Tg. Pelandok between Sungei Baju Bergantong and the sea, west to Tg. Pelandok and south to the line of the above mentioned river.

In hand specimen, the gabbro consists of a dark grey coarse grained rock with visible ferromagnesian crystals. Two specimens of those examined have the following composition:-

No.	Locality and Rock.	Description.
S.705	Outcrop in bank of S. Baju Bergantong 500 yds. W of the Lundu Sematan track. Altered quartz gabbro.	Section shows euhedral andesine-labradorite laths, greenhornblende and chlorite set in a matrix of coarse crystals. Iron oxide occurs and some hornblende is altered to chlorite. A little interstitial quartz is found.

Other specimens show alteration to a marked extent, pyroxene being replaced by hornblende which in turn is partly altered to chlorite.

The hornblende diorite outcrops at Tg. Pelandok just north of the S. Baju where it a dark green medium grained veined rock with visible ferromagnesian crystals in a finer groundmass. It is represented by:-

No.	Locality and Rock.	Description.
S. 722	Headland of Tg. Pelandok. Hornblende diorite pierced by a granite vein.	Microsection shows andesine laths in a matrix of pyroxene, hornblende and iron oxides. The veins consist of coarse grained quartz, anhedral hornblende and andesine.

This specimen has been affected by metamorphism to a lesser extent than the gabbro as all stages in the alteration of pyroxene to hornblende can be observed. The vein probably represents a cooling crack into which residual magma of granitic composition which cooled latest of all was injected.

The pyroxene granite is exposed on Munggu S. Baju where it is seen as an outcrop projecting through weathered clay. It is a dark medium grained rock with visible biotite and quartz.

No.	Locality and Rock.	Description.
S. 704	Munggu S. Baju Pyroxene granite.	Microsection shows laths of oligoclase plates of oligoclase biotite and rare pyroxene enclosed in coarse quartz crystals. Myrmekite occurs and the plagioclase is zoned. The biotite chow alteration to chlorite ofte enclosing iron oxide grains

Other specimens of pyroxene granite show partial recrystallization of quartz. This intrusion is bounded to the west and east and south by quartzite. The quartzite is severely affected by the intrusion, complete recrystallization of the quartz in the original sandstone having taken place, the argillaceous matter having been converted into biotite. Xenoliths of quartzite have been observed in this rock at the headland and at Munggu Sungei Baju. They are not frequent.

As mentioned above, these rocks have been subjected to thermal metamorphism, the principal change being the alteration of pyroxene to hornblende and the partial recrystallization of quartz in pyroxene granite. The alteration of hornblende to chlorite is believed to be the result of thermal metamorphism due to the later intrusion of granite.

The principal feature of these rocks is the extraordinary and capricious variation of gabbro, diorite and pyroxene and hornblende granite and also the the equally inconsistent variation in grain size, coarse grained diorite and gabbro occurring side by side with fine grained varieties of different composition.

This feature is general for all the basic intrusions in this area. According to Harker (1932 p.330) this capricious distribution suggests intrusion during a period of orogenic stress.

Tanjong Pandan and Ulu Blungi.

A large intrusion of hornblende diorite and gabbro extends from the sea at Tanjong Pandan into Ulu Blungi. It is partly covered by alluvium. In character it is similar to the Tg. Pelandok intrusion except that it is cut by a small granite stock of slightly later age.

The diorite is exposed at Tg. Pandan and at Munggu Blungi, where it is seen to be a dark grey rock with visible ferromagnesian crystals and felspar. The specimens described below are typical.

No.	Locality and Rock.	Description.
S.721	1,000 ft. of Ulu Blungi Kechil along the Lundu track.	This section shows hornblende and laths of andesine-labradorite with patches of iron oxide.
S. 725	Tg. Pandan	Thin section consists chiefly of green hornblende and laths of andesine with interstitial coarse grained recrystallized quartz crystal Biotite, chlorite, iron oxide and pyrites also occur.
S. 729	6 inches from thin granite dyke 100 yds. W. of eastern extremity of Tg. Pandan.	Section shows andesine labradorite and hornblende with little interstitial quartz. Sphene and iron oxides are present.

These three specimens are clearly metamorphosed rocks, probably quartz pyroxene diorite originally in which the pyroxene has been completely altered to hornblende.

Quartz gabbro is found in both areas, the following specimens being representative:-

No.	Locality and Rock.	Description.
S. 726	Tg. Pandan N. of aplite dyke	Section shows hornblende labradorite and myrmekite. Iron oxides are present.
S. 728	Tg. Pandan 100 yds. E. of Aplite dyke.	Microsection consists of green hornblende laths, diallage partly altered to hornblende, labradorite quartz and iron oxides. Intergrowth of quartz and felspar occurs
S. 733	Tg. Pandan.	Microsection shows labradorite laths, green hornblende, rare pyroxene probably diallage rimmed with hornblende, quartz often intergrown with felspar and needles of iron oxide.

No.	Locality and Rock.	Description.
S. 728	Tg. Pandan 100 yds. E. of Aplite dyke.	Microsection consists of green hornblende laths, dial-lage partly altered to horn-blende,labradorite quartz and iron oxides. Intergrowth of quartz and felspar occurs.
S. 733	Tg. Pandan	Microsection shows labradorite laths, green hornblende, rare pyroxene probably diallage rimmed with hornblende, quartz often intergrown with felspar and needles of iron oxide.

These rocks have similarly been affected by the Lundu intrusion and the same considerations apply as above.

Tanjong Pandan.

A small stock-like intrusion 150 yds. wide is exposed at the headland of Tg. Pandan. In general it is a hornblende-biotite aplite with coarse grained hornblende granodiorite forming the margin of the intrusion.

The aplite is intruded into gabbro and diorite which it has presumably altered, although it is impossible to say what alteration is due to the Lundu granodiorite and what to the Tg. Pandan granite.

The contacts are generally sharp but lenses of granite occur in the gabbro up to 50 ft. away from the contact and extensive interpenetration by small veins of coarse grained granite penetrate the gabbro for a considerable distance.

In general the rock is a fine grained whitish grey rock with visible ferromagnesian crystals, in some cases the concentration of hornblende is great enough to give the rock a dark appearance. The coarse grained marginal facies consists of large ferromagnesian crystals up to 1 cm. in length in a coarse grained matrix of felspar quartz and biotite. These marginal coarse grained facies suggest that the granite was intruded into highly heated country rock. Intense shearing is noticeable in some specimens. Stages in the alteration of pyroxene to hornblende are seen.

Over fifteen specimens have been examined and the following are representative:-

No.	Locality and Rock.	Description.
72 S.724	Lens in gabbro to the west of the headland. Hornblende granodiorite.	Coarse grained rock with visible biotite, quartz, felspar and elongated ferromagnesian crystals. Thin sections show laths of oligoclase, orthoclase, biotite (altered to chlorite) and green hornblende. Intergrowth of plagioclase and quartz noted.
75 S.727	Small dyke penetrating gabbro intruded in a dirextion 25°W. of S. Hornblende granodiorite.	Coarse grained light grey rock with large laths of ferromagnesian crystals in a finer grained groundmass of quartz and felspar. Thin section shows andesine intergrown with quartz, orthoclase and laths of hornblende apatite sphene and iron oxide are the principal accessories

No.	Locality and Rock.	Description.
78 S.730	Centre of intrusion.	Light fine and whitish grey mottled rock with dark ferro magnesian crystals. Microsection shows quartz, orthoclase and albite with rare hornblende, biotite and iron oxides. Granophyric intergrowth between quartz and felspar is common.
S. 738	Centre of intrusion	Hand specimen similar to S.730. Microsection shows quartz orthoclase and albite with rare hornblende, biotite and iron oxides. Granophyric intergrowth between quartz and felspar is common.
79 S.731	1 inch from contact with gabbro.	Hand specimen is a coarse grained mottled green and grey rock with visible ferro magnesian crystals in contact with a fine grained dark green rock. Thin sections show oligoclase, orthoaclose, orthoclase hornblende (in some crystals formed at the expense of pyroxene) and quartz. Accessory minerals are sphen apatite and iron oxide. A vein containing quartz and epidote cuts the section.
80 S.732.		As for 78 S.730.
82 S 734	Centre of intrusion.	Hand specimen No.79. Thin section shows andesine, orthoclase, microperthite biotite and hornblende laths with rare pyroxene. Quartz occurs as intergrowths with felspar and as separate grai grains.
87 S.739	Occurrence and description as No.82 754.	

Bukit Gebong.

A large intrusion of gabbro altered to anphibole plagioclase schist in the south occurs between Perigi and Selarat where it is intruded into quartzite.

Specimen No. 712 is characteristic of the unaltered rock showing very large crystals of a ferromagnesian mineral (up to 6 mm. in diameter) in a finer but still coarse grained groundmass of plagioclase laths and ferromagnesian crystals. The thin section shows intergrown diallage and labradorite in approximately equal proportions.

This specimen is from the N. sector of the hill in the Sungai Perigi Kechil. In the south of the intrusion the pyroxene is totally replaced by hornblende and in pit No. 1 and No. 31, plagioclase amphibole schist is found. Pyroxene granite is found in pits 80 and 82 in the N.W. foothills of G. Gebong. It is a dark grained rock with visible quartz felspar, ferromagnesian crystals and biotite. The rock is weathered to bauxite and stages in the alteration of gabbro to schist cannot be traced.

Gunong Angus.

This intrusion consists of diorite and gabbro locally altered in the south into hornblende diorite and gabbro. It is intensely sheared and slickensided in hand specimens abd in thin section, shearing and alteration of ferromagnesian crystals, undulose extinction of felspar and quartz crystals are noted. The intrusion is flanked by unmetamorphosed mudstones found in pits sunk to the E. of the hill by J. V½ Puckey.

The rock varies from a grey to light green porphyritic to evenly coarse grained rock and is well exposed on the scarp face to the south of the top of the mountain. Details of cpmposition are given below:-

No.	Locality and Rock.	Description.
S. 698	N. slopes of G. Angus. Metamorphosed gabbro.	Thin section consists predominantly of pyroxene in part altered to an aggregate of actinolite and chlorite. Intensely altered plagioclase grains occur set in a very fine grained partly isotropic groundmass together with wisps of actinolite.
S. 699	Eastern foothills of G. Angus. Metamorphosed gabbro.	Microsection shows laths of labrodorite poikilitically enclosed in a very coarse grained pyroxene. The pyroxene is ggreen and some crystals show a fine parting or cleavage parallel to the crystal outlime probably diallage. The pyroxene is also altered in part to chlorite, hornblende and actinolite.

No.	Locality and Rock.	Description.
S. 700.	Top of G. Angus.	Thin section shows relict plagioclase in a groundmass predominantly of hornblende with interstitial felspar. Fine quartz veining is common.
S.703.	S. foothills of G. Angus Altered quartz dolerite.	Microsection shows predominantly pyroxene, hornblend and chlorite in a quartz-felspathic groundmass. Several grains of plagioclase (labradorite ?) occur
S. 687	S. slopes of G. Angus, Metamorphosed pyroxene diorite.	Microsection consists of very coarse plates of diallage, chlorite and andesine. Aggreggates of actinolite bordered by chlorite occur.
S. 701	As S. 687	Microsection shows pyroxene altered to an aggregate of a actinolite and chlorite and a basic andesine felspar.

The appearance of crystals in these specimens under the microscope shows that the intrusion has undergone considerable tectonic movement since its emplacement. Quartz crystals in addition show pronounced fracturing and undulose extinction.

In addition to variation of composition a notable variation in texture occurs ranging from fine grained dolerite to porphyritic very coarse grained poikilitic gabbro and diorite. In some hand specimens, elongated crystals of ferromagnesian minerals up to 10 mm. in length have been noted.

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The boundaries of this intrusion are not exposed and it is not certain what they are intruded into but it is believed that quartzites form the country rock.

<u>Gunong Tamin Menari</u>.

Little is known about this intrusion, specimens in my possession having been brought in by rock sollectors. They are all plagioclase amphibolites with a little quartz. Iron oxides occur and alteration of hornblende to chlorite is noted (S.706). Complete obliteration of any cataclastic structure and textures has occurred and it is clear that this intrusion has been severely affected by the Pueh intrusion. This and the following intrusion ar are flanked by unmetamorphosed mudstones.

<u>Gunong Tamin Tungku</u>.

Specimens of amphibolite have been brought in from this hill by rock collectors.

The differentiation undergone by this basic to intermediate series is taken to mean that they were intruded during a period of crustal stress. (Harker 1932 p.330)

The quartzites into which they have been intruded are believed to be Permian and Carboniferous in age and the gabbro is believed to be either Permian or Carboniferous in age possibly late Permian.

Gunong Asoeansang.

In his description of the rocks of W. Borneo van Bemmelem describes intrusions from G. Asoeansang and G. Batu in Paloh. In view of the differences they show from the Pueh, Lundu and Tg. Datu granites, van Bemmelen's remarks are quoted here in order to present fuller evidence for a correlation of the rocks in our atea.

He writes:-

" In the Asoeansang complex which occurs in the mountainous country near the N.N.W. flowing stretch of the S. Bemban, plutonic rocks have only recently been exposed by denudation. We find ourselves chiefly in the intensely metamorphosed cover to these plutonic rocks, consisting chiefly of crystalline schists and rocks classified into the Permian and Carboniferous systems and it is only occasionally that exposures of the igneous rocks are seen.

No.	Locality and Rock.	Description.
No.191P.	Hill to the E. of the junction of the S. Poetih (Puteh) with the S. Bemban N.N.W. of G. Batu.	Amphibole syenite, highly sheared. The rock consists of alkali felspar (presumably also anorthoclase) very acid plagioclase and a little amphibole. The rock is intensely affected by dynamic metamorphism.

No.	Locality and Rock.	Description.
No. 111P.	S. Bajoer 110 m. upstream from a chal-copyrites deposit in the S.E. part of the G. Asoeansang complex.	Mylonitized granite in part completely crushed. Con-sisting of quartz, ortho-clase, very acid plagioclas and green amphibole. The constituent minerals are be bent and fractured and show undulose extinction. In specimens from nearby ex-posures (112 & 113 p) re-generation of the rock has commenced with subsequent large scale formation of prelinite and regeneration of quartz is also noted. Sulphide ores occur in addition. After or during the dynamic metamorphism the rocks have subsequently been affected by an intensi sive hydrothermal metamor-phism.
S. 105 P	S. Bajoer E. slopes of G, Asoeansang near the ahalcopyrite deposit.	Amphibole granite: inten-sely sheared: microcline, very acid plagioclase, quar quartz and green amphibole are the constituents. In the sheared zones which traverse the rock, chlorite epidote and pyrites have been formed. The crushing process was therefore ac-companied or followed by a hydrothermal metamorphism.

iii. Younger intrusions of biotite granite and granodiorite

These rocks are exposed in three areas where they form intrusions of a considerable size. They occur in the Lundu 'massif', the Pueh range including Ulu Samunsam and Tg. Datu.

They show certain features in common. They are all remarkably constant within limits, consisting of coarse grained biotite granodiorites and with the exception of Tg. Datu granite all have extraordinary sharp contacts, little evidence of the assimilation of the country rock having been noted. In contrast to the Asoeansang and Tg. Pandan granites and syenites they are not affected by shearing and show in addition a different mineralogical constitution.

The Lundu granites.

This granite outcrops to the west of the Lundu-Sematan track via Siar and to the east of the Lundu-Serayan track. It forms Gunong Selarat, Gunong Perigi, Gunong Lundu, G. Gading and G. Sebuloh and occupies an approximate area of twelve square miles.

Specimens of granite have been described by van Bemmelen (1939) and are quoted below. The numbers refer to the specimens in the Geological Museum at Bandoeng

No.	Locality and Rock.	Description.
253 SW.	Waterfall near the foothills of Gunong Lundu.	Two mica granite consisting of colourless and dark mica (with pleochroic haloes based on a zircon nucleus), In addition plagioclase, orthoclase (occasionally microperthitic) and quartz. Accessory minerals are apatite and iron ore.

No.	Locality and Rock.	Description.
258 SW.	S. Semunin to the west of Lundu.	Two mica granite as No. 253SW.

Few specimens were collected as exposures are rare owing to deep weathering, but of the eight examined the following two are representative:-

No.	Locality and Rock.	Description.
S. 720	Top of G. Selarat	Biotite granodiorite For details see No.S.737.
S. 737	G. Pulau Aver, Lundu.	Microsection shows andesine, less common orthoclase and biotite. Grains of zircon and apatite are common.

This granite is intruded as a batholith. It is believed to be contemporaneous with the Pueh granite to which it bears a remarkable resemblance.

It metamorphoses the nearby gabbros and the quartzites which were previously metamorphosed by the gabbro. Only a few xenoliths have been noted in this intrusion.

The granite shows sharp contacts and little evidence of assimilation of the country rock.

Near Gunong Sebuloh veins of quartz and pyrites have been observed. In the Selarat - Serayan area no veins have been seen in situ but pebbles of vein quartz with fluorspar are common in streams as are vein quartz pebbles with stibnite, pyrite and arsenopyrite. At Sebiris, quartz ceins with fluorspar have been noted and at Gunong Pulau Aver near Lundu, vein quartz with beautifully formed crystals of quartz and tourmaline amd a grass green flakey mineral provisionally identified as torbenite occurs.

The Pueh intrusion.

This intrusion forms the mountainous country between Benterang and Pueh in the north to Sadjingan in the south and covers an approximate area of 36 square miles. In general it is an extraordinary uniform intrusion consisting of medium to coarse grained granite, fine grained aplite being common in the south.

A few petrological details of this granite were published by van Bemmelen in 1939 and are quoted below as are others of specimens in the author's collection and duplicated at Kuching.

The Sandoeng specimen numbers are followed by the letter P., the Kuching specimens preceded by the letter S. Specimen S.659 is from a stock in Ulu Samunsam which is probably part of the same intrusion, the sedimentary cover between the two exposures being underlain by granite. The remainder are all from the main intrusion.

No.	Locality and Rock.	Description.
9 (S.659)	Stock of Ulu Samunsam 1½ miles SE. of Pueh-Sambas ford over S. Samunsam.	Thiss section shows quartz 45%, andesine 45%, biotite 8%, muscovite and chlorite 2%.
65 (S.717)	7,500 ft. S. of junction of Company's E.P.L. rentis S. of Pueh.	Biotite granodiorite, being a mottled light grey coarse grained rock with visible biotite, quartz and felspar This section consists of biotite laths, quartz oligoclase -andesine plagioclase occurring interstitially and as small rounded grains in the felspar.
3 (S.715)	16,000 ft. from same junction as S.717 along E.P.L. boundary rentis.	Biotite granodiorite being a light grey mottled rock with discernable green ferromagnesian crystals in a light quartz felspar groundmass. Thin section shows biotite altered to chlorite and muscovite and oligoclase - andesine plagioclase partly altered to a sericite in a matrix of quartz. The quartz has a marked undulose extinction. Veins of calcite occur and grains of zircon and apatite are common.
61 (S.713)	E. slopes of Pueh range in the S. Chali near Sebat.	Hypidiomorphic grey mottled rock with discernable biotite, quartz and felspar. Under the microscope it consists of andesine, quartz and biotite. A patch of green hornblende granules, muscovite and iron oxides occur.

61 (S.713) continued.		Zircons and iron oxides are the principal accessories and the biotite shows alteration to chlorite and iron oxides.
42 (S.694)	Foothills of G. Sebat between Ulu Sebat Kechil and Ulu Tembaga ($\frac{1}{2}$ mile N. of latter) Biotite adamellite.	Hand specimen is a coarse grained hypidiomorphic grey mottled rock. This section shows equal amounts of orthoclase (Carlsbad twinned) and zoned oligoclase-andesine plagioclase. Biotite flakes and muscovite show alteration to chlorite. Some plagioclase felspar contains fine sericite flakes along cleavage traces There is a small development of graphic intergrowth between orthoclase and quartz and an inclusion of biotite hornfels occur.
56 (s.708)	S. Nyawang, Ulu Sebat Kechil. Biotite granodiorite.	Hand specimen is a grey mottled coarse grained rock with visible hypidiomorphic biotite, felspar and quartz. Thin section shows orthoclase 4%, oligoclase 25% and chloritized biotite, Sphene and iron occur, the latter conspicuous in the biotite.
62 (S.714)	Headwaters of S. Tembago. Biotite granodiorite with garnet.	Medium grained rock with hypidiomorphic crystals of biotite, quartz and felspar. Thin section consists of andesine, quartz and biotite Red garnet occurs in patches

No.	Locality and Rock.	Description.
49 P.	Batu Begupit near Kg. Sadjingan, Indonesia. Biotite grano-diorite.	Holocrystalline hypidio-morphic plutonic rock consisting of biotite, potash felspar, zoned andesine with albite forming the outer layers. Accessory minerals are apatite, zircon and ilmenite, the zircon forms the nucleus of abundant pleochroic haloes in the biotite.
47 P.	S. Sinlo near Kg. Sadjingan, near Sambas-Sarawak frontier, Indonesia. Biotite muscovite adamellite.	Holocrystalline hypidiomorph phic plutonic rock with biotite and to a lesser extent muscovite zoned andesine (idiomorphic) orthoclase and abundant quartz. The biotit is frequently altered to chlorite, accessory minerals are apatite, ilmenite and zircon, the latter forming the nucleus of pleochroic haloes in the biotite and an azure blue, optically negative uniaxial idiomorphic six sided mineral. The colour is too intense for sapphire, possibly tourmaline. Secondary rutile occurs in the chlorite. A xenolith of hornfels with well developed decussate texture and consisting of actinolite, quartz and plagioclase with a strong pleoch roic mineral (possibly tourmaline) forming a conspicuous halo in the actinolite.
140 P.	Headwaters of the S. Bemban, N.Paloh (N.E.I.) Biotite muscovite granophyre.	Thin section shows quartz orthoclase, andesine and biotite (frequently altered to chlorite) and muscovite. The quartz and orthoclase frequently intergrown. Accessory minerals are garnet, zircon, tourmaline, iron ore and the latter again forming the nuclei of pleochroic haloes.

As will be seen there is a remarkable uniformity of texture, a coarse granitic texture being general and a granophyric texture occurring in the fine grained varieties. In composition the intrusion is predominantly a biotite granodiorite with occasional development of muscovite and varying occasionally into adamellite and potash granite.

Xenoliths occur in specimen 47 P. where a basic igneous rock has been converted into a plagioclase - amphibole - quartz rock and in spedimen S.713, the hornblende muscovite granules probably represent assimilated country rock. At Tekorong, a xenolith of plagioclase amphibolite 3 ft. across occurs in the granite about 20 yds. from the contact.

No pegmatites in situ have been observed but in the headwaters of the Sungei Samunsam pebbles and boulders of plagioclase quartz muscovite pegmatite with stibnite and brownish black tourmaline have been observed. These occur frequently.

Similar pebbles but of considerably smaller size have been observed in the Sungei Tekorong (Tekorok) and A. Nyawang and Sungei Sebat Kechil.

Hydrothermal veins with epidote, tourmaline and quartz associated with this intrusion have been observed in the Tekorong area. The granite is intruded into schist and quartzite.

Deposits of haematite south-east of G. Nibong are associated with this granite.

<u>Tanjong Datu</u>.

This granite occupies a relatively small area in the Tg. Datu peninsula where it exhibits some striking contrasts to the other two large intrusions of biotite granodiorite. At its contact extensive interpenetration and mixing of the country rock and the granite occurs and xenoliths abound in the granite itself. Gneiss forms a belt 600 yds. wide south of Kuala Labuhan. In addition the granite contains large numbers of schlieren or clots of biotite which give the granite a very characteristic appearance. Specimens have been collected from this granite and a specimen from the Indonesian side of this intrusion is described by van Bemmelen and is quoted below:-

No.	Locality and Rock.	Description.
174 P.	1 km. N. of the summit of G. Datu, Near Paloh.	Fine grained granite with dark schlieren giving the rock the appearance of lit par lit injection gneiss . The colourless minerals are orthoclase and quartz, the latter enclosing idiomorphic andesine crystals Biotite also occurs concentrated in bands thereby forming the schlieren which give the granite its characteristic appearance.

The marginal areas of this intrusion are biotite granite, the main mass being a biotite granodiorite.

No.	Locality and Rock.	Description.
89 (S.741)	Just N. of K. Temajok near the border of intrusion. Biotite granite.	Hand specimen is a coarse grained rock consisting of nquartz, felspar and biotite The microscope shows orthoclase, a little andesine biotite, muscovite and a little chlorite.
86 (S.750) 109. (S. 750)	Kuala Labuhan. Biotite Granite.	Hand specimen is a coarse grained rock consisting of quartz felspar and biotite. Several crystals of felspar enclose both quartz and felspar. The thin section shows quartz with plates of orthoclase enclosing corroded andesine crystals, biotite and muscovite. Apatite and iron oxides are accessory. The biotite is concentrated into clots or achileren.

The main part of the intrusion is biotite granodiorite and the 15 specimens examined are represented by the following:-

109 (S.211)	Small stream on G. Datu.	Hand specimen as 59 (S.741) and under the microscope shows zoned plagioclase (? oligoclase), orthoclase, biotite and quartz and a little muscovite. The accessories are chlorite, apatite and zircon. The zircon showed pleochroic haloes.

No.	Locality and Rock.	Description.
110 (S.1212)	1,000 yds. S of the top of Tanjong Datu.	Description as above except that the biotite is concentrated into schlieren and chlorite does not occur.
103 (.1215)	S. Bakau, Indonesia.	Description as specimen 109 except that plagioclase is andesine and is not zoned.

The granodiorite is intruded into schists and siliceous slates, the latter metamorphosed into quartzites and seen extensively on the east coast of Tanjong Datu, the metamorphosed schists being exposed south of the Sungei Temajok where they are altered into biotite-muscovite-cordierite hornfels and andalusite biotite hornfels.

Extensive mineralization is associated with this granite, veins being especially pronounced north of Kuala Samunsam and south of Sungei China where the minerals associated with the veins contrast to those in veins exposed north of S. Melanau.

In the north of Kuala Samunsam, the veins of quartz are intruded into hardened slates, the veins being responsible for the local induration of the slates, and the cleavage planes determining the direction of intrusion which is in general N. 53°E to S.53°E.

Extensive faulting of later age than the quartz vein intrusions has displaced the veins extensively. The quartz is associated with haematite which is believed to form extensive deposits in the ridge between S. China and S. Samunsam. In connection with this, marked compass deviation is noted in the area.

At Tanjong Nyawang, a larger barren vein of quartz is intruded into a large fault.

At Kuala Nyawang, a few hundred feet to the N.E. of the river, barren veins of quartz occur as well.

At Telok Jinsiang, about 1 mile north of Kuala Melanau, small veins of quartz containing tourmaline and a grass green mineral provisionally identified as torbenite.

In Ulu Melanau, in pits 4 and 7, decomposing vein quartz with stibnite is found.

South of Kuala Temajok, thin veins of quartz, epidote and pyroxene occur.

Age of the Igneous Rocks.

We have seen that two types of intrusions occur, An older differentiated series containing granite, diorite and gabbro, the granite in which contains hornblende and pyroxene (when not near enough to an intrusion) as the principal ferromagnesian mineral and in which biotite is prominent by its scarcity and which in addition are highly sheared where recrystallization and regeneration has not occurred. These are in contrast to the unsheared fairly uniform biotite granodiorites of Pueh, Lundu and Tanjong Datu which are believed to be contemporaneous.

The relation between the Lundu and Pueh granites and the differentiated series is fairly clear.. We have seen that two dynamic metamorphisms have affected the area. An older pre-Triassic one during the peak of which the differentiated series of igneous rocks were intruded. The shearing in hand specimens, fractured crystals and undulose extinction shown by the constituents of the G. Angus intrusion show that the post-Triassic dynamic metamorphism is younger. The destruction of the cataclastic structures and textures in the G. Tamin Tungku and G. Tamin Menari intrusions and the Gebong-Ulu-Blungi intrusions by the Lundu intrusion show thatt the granodiorites are younger than the post Triassic dynamic metamorphism.

The relation between the Gunong Aseeansang intrusions and the Tanjong Datu intrusion is even clearer. Rrom van Bemmelen's description of the former, it is clear that the hornblende granite is older than the post Triassic dynamic metamorphism and we have seen that the Tg. Datu granite is younger than this dynamic metamorphism.

Since Zeylmans van Emmichoven has shown that this younger metamorphism is post Triassic (Upper), the older intrusions are pre Upper Triassic and since they are intruded into sediments which by comparison with Central Borneo are believed to be Permian and Carboniferous they are probably late Permian and Lower Triassic.

The overlap of Tertiary rocks on to the Pueh granodiorites shows that these younger intrusions are pre Tertiary and are therefore possibly late Jurassic or early Cretaceous. It was pointed out that there was a possibility that the top of the Tanjong Datu sediments may be the terrestial equivalent of Wing Easton's marine lower Jurassic in the Sambas area. This age for the granodiorites correlates them with the Malayan granites to which they bear a marked lithological resemblance and also to granites exposed in the northern continuation of this zone in the Natuna islands and to granites in the area lying south of the Schwaner mountains N. of the Java Sea and which van Bemmelen proved to have a possibly late Jurassic early Cretaceous age.

I. Structure.

Structure in the crystalline schists is indecipherable owing to the depth to which these rocks have weathered and the paucity of fresh exposures.

The quartzites are generally massive but when in thin beds of indurated schist are seen, they show that the quartzites are closely folded along N-S axes. Exposures at Tg. Hashim where these shales are more frequent than usual show that considerable overfolding has occurred and the direction of folding shows that pressure was directed from the west. The cores of the overfolds pass locally into thrusts just to the west of Tanjong Pelandok.

In the Sebat valley, the general N-S direction of the folding is confirmed as it is at Tanjong Limoh. Only two dips were recorded in the Gunong Puting area.

In the slatey conglomerates, slates and quartzites coastal sections are good. A large thrust whose plane strikes 53°W. of N.- 53°E.of S. is exposed at Tg. Labahan. To the south the rocks are highly folded, dips ranging from 72o to vertical and overfolding towards the south west is developed.

To the south of Tg. Serabang faulting is severe

TABLE.

Age.	Stratigraphy.	Igneous intrusion	Unconformity.	Tectonics and metamorphism.
Recent & Quatenary	Alluvium		Local in alluvium at Sematan.	Epeirogenetic movements of considerable extent.
Tertiary	Laterites and bauxites		Major unconformity	Earth movements folding consolidated plateau sandstones into gentle anticline and synclines. Chiefly manifested in severe faulting
	Plateau sandstones at Sampadi and N. of Pueh.		Sedimentation	
MESOZOIC.				
Early Cretaceous - late Jurassic		Intrusion of biotite granodiorite	Major unconformity	Thermal metamorphism.
Middle to late Jurassic				Dynamic metamorphism towards end of which the biotite granodiorite were intruded. Structures aligned along axes trending N.53°W-S.53°E
Early Jurassic	Coal bearing rocks of Tg. Datu, thin alternating quartzites and slates		Sedimentation	

(Contd. over.)

Age	Stratigraphy	Igheous intrusion	Unconformity.	Tectonics & metamorphism
	Basal slatey conglomerates.			
Late Palaeo-xoic. Permian and Carboniferous.		Intrusion of gabbros, nor-ites, diorites and pyroxene - and hornblende granites at Lundu - Sema-tan, Tg. Api and G. Asoean-sang.	Unconformity	Thermal dynamic meta morphism during the peak of which the gabbro etc. were intrud Structures due to the dynamic ele-ment aligned along axes ttending N-S
	Quartzites and thin indurated shales.	Extrusion of volcanics at G.Asoeansang in Paloh.	Sedimentation.	
Devonian	Crystalline schists		Unconformity Sedimentation.	Regional metamorphism

and is responsible for the upthrusted block of actinolite quartzite at Tg. Sungei China. This faulting and its effects have already been described in the section on slates and quartzites.

It appears that the older quartzite and igneous rocks of the Gunong Puting area formed a stable foreland against which the younger Upper Triassic rocks were thrust and folded.

The Tertiary rocks of the Bedaun hills are gently folded along NE - SW axes and faulting is severe. The faults trend along NE - Sw axes. A very large fault trending along a similar axis in the Kuala Samunsam area has thrown actinolite quartzite up against slates and cut across older faults injected with quartz and haematite and displaced then fairly considerably. The lower reaches of the Samunsam valley are developed along this fault.

Major unconformities occur between the crystalline schists and the Permian and Carboniferous quartzites, the latter and the Upper Triassic-Jurassic slates and quartzites, etc., and between the latter and the Lower Tertiary rocks. Laterites and bauxites represent a break in sedimentation corresponding to the Middle and late Tertiary periods and sedimentation was resumed again possibly during late Tertiary times or more likely during the Quarternary. A local break in sedimentation is represented by the soil bed at depth west of Munggu Behan.

PART V.

PALAEOGEOGRAPHY.

During presumably early Devonian times, shaley sandstones with chloritic sandstones in the west (corresponding to Sadjingen and Soengai Radja) were deposited in a sea and subsequently consolidated. Prior to Carboniferous times, these rocks were subjected to regional metamorphism, the grade of metamorphism increasing from east to west. A marine invasion then took place during Permian and Carboniferous times and shaley sandstones and thin shales were deposited.

During late Permian or early Triassic times considerable earth movements took place, the rocks being folded along N-S axes and well established mountain ranges being formed.

Prior to the main movements, it is possible that the volcanic basic rocks which form the highly metamorphosed aureole to the Gunong Batoe and G. Asoeansang granites were extruded. During the peak of the orogeny the gabbros, diorites and pyroxene and hornblende granites of the Lundu Sematan area and G. Batoe and G. Asoeansang were intruded.

During late Triassic and Jurassic times a marine invasion must have occurred to the south of the area at least as far N. as Ban Pin San in the Sambas area, deltaic deposits being formed in an elongated narrow basin in the Tanjong Datu area. This basin eventually silted up giving rise to swamp with deposition of mudstones and coal measures.

During late Jurassic to early Cretaceous times another severe series of earth movements affected the area, the tectonic forces being directed from the north-east, the G. Puting and G. Batoe mountains acting as a stable foreland against which the younger rocks were compressed, folded and overthrust. Towards the end of these movements, the granodiorites of Pueh, Lundu and Tanjong Datu were intruded.

Sedimentation was resumed during early Tertiary times in a large basin whose main area lay to the west of the Pueh mountains and with arms running through a gap between the Pueh and G. Puting mountains, or the Pueh and Lundu mountains and a third and large arm, probably part of the main basin to the east of the Batang Kayan. The Pueh, Lundu, Tg. Datu, G. Puting, G. Aruk and Tg.Limoh mountains were present as such, the presence of the granite pebbles in the basal breccias showing that the granite was exposed to denudation by then.

The climate was dry throughout Borneo at that time although to the north west in Malaya swamp comditions prevailed in Tohore and Selangor.

During middle and late Tertiary times, the climate became established as at present, widespread pre-Quarternary bauxites and laterites being formed throughout this period. Towards the close of the Tertiary a major marine invasion took place flooding this part of the country to a depth of 1,100 ft. above present sea level. The sequence of events after this are summarized in the table below.

First marine invasion with maximum inundation of probably about 1,100 ft.

1st period of recession.	A relative fall in sea level to about 700 ft.
1st period of stability.	Represented by a wave eroded platform at about this level on G. Gebong. In the N. at G. Melanau two additional beaches are recognisable at 700 ft. and 800 ft.
2nd period of recession	A fall in sea level to ±350 ft.
2nd period of stability.	Represented by widespread wave eroded platforms or raised beaches of wide distribution at 300 ft. om G. Gebong, G.Sebuloh, and G. Serabang, and pronounced cliff and scree development on the former two mountains

3rd period of recession.	Sea level appears to have receded to its present-day level with the formation of a dry tongue of land lying to the west of Sematan. A lake probably lay in the Serayan-Palon ares as borings to the west of Munggu Belian show that the soil horizon is a local one.
2nd marine invasion.	Land formed during the last period of recession partially flooded not to any depth but sufficient to enable clays to be deposited in the valleys of the previously exposed land area. The distribution of beach sands lends support to the idea that this shallow invasion did not stretch beyond Serayan and Sebako in the Sematan area and not more than ¼ mile inland from Kuala Melanau.
4th period of recession.	Sea level receded to its present position with formation of raised beaches at Sematan and Pueh.

At the present time the formation of young deltas at the mouth of the Sampadi river and the Batang Kayan suggest that the land surface is stable.

PART VI.

WEATHERING.

Nature of weathering.

The weathering phenomena encountered here are those typically associated with alternate dry and wet seasons in a tropical climate whereby the products formed are oxides of silicon, aluminium, iron, manganese and titanium. The depth of weathering depends on the nature of the rock both its chemical and physical properties being involved, the final product depending on the chemical nature of the rock and the stability under normal surface conditions of the constituent minerals of the rock.

Depth of weathering.

This depends on the nature of the rock. In general sedimentary rocks which have not been thermally or regionally metamorphosed are not seriously affected. Pits on G. Melanau, G. Serabang, and G. Panggi and small hills N. of G. Chermai are only weathered to a depth of 8 ft. or so. These pits show slate, carbonaceous slate and graphitic shale or mudstone.

Regionally and thermally metamorphosed rocks are deeply weathered as are igneous rocks of all kinds, Two pits on G. Gebong went through 100 ft. of weathered deposits and no sign of bed rock was apparent.

In other words rocks whose constituent minerals are high temperature minerals and consequently metastable at ordinary temperatures are severely affected by chemical decay whereas rocks whose constituent rocks are derived from those of older rocks as a result of a process of denudation, transport and deposition are reasonably stable to the agents of weathering and are not deeply affected.

Before going on to describe the products of weathering, it would be advisable to define the terms to be used in the subsequent section.

The final product of weathering as has been stated above is a laterite. This is a term used in a variety of ways and needs definition, the following which is adopted is taken from Sir Lewis Fermor's paper "What is laterite?" (Geol. Mag. Dec. 1911 pp. 454, 507, and 559)

1. "The term 'laterite' is used in two ways, namely stratigraphically as the name of a geological formation, and petrographically as the name of a superficial tropical rock.

2. "Laterite" (or some varieties of it) is formed by a process, the modus operandi of which does not concern us here, by which certain rocks undergo superficial decomposition with the removal in solution of combined silica, lime, magnesia, soda and potash and with residual accumulation, assisted, no doubt, by capillary action, metasomatic replacement and segregated changes of a hydrated mixture of oxides of iron, aluminium and titanium with more rarely manganese. These oxides and

hydroxides of iron, titanium, aluminium and manganese are denoted by the lateritic constituents.

3. The residual rock is true laterite and the presence of any considerable proportion of non-lateritic constituents requires an expression in the name as it always indicates want of completion in the process of lateritization. True laterite then consists of 90 to 100% of lateritic constituents."

In the process of work carried out during the survey for the British Aluminium Co. Ltd., it was found necessary to distinguish sharply between aluminous varieties and in view of the economic importance which the proportion of silica in the ore plays, a further expansion of the nomenclature was drawn up. The term 'laterite' is therefore restricted to ferruginous varieties. In order to enlarge on this it is necessary to refer to work carried on by the author in Johore, Malaya.

It was found that in plotting the values of the percentages of silica, iron and alumina against depth that iron and alumina were antipathetic. This was established by plotting the analyses for 2 ft. samples from over 100 pits in the Batu Pahat area. The curve shown in fig. plotted from a pit at Parit Wak Lahu in the same area is typical.

SIMPANG RENGAM JOHORE MALAYA

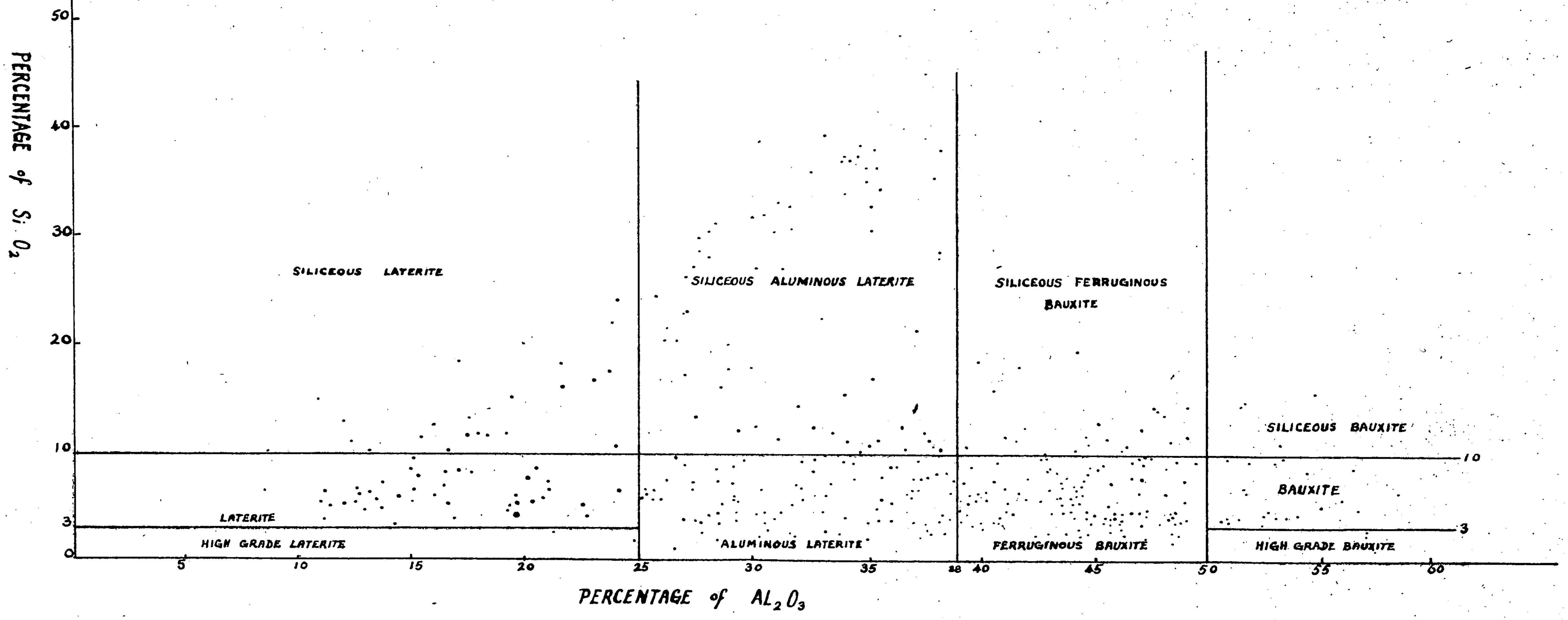


DIAGRAM SHOWING NOMENCLATURE OF LATERITIC DEPOSITS

Bearing in mind this antipathetic relation-ship between iron and alumina, the composition of 300 specimens of laterite from Simpang Rengam district of Johore with respect to alumina and silica were plotted and the following nomenclature drawn up and based on an alumina silica basis.

% Alumina	% Silica	Name.
50 +	0 - 3	high grade bauxite.
50 +	3 -10	bauxite
50 +	10 +	siliceous bauxite
38 - 50	0 -10	ferruginous bauxite
38 - 50	10 +	siliceous ferruginous bauxite
25 - 38	0 - 10	aluminous laterite.
25 - 38	10 +	siliceous aluminous laterite
0 - 25	0 - 3	high grade laterite.
0 - 25	3 -10	laterite
0 - 25	10 +	siliceous laterite.

Titanium in all these specimens ranged from 0.8% to 1.28%. Manganese of the order of .15% was general. In no case, either in Malaya or Sarawak has the manganese content been found to be more than 1.31% They do, therefore, not affect this nomenclature.

Products of Weathering.

The Tertiary sandstones of the Pueh area gave as a final product a highly siliceous laterite in which the constituents were free quartz and limerite. Silica averaged 63% and iron 23%. This was the average for 18 specimens analyzed. The iron was present as limonite.

The Tertiary mudstones of the Sebako valley were hardly affected by weathering, a reddish yellow clay being formed to a depth of 7 ft. in six pits when the unweathered mudstone penetrated.

The granites gave a siliceous ferruginous bauxite in which corroded hypidiomorphic grains of quartz occurred together with pseudomorphs of limonite and haematite after biotite, the remainder of the material being gibbsite.

Schists at Sematan gave rise to high grade bauxites averaging 58.37% Al_2O_3, 11.21% Fe_2O_3, 29.54% H_2O and 1.06% SiO_2 for 800 samples.

The gabbro at Bt. Gebong gave three bauxites depending on their altitude. Above the 750 ft. marine erosion level, high grade bauxite occurred with 63.08% Al_2O_3 and 1.06% SiO_2. This rock consisted of segregated patches of white gibbsite alternating with patches of yellow limonite. On examination under the microscope, the gibbsite was found to form pseudomorphs after plagioclase. The limonite formed corrugated laths and is presumably derived from ferromagnesian elements of the gabbro.

Below the second marine erosion level and above the 300 ft. level, the bauxite averaged 50.1% Al_2O_3 and 4.8% SiO_2. It should be pointed out that below the screes on the cliff face formed along the western slopes of G. Gebong boulders of gabbro were found with a skin of bauxite, 3 ft. to 6 inches thick in which the gabbro passed abruptly into high grade bauxite and that the mottled white yellow effect due to the formation of gibbsite and limonite was very conspicuous.

Below the 300 ft. level, bauxite of poorer grade averaging 7.21% silica and 49% alumina is found.

The igneous rocks of Tanjong Pandan, Tg. Pelandok, and G. Angus gave a yellow fine-grained slightly ferruginous bauxite averaging 49% Al_2O_3, and 6.21% SiO_2. Under the microscope the ore showed small oolitic grains of limonite, gibbsite and a little diaspore.

The siliceous schists of Sungau Pasir and Biawak gave in general siliceous aluminous laterites in which Al_2O_3 averaged 30% and silica 15%. To the east of G. Puting siliceous ferruginous bauxite were found averaging two feet in thickness.

The quartzites and slates of the Tanjong Datu peninsula together with the quartzites of Gunong Puting gave siliceous laterites in which 40 to 60% of the product ~~with~~ was silica. It was found that the slates rarely weathered to a laterite, the general product being a yellowish stiff mottled clay with in one or two pits a few softish nodules.

In general it can be said that bauxite will be produced as the end product if the Al:Fe ratio in the original rock is greater than 2:1.

Succession through the weathered zone.

The following account is chiefly based on the bauxite deposit at Munggu Belian as it was found to be general for most areas.

In general the succession is as follows, tthe thickness of the zones being dependent on the amount of weathering.

4. Reddish to yellow siliceous clay.

3. Reddish to yellow clay with hard nodules and boulders of laterite and bauxite.

2. Reddish to yellow clay with soft largish nodules and boulders of soft lateritic material, these concretions getting larger and softer with depth until they merge into a bed of

1. Mottled clay, generally red, yellow and white. This bed increases in hardness with depth, and assumes gradually the character and hardness of the weathered rock.

In sedimentary unmetamorphosed rocks these zones are thin and pass rapidly from one to the other. The slates on G. Panggi and the southern slopes of G. Melanau the whole sequence is exposed in pits 6 ft. deep whereas on G. Gebong and Munggu Belian near Sematan, zone 2 was found in pits 98 ft. and 68 ft. deep respectively. In P. Bintan near Singapore a shaft sunk through bau bauxite into the unweathered rock penetrated 164 ft. 4 ins. before bedrock was reached.

The following description is given for deeply weathered sections on Munggi Belian. The brown to yellow siliceous clay varied from 0 to 4 ft. 6 ins. and is a light brown to reddish brown stiff clay with rootlets in the upper six inches, generally siliceous averaging roughly 60% SiO_2, and also highly ferruginous. This clay generally forms the oxerburden to economic sites of bauxite and is of no economic value.

The zone with hard nodules and concretions of bauxite varies at Munggu Belian from 5 ft. to 16 ft. , consisting of a reddish clay with pebbles, nodules and small concretions of pink to grey and reddish bauxite in which the percentage of nodules caries from 48 to 93. The clay is more highly siliceous than the nodules and also the iron content is higher. The nodules are fine grained and consist of small oolitic grains of gibbsite with reddish yellow patches due to limonite. The silica content throughout these nodules is fairly constant until the bottom two feet are reached when it increases very rapidly from ±4% to ± 25%.

The nodules get larger with this increase in silica and an admixture of softer and larger nodules of presumably only partially formed pebbles of laterite occur.

Zone 3 consists of an admixture of reddish to greyish coloured clay with larger nodules of this softer semi-consolidated bauxite and is of considerable thickness. In no bauxite site in Sarawak was this zone penetrated although two pits went down to 65 ft. at Munggi Belian and one at G. Gebong went down to 93 ft. The general characteristics are that the nodules get larger with depth and eventually they grade into a massive deposit of similar constitution. The composition of these nodules corresponds to that of a mixture of kaolin and limonite. At 36 ft. below the level of zone 2, these pebbles take on a schistose habit which becomes more pronounced with depth. These pebbles are well jointed, the joints being coated with limonite and in a few cases the joints were slickensided.

As previously stated Zone 4 was not penetrated at Munggi Belian or at G. Gebong but was seen in pits sunk to the east of G. Puting where the upper three zones were attenuated. It consisted of a hard white, red and yellow clay with a schistose habit and in pit 161 was seen to pass into weathered schist.

Chemical analyses for the upper three zones are given in the following tables:-

Depth	Zone	Stratigraphical details	Sample depth	SiO_2	Fe_2O_3	Al_2O_3	H_2O
0'0'-0'3	4	Brown clay with humus					
0'3-1!6	4	Brown clay					
1'6-6'6	3	Brown clay with nodules of high grade bauxite	1'6-2'6	1.18	17.28	52.80	28.74
			2'6-3'6	0.89	21.04	49.17	28.90
			3!6-4'6	0.78	19.04	50.64	28.60
			4'6-5'6	0.81	21.36	49.25	23.58
			5'6-6'6	0.77	21.12	49.97	28.14
6'6-7'6	3	Yellowish brown with abundant pebbles	6'6-7'6	5.88	12,16	53.48	28.48
7'6-8'6	Transition	Yellowish brown clay with admixture of hard and soft pebbles.	7'6-8'6	13.27	11.36	49.07	26.30
8'6-43'	2	Greyish brown clay with soft angular clayey grey pebbles.	8'6-9'6	10.68	18.08	46.33	24.94
			9'6-10'6	16. 0	20.00	41.92	21.72
			10'6-11'6	26.13	22.72	32.61	18.58
			11'6-12'6	32.94	21.20	28.70	17.16
			12'6-14'6	25.05	28.72	30.07	16.16
			14'6-16	26.18	24.88	31.60	17.34
			16'-18'	27.79	24.00	31.61	16.70
			18'-20'	.30.11	23.60	29.29	17.00
			20'-22'	29.90	20.64	31.14	18.52
			22'-24'	33.36	19.76	30.16	16.72

Sample depth	SiO_2	Fe_2O_3	Al_2O_3	H_2O
24'-26'	23.75	21.36	36.47	18.42
26'-28'	27.86	22.00	32.04	18.10
28'-30'	44.55	17.28	20.99	17.18
30'-32'	32.49	20.64	29.81	17.06
32'-34'	35.72	19,28	15.92	34.92
34'-36'	35.86	20.80	28.32	15.02
36'-38'	43.38	17.68	25.12	13.84
38'-40'	37.91	19.92	27.84	14.32

Pit No.6 Munggi Belian.

Depth	Zone	Strati-graphical horizon	Sample depth	SiO_2	Fe_2O_3	Al_2O_3	H_2O
0'0-0'4	4	Brown clay with humus	2'-4'	1.73	18.80	50.51	28.96
			4'-6'	1.48	20.00	49.86	28.66
0'4-11'9	3	Brown clay with abundant small pebbles of pink to grey cesicular oolitic bauxite.	6'-8'	1.11	20.08	49.15	29.66
			8'-10'	1.49	21.04	49.73	27.74
			10'-12'	2.74	21.42	47.44	28.40
11'9-14'11	3	Brown clay with few pebbles interspersed.	12'-14'	4.59	23.44	44.68	27.30
14'11-16'1	Tr.	Brown clay with mixed soft and hard, and hard pebbles.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			14'-16'	13.87	20.32	41.67	24.14
16'1-18'	2	Greyish brown clay with angular pebbles of soft grey alayey material.	16'-18'	28.15	21.28	31.87	18.70

Depth	Zone	Stratigraphical horizon.	Sample depth	SiO_2	Fe_2O_3	Al_2O_3	H_2O
18'-40'8	2	As for 16'-18' but proportion of clay decreasing considerably with depth.	18'-20'	35.91	18.72	21.47	16.90
			20'-22'	36.48	19.44	26.84	17.34
			22'-24'	25.50	18.40	28.14	17.96
			24'-26'	36.05	20.96	29.43	13.86
			28'-30'	36.11	20.72	29.29	13.88
			30'-32'	26.88	19.52	39.74	13.86
			32'-34'	38.55	17.44	30.89	13.32
			34'-36'	38.05	20.96	27.97	13.04
			36'-38'	35.83	20.64	29.87	13.66
			38'-40'8	38.80	17.44	29.32	14.24

The average composition of this bottom zone is

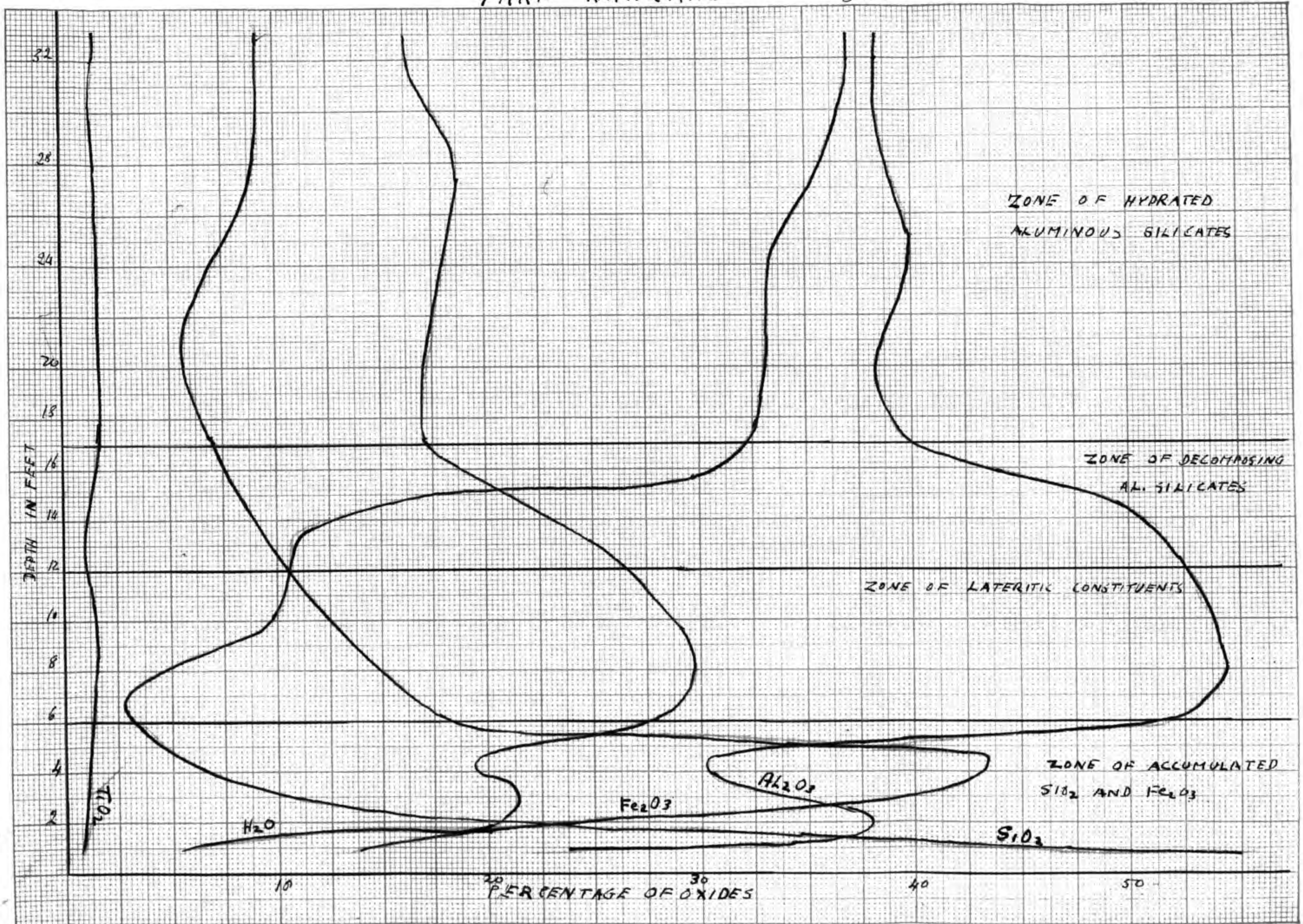
SiO_2 35.73; Al_2O_3 30.11; H_2O 14.69 and Fe_2O_3 19.47

The results for Pit 6 when plotted as oxides against depth show that at 40' limonite has already formed (confirmed by the presence of limonite in joints and as patches seen under the microscope) and that the alumina is present as kaolin to a depth of 20 ft. At this depth the kaolin breaks down into gibbsite (the curves for H_2O and Al_2O_3 are sympathetic) and silica which is leached out.

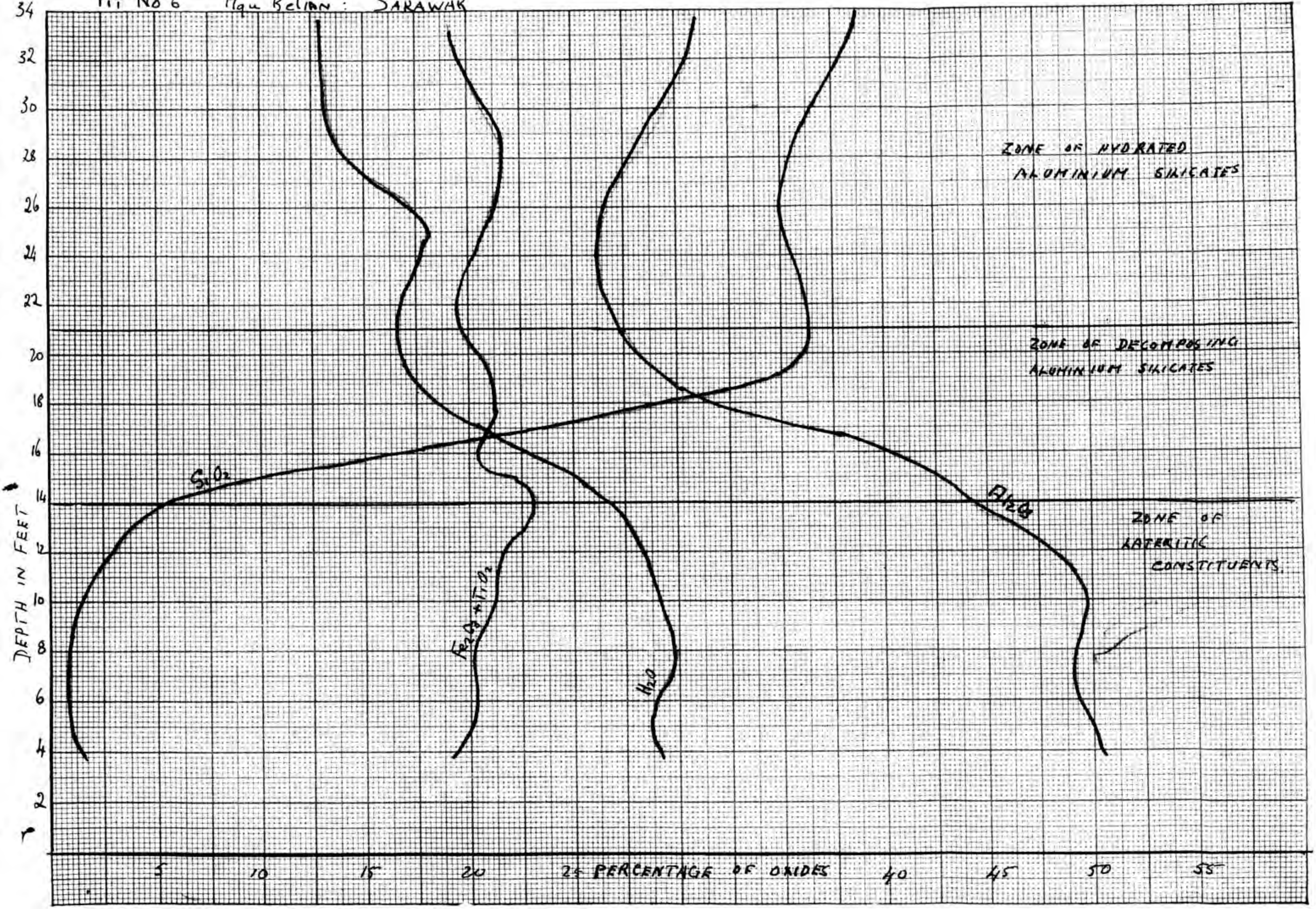
Analysis of ground water at Munggu Belian in the Company's laboratory in Singapore showed 2.8 parts of SiO_2 per million.

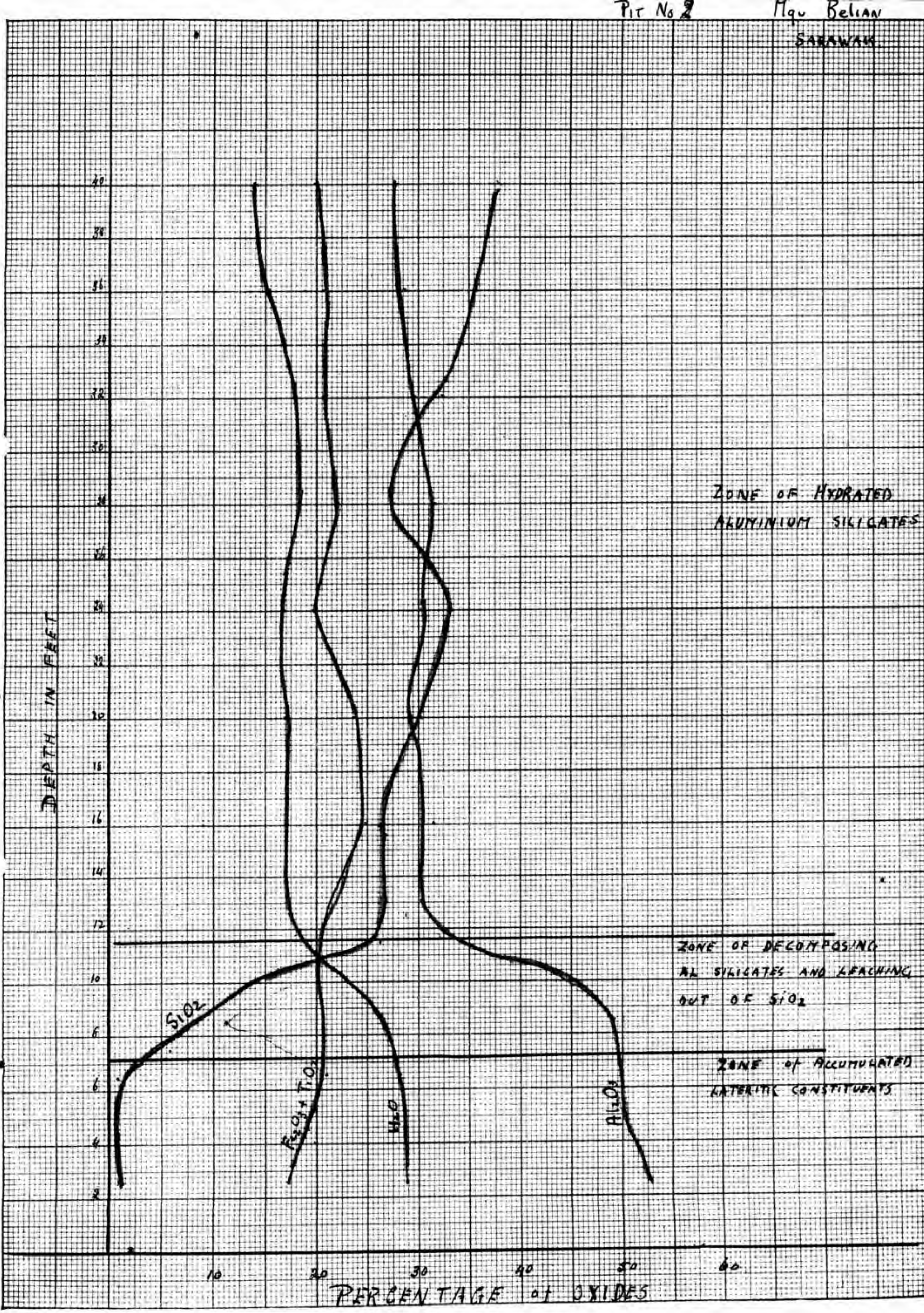
The graph shows that limonite is present as such in zones 2 and 3, the percentage remaining at approximately the same concentration throughout. Removal of the silica leads to concentration of the gibbsite.

PARIT WAK LAHU BATU PAHAT JOHORE



Pit No 6 Mau Belian : Sarawak





PIT No 2
Mgu Belian
SARAWAK
ZONE OF HYDRATED ALUMINIUM SILICATES
ZONE OF DECOMPOSING AL SILICATES AND LEACHING OUT OF SiO_2
ZONE of ACCUMULATED LATERITIC CONSTITUENTS
SiO_2
$Fe_2O_3 + TiO_2$
H_2O
Al_2O_3
DEPTH IN FEET
PERCENTAGE of OXIDES
10
20
30
40
50
60

It is possible therefore to classify these stratigraphical zones on a chemical basis. This is shown below:-

Chemical zone.	Stratigraphical zone	Ref. to Pit 6.
Zone of accumulated silica.	4	0'0-0'4
Zone of accumulated lateritic constituents	3	20'4-14'
Zone of breakdown of hydrated aluminium silicates.	Transition zone between 2 and 3	14'-20'
Zone of hydrated aluminium silicates	2	20'-40'3

Zone 1 presumably corresponds to a zone in which complex aluminium silicates are broken down into hydrated aluminium silicates and has not been encountered in the Mungu Belian or G. Gebong site. Bedrock is referred to as a zone of complex aluminium silicates.

This sequence of events is found to be general in the Sematan area for complete sequences of weathered rock in which bauxite is produced as the end product.

Factors which are involved in the formation of laterites.

The following are believed to be the principal factors affecting the formation of high grade laterites or bauxites:-

(a) The chemical nature of the parent rock.

It has already been pointed out that rocks whose constituents are high temperature minerals are those which are consequently metastable at ordinary temperatures are deeply affected by weathering. It is found by observation that rocks which have been exposed to tropical weathering for a sufficiently long period of time to enable the process to reach completion that the following will be the final products:-

Rocks in which Al:Fe > 2:1, and free silica is restricted to not more than 5% or so will give a bauxite of ore grade.

Rocks with a Al:Fe > 2:1, in which a fair proportion of free silica occurs will generally give a siliceous bauxite.

It appears from the author's observation that SiO_2 formed as such from direct breakdown of silicate minerals is removed in solution whereas free silica is hardly affected by the process of weathering. This can be proved at Gunong Sebarat where granite with a free silica content of 14% (established on a microscope slide) and which lies above 750 ft. marine erosion level produces a siliceous bauxite in which free silica is present to the extent of 13.5%

Gabbro on the adjoining G. Gebong which contains no free silica weathers to a high grade bauxite with only 1.06% SiO_2 (average)

Rocks with Al:Fe less than 2:1 will generally give aluminous laterites or siliceous as the case may be again bearing the quantity of free silica in mind.

(b) The physical nature of the parent rock.

It stands to reason that a highly jointed or highly permeable rock will be more rapidly attacked by the agents of chemical decay than a rock which is relatively impermeable to solutions carrying these agents.

(c) Temperature and Climate.

That weathering will proceed more rapidly at a high temperature than at a low temperature is evident from the fact that nearly all chemical reactions are considerably speeded up with increase of temperature.

A climate of alternating dry and wet seasons is necessary. During the wet season an ample supply of humic and carbonic acids which are regarded as being the principal agents of destruction in chemical weathering is provided, causing the breakdown of the parent rock into hydrated simple silicates and the subsequent breakdown of the latter into the lateritic constituents. During the dry season, the silica, magnesia, soda, potash, lime etc., are leached out.

Rainfall.

A substantial annual rainfall is necessary in order to provide an ample supply of carbonic and humic

Time.

That time is an important factor can be realised on Gunong Gebong, where three levels of marine erosion have been found, each associated with bauxite of different grade, the oldest with high grade ore and the youngest with a marginal grade ore, the oldest being also the thickest and the younger the thinner. To produce a 16' bed of bauxite which contains 60% of Al_2O_3 means that 65 ft. of gabbro has been subjected to chemical decay. If 54% of this rock is silica, this represents a thickness of 35 ft. of SiO_2. If this is removed in a solution of a concentration of 2.8 parts per million, then 12.5×10^6 feet of water are required. This at a fair average of 150 inches of rainfall a year represents a period 1,000,000 years which takes us to the beginning of the Pleistocene, which according to van Bemmelen is when the submergence of the old Sunda continent took place.

Finally it should be stated that it is the author's belief that tropical weathering is not a special form of chemical weathering but that it is merely chemical weathering carried to its conclusion. The author believes that the formation of stable aluminium silicates characteristic of temperate climates as a result of weathering is merely an arrested stage of the process which probably owing to insufficient rainfall or too low a temperature is not able to proceed to completion.

The author also believes, in spite of views stated to the contrary by many other authors that the formation of kaolin is an essential step in the formation of a bauxite. He bease his conclusion on the examination of over 2,000 sections through weathered rocks involving aluminous compounds in Malaya and Sarawak and in every case where calculation on chemical analysis for the beds underlying bauxite have been carried out; these lower beds can be shewn to be mixtures of kaolin and iron compounds.

PART VII.

As stated previously the Sematan area together with the western seaboard of Borneo forms part of the old Sunda continent which at the beginning of the Pleistocene times descended beneath the waves.

A comparative table is included with the maps which accompany this thesis showing the geology of the various zones of the old Sunda continent and which brings out the principal points of resemblance and difference.

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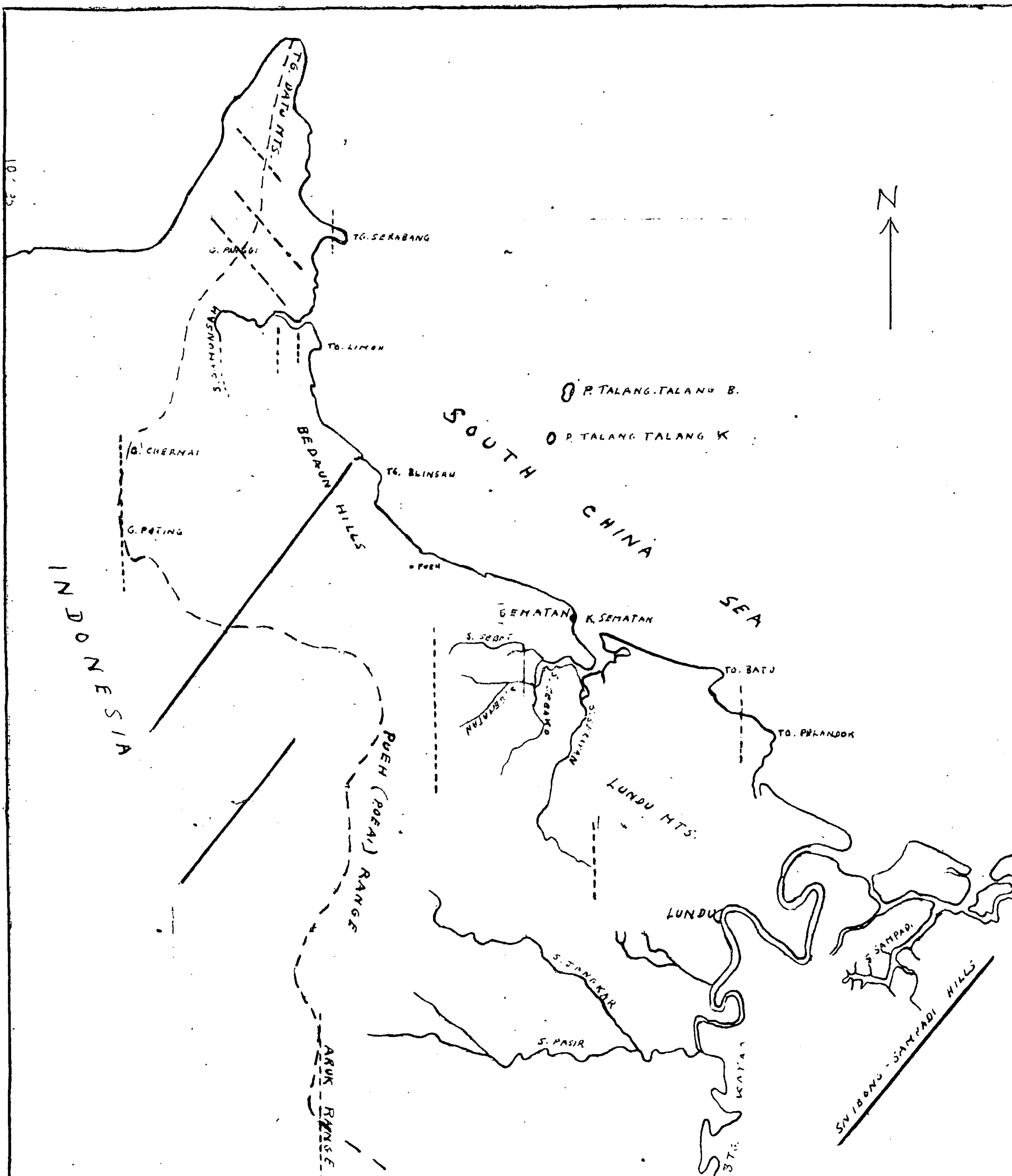


Fig. 2 Scale 1: 253,440

MAP SHOWING STRUCTURAL TRENDS IN THE LUNDU DISTRICT

TERTIARY (NE - SW

LATE JURASSIC - EARLY CRETACEOUS (N53°W - S53°E)

PERMIAN AND CARBONIFEROUS (N - S)

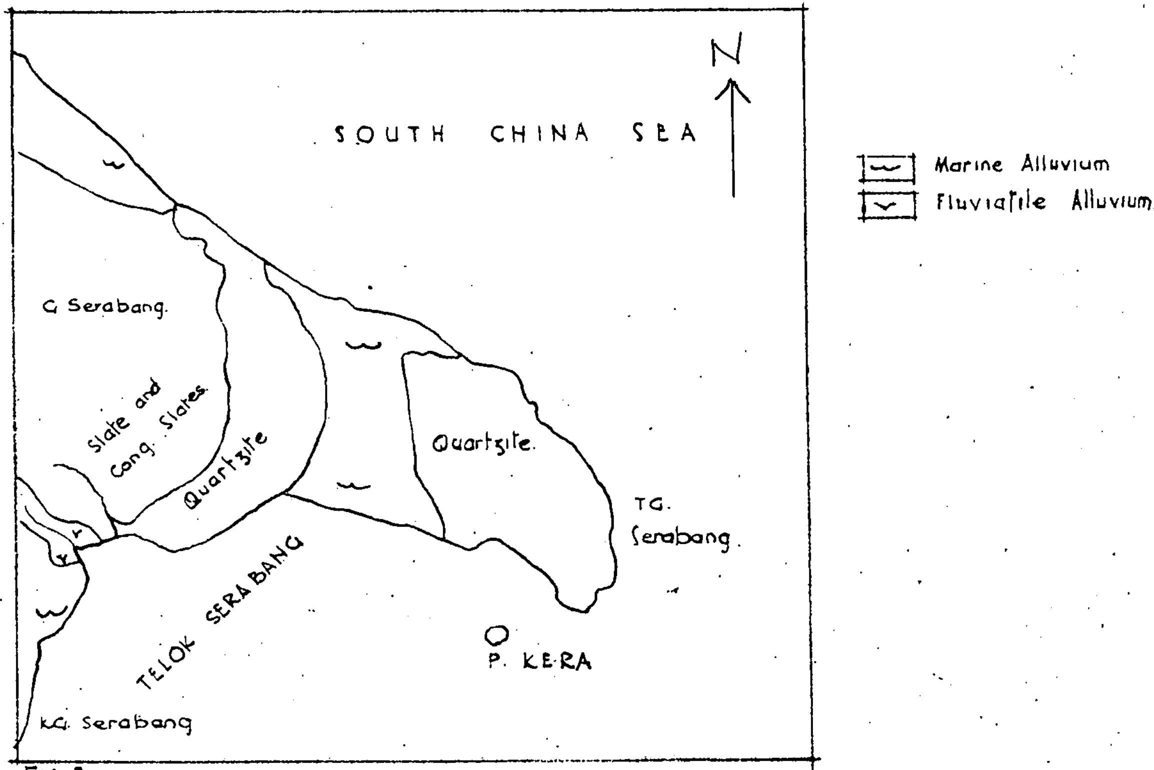
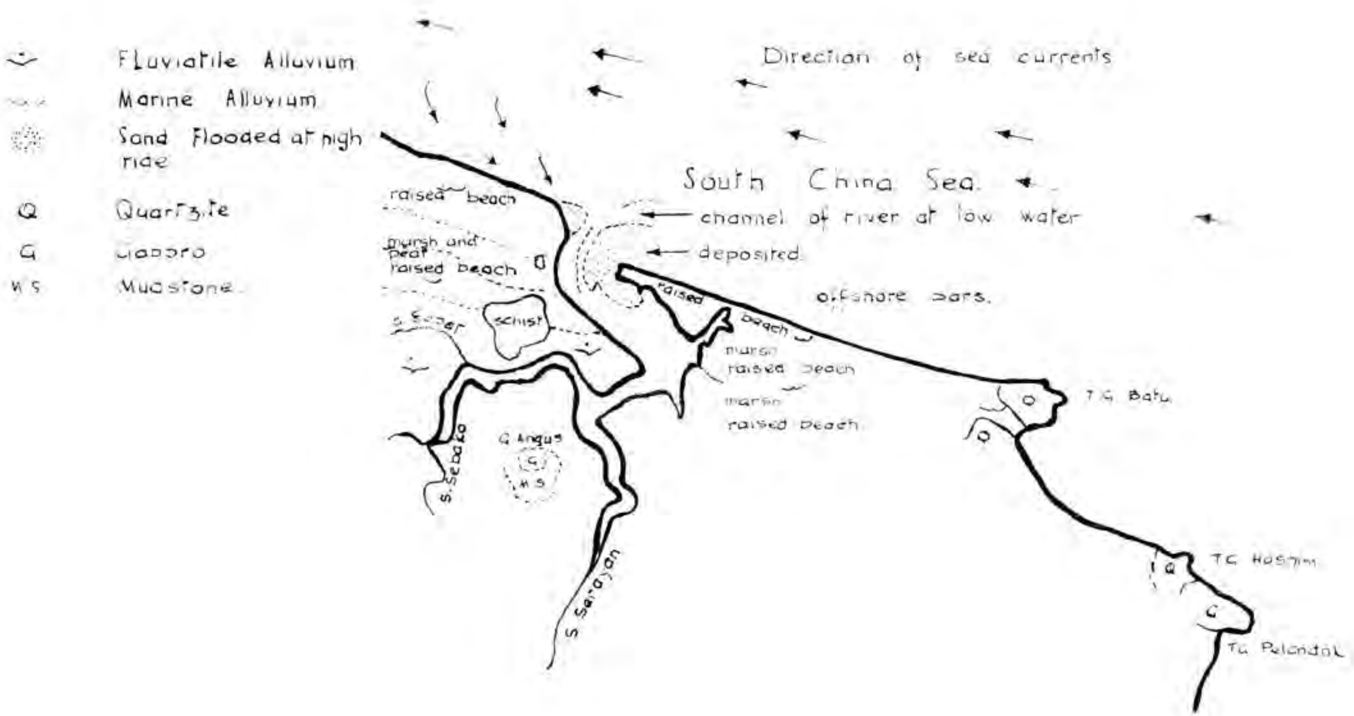


FIG. 3
MAP SHOWING MARINE CHANNEL AT TANJONG SERABANG Scale : 1/25,000



Sketch map of Sematan area to show area of present coastal erosion on west bank of river and deposition on east bank

Disposition of recent sediments also shown.

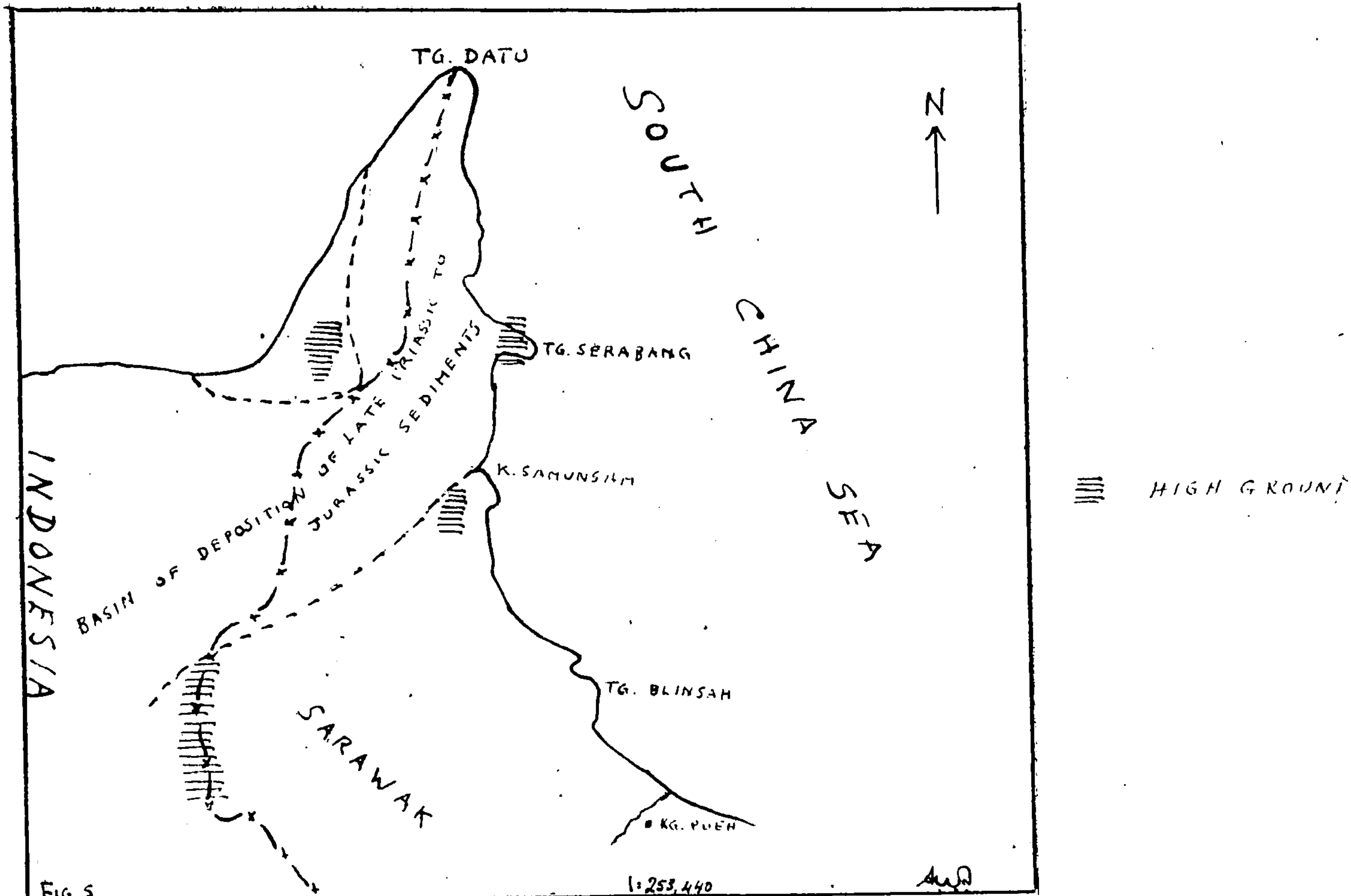
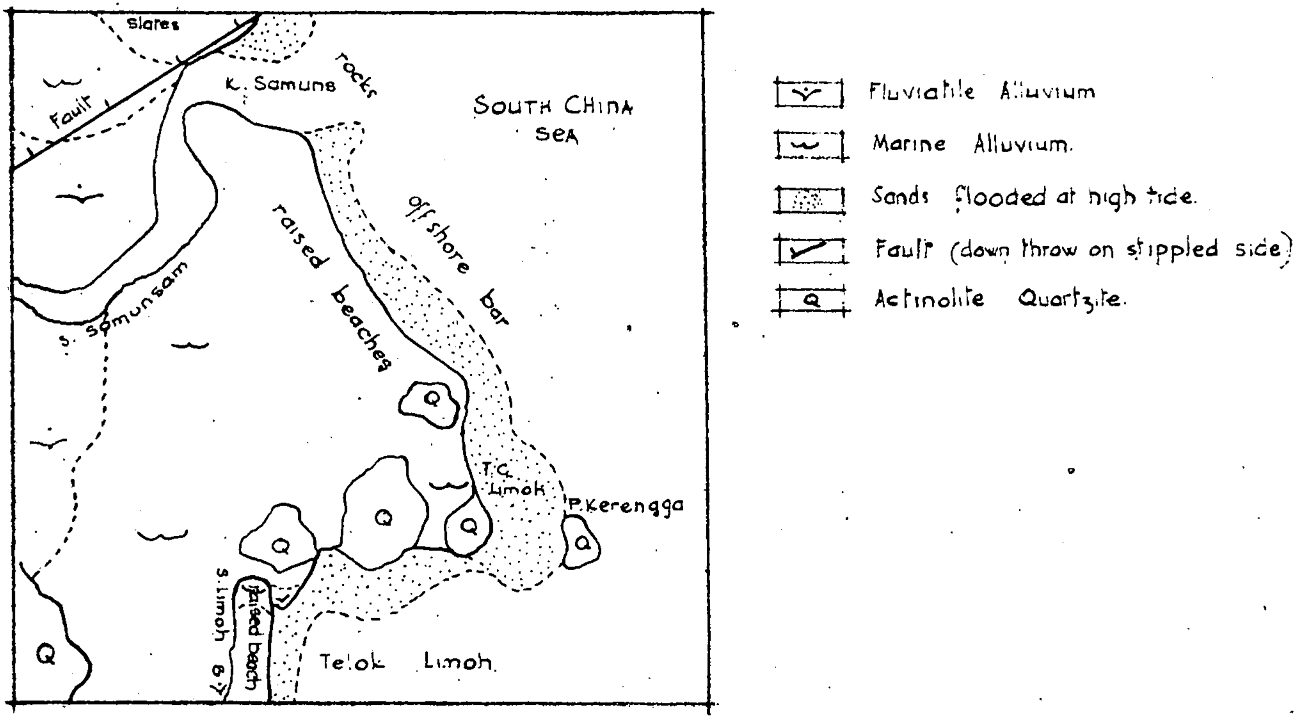
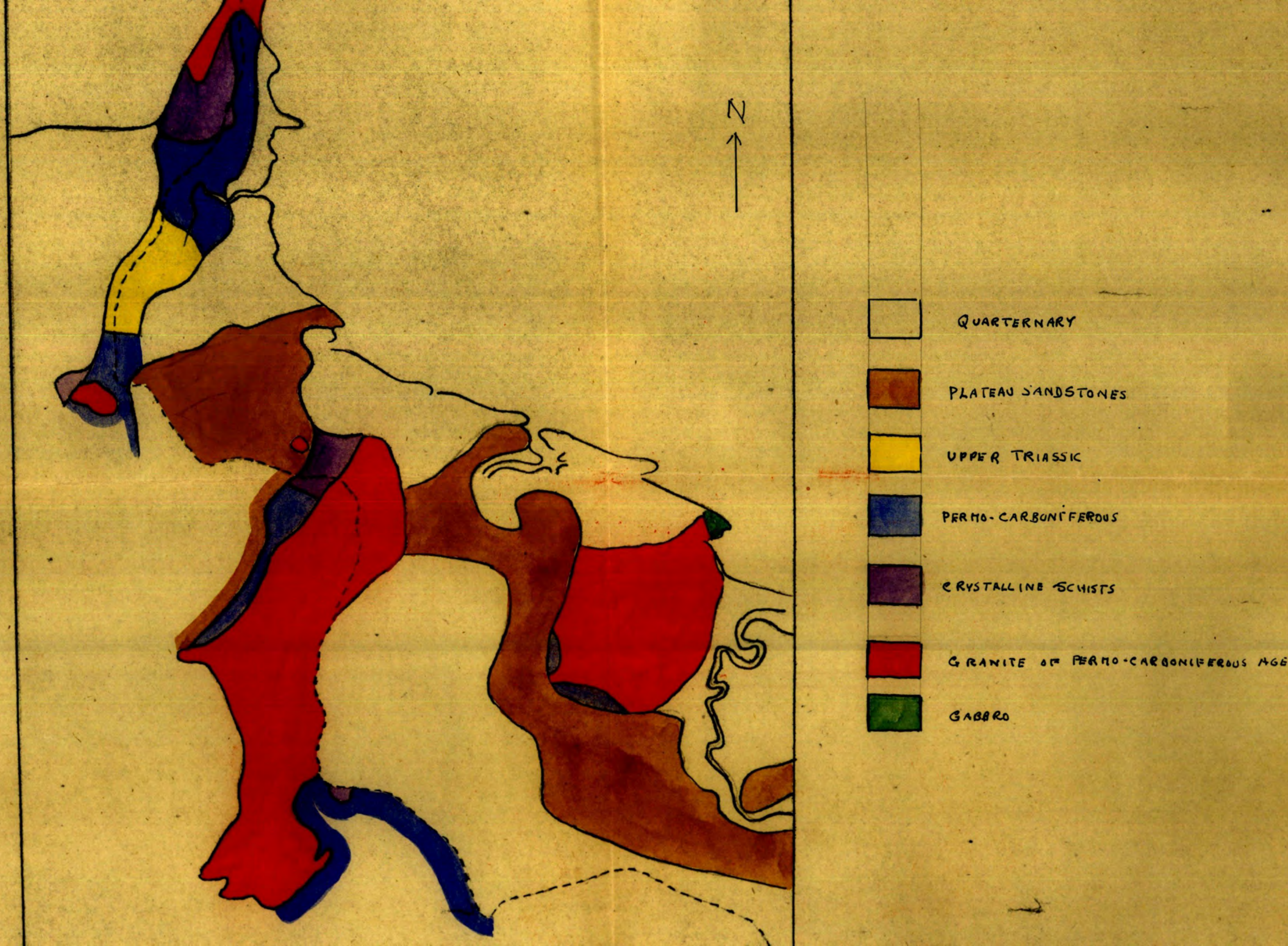


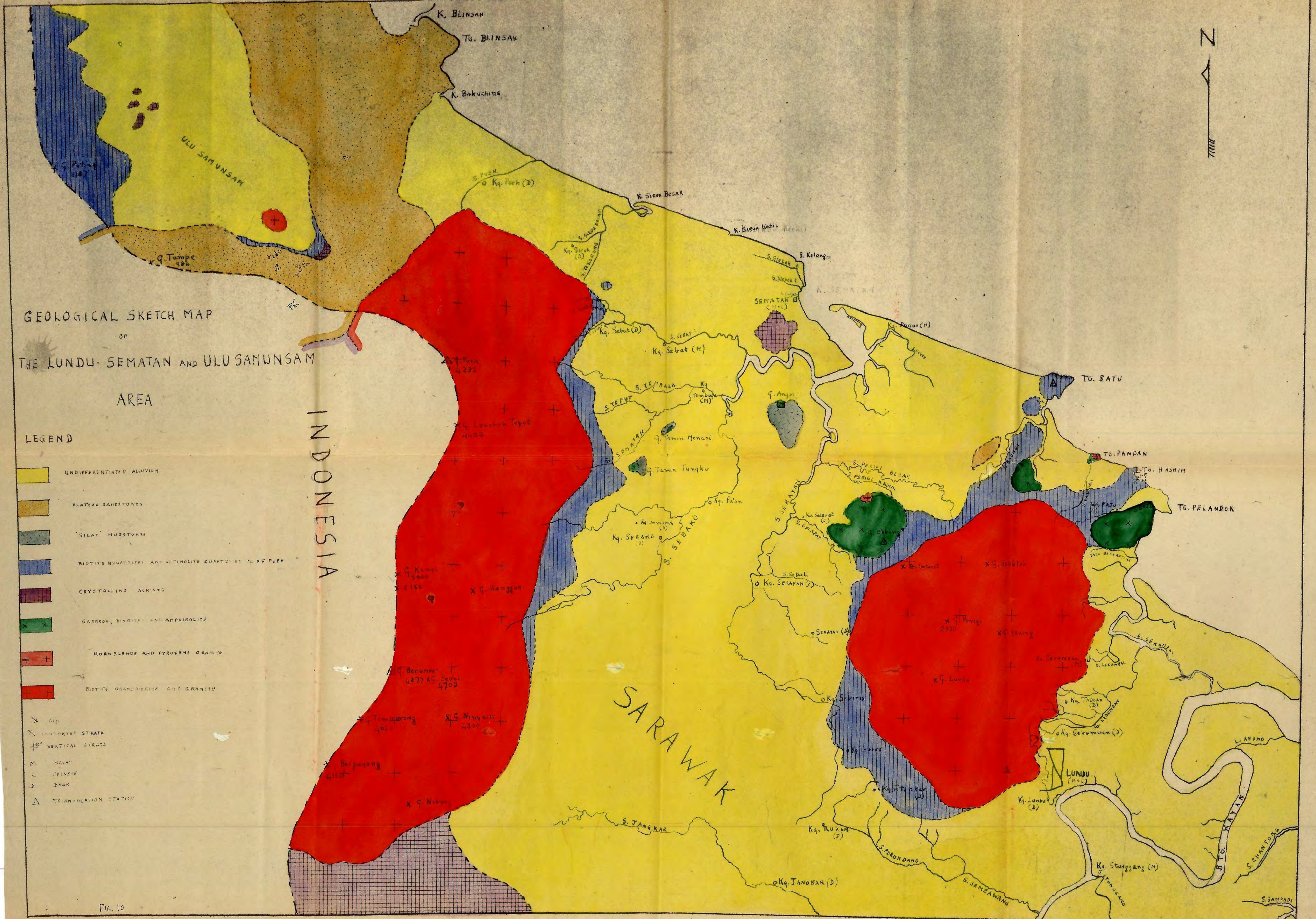
FIG. 5

MAP SHOWING BASIN IN WHICH LATE TRIASSIC TO JURASSIC SEDIMENTS ACCUMULATED



MAP TO SHOW ADDITION of PULAU KERENGGA TO MAINLAND AT T.G. LIMOH AND DISTRIBUTION of RECENT SEDIMENTS.


N
QUARTERNARY
PLATEAU SANDSTONES
UPPER TRIASSIC
PERMO-CARBONIFEROUS
CRYSTALLINE SCHISTS
GRANITE OF PERMO-CARBONIFEROUS AGE
GABBRO


GEOLOGICAL SKETCH MAP
OF
THE LUNDU-SEMATAN AND ULU SAMUNSAM
AREA
LEGEND
UNDIFFERENTIATED ALLUVIUM
PLATEAU SANDSTONES
'SILAT' MUDSTONES
BIOTITE QUARTZITES AND ACTINOLITE QUARTZITES N. OF PUEH
CRYSTALLINE SCHISTS
GABBROS, DIORITES AND AMPHIBOLITES
HORNBLENDE AND PYROXENE GRANITE
BIOTITE GRANODIORITE AND GRANITE
VERTICAL STRATA
MALAY
CHINESE
DYAK
TRIANGULATION STATION
N
INDONESIA
SARAWAK
ULU SAMUNSAM
K. BLINSAH
TG. BLINSAH
K. Bakuching
K. SIRUH BESAR
K. Siruh Kecil
S. Kelong
SEMATAN
Kq. Pagua (M)
TG. BATU
TG. PANDAN
TG. HASHIM
TG. PELANDOK
LUNDU
S. JANGKAR
Kq. JANGKAR (D)
S. SEMBAWANG
S. STUNGGANG
BTG. KAYAN
S. CHANTONG
S. SAMPADI
Kq. Puch (D)
G. Tampe
G. Puting
Kq. Sebat (M)
S. TEMBAWA
S. TEPUT
G. Tamin Menari
G. Tamin Tungku
Kq. SEBAKO
S. SEBAKO
S. SERAYAN
Kq. SERAYAN
G. Angus
S. PERIGI BESAR
Kq. Rukam
Kq. Sempadi
G. Nibong
SARAWAK
FIG. 10

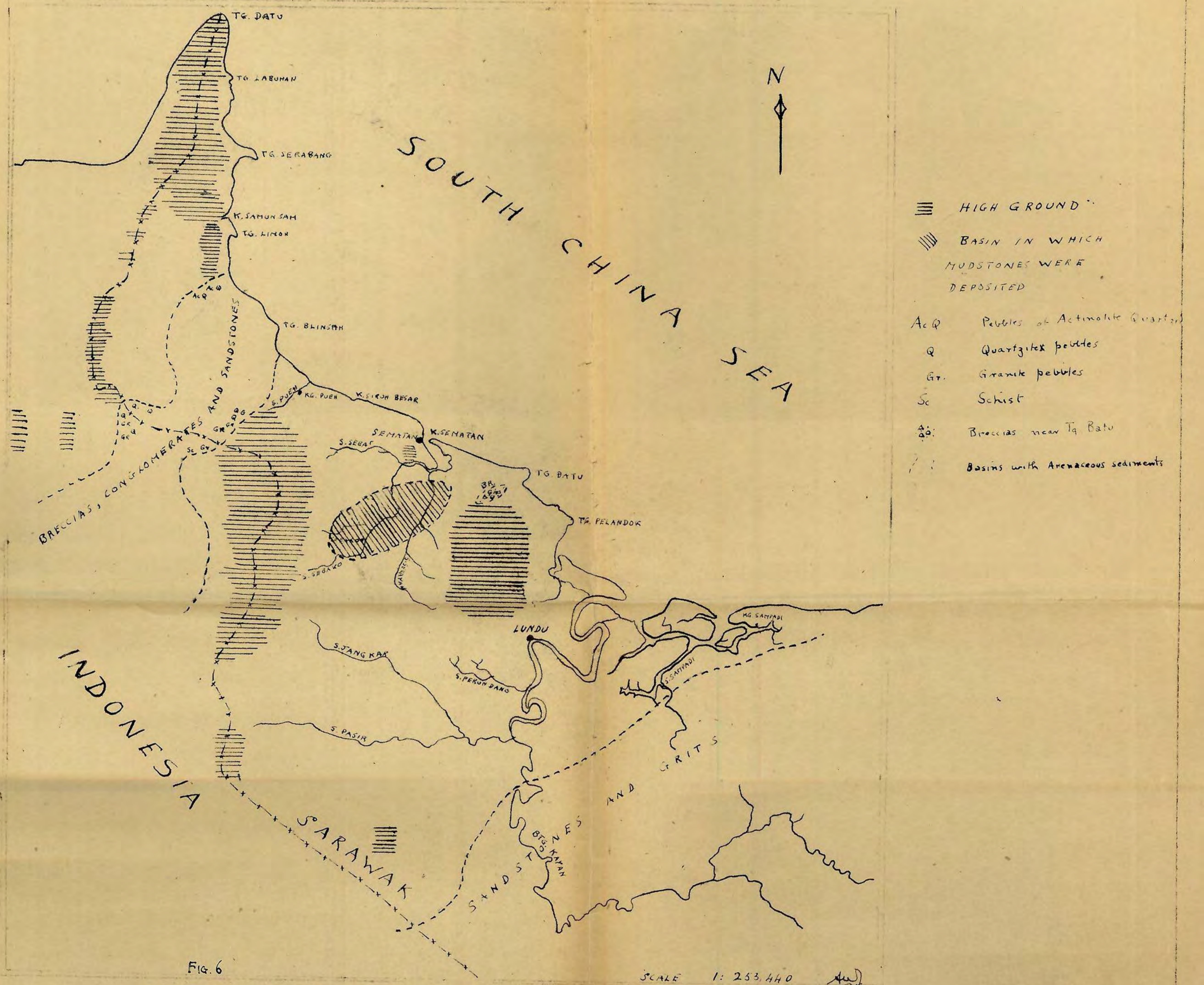


FIG. 6

MAP SHOWING DISTRIBUTION OF TERTIARY BASINS OF DEPOSITION.

AND DISTRIBUTION OF HIGH GROUND AT THE END OF THE MESOZOIC ERA

COMPARATIVE TABLE.
SHOWING ZONES of THE SUNDA CONTINENT AND ITS GEOLOGY.

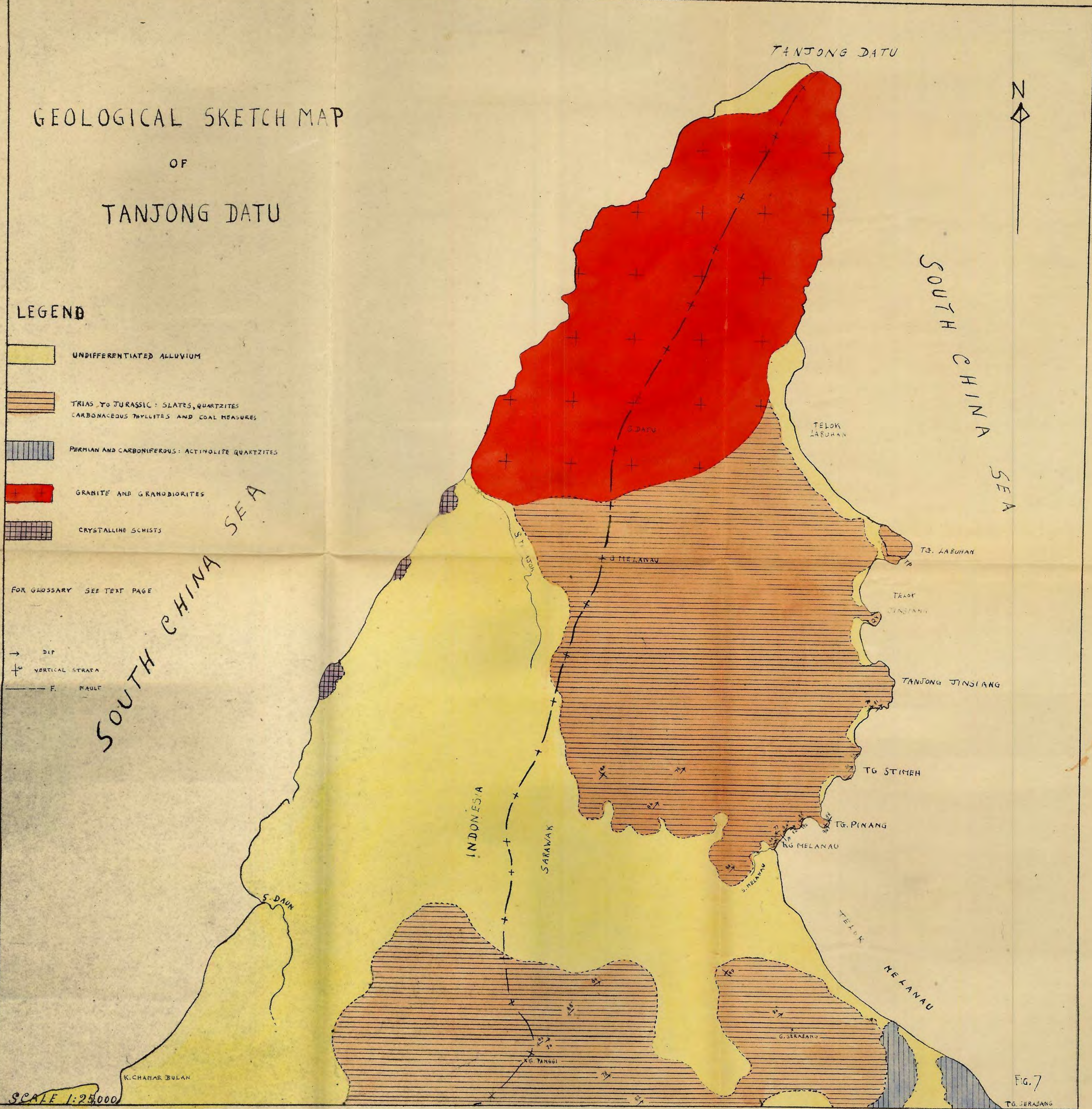
SYSTEM.	ZONE α (SEMATAN - PALOH - NATUNA) SEDIMENTATION.	ZONE α IGNEOUS ACTIVITY.	ZONE α METAMORPAISM and EARTH MOVEMENTS	ZONE β (ANAMBAS & SCHWANER AXIS) SEDIMENTATION.	ZONE β IGNEOUS ACTIVITY.	ZONE β METAMORPAISM and EARTH MOVEMENTS.	ZONE γ (KETAPANG & KARIMATA) SEDIMENTATION.	ZONE γ VOLCANIC ACTIVITY.	ZONE γ IGNEOUS INTRUSION	ZONE d (MALAYA) SEDIMENTATION.	ZONE d VOLCANIC ACTIVITY.	ZONE d IGNEOUS INTRUSION.
QUARTERNARY	2nd Marine Stage ∿∿∿∿∿∿ 1st Marine Stage both at Sematan ∿∿∿∿∿∿	Extrusion of Basalt at Midal and Nioet	Epeirogenetic movements							Quarternary marine sediments		
TERTIARY Upper												
Middle			Epeirogenetic movements accompanied by gentle folding along NE-SW arcs		Extrusion of dacites andesites and basalts on G. Rajah			Acid - intermediate calc-alkaline volcanic rocks		?	Extrusion of basalts near Kuantan (Fitch)	
Lower	Plateau sandstones and silat shales			Brackish water facies of Mtlawi sencs: Continental Plateau sandstones: Silat shales			Lower tertiary sediments presumably present			∿∿∿∿∿∿ Coal series of Batu Arang Selangor & Nyior Johore		
PRE TERTIARY Cretaceous												
Jurassic	∿∿∿∿∿∿	Intrusion of Biotite Granodiorites and Granites	Thermal metamorphism	∿∿∿∿∿∿					Intrusion of Biotite Granite, Riebeckite-aegerine-Granite & Aplite Granite			Intrusion of Tin bearing Granites, Granite porphynes etc., accompanied by Folding movements
Upper Triassic	Coal Measures Slates and Quartzites, Slatey Conglomerates		Dynamic metamorphism Structures trending NW - SE	Phyllites Sandstones and Shales	Extrusion of acid to intermediate volcanic rocks	Dynamic metamorphism	KEPATANG SERIES Varigated Sandy Shales of Flysch Facies Calcareous Sediments believed to be Parms. Carboniferous image	MATAN COMPLEX		Arenaceous Series of W. Malaya	PAHANG VOLCANIC SERIES	
Lower Triassic												
Parmian and Carboniferous	∿∿∿∿∿∿	Intrusion of Pyroxene and Hornblende Granites, Diorites and Gabbros	Dynamic - Cum-thermal metamorphism (Structures trending N-S)	∿∿∿∿∿∿	Intrusion of Quartz Diorites, Diorites and Granites	Dynamic-Cum-Thermal metamorphism			Intrusions of this Age probably present			Granite not known in situ but pebbles of Granite found in agglomerate on P Nanas Singapore (Serivenor) ? Intrusion of Gabbro in S. Johore
	Quartzites and Shales at Sematan: Radiolarites, Siliceous and Argillaceous Rocks on Natuna	Extrusion of basic Volcanic Rocks on G. Asoeansang and Natuna		Quartzites and Siliceous Cherts, Radiolarites, Hornfelses and Cornubianites	Extrusion of Basic Silicified Volcanic Rocks		Perms - Carboniferous sediments presumed present			Calcareous Series and Slates & Phyllites. Arenaceous Series of Langkawi Islands		
? Devonian	∿∿∿∿∿∿		Regional metamorphism	∿∿∿∿∿∿		Regional metamorphism				? Arenaceous formation of Main Range Port Hills (Richardson)		
	Chrystalline Schists			Chrystalline Schists			Chrystalline Schists presumed present					

AFTER A. W. ALLEN (1950)
R. W. VAN BEMMELEN (1939)
A. CHR. de BOTHÉ (1928)

AFTER ZEYLMANS VAN EMMICHOVEN (1934)
A. CH. de BOTHÉ (1928)

AFTER R W VAN BEMMELEN (1939 & 1949)

AFTER E. S. WILLBOURN, F.T INGHAM & OFFICERS OF THE MALAYAN GEOLOGICAL SURVEY AND ALSO FROM T. B. SERIVENOR (1931)


GEOLOGICAL SKETCH MAP
OF
TANJONG DATU
LEGEND
UNDIFFERENTIATED ALLUVIUM
TRIAS TO JURASSIC : SLATES, QUARTZITES CARBONACEOUS PHYLLITES AND COAL MEASURES
PERMIAN AND CARBONIFEROUS : ACTINOLITE QUARTZITES
GRANITE AND GRANODIORITES
CRYSTALLINE SCHISTS
FOR GLOSSARY SEE TEXT PAGE
DIP
VERTICAL STRATA
F. FAULT
TANJONG DATU
N
SOUTH CHINA SEA
SOUTH CHINA SEA
G. DATU
TELOK LABUHAN
G. MELANAU
TG. LABUHAN
TANJONG JINSIANG
TG STIMEH
TG. PINANG
KG MELANAU
S. MELANAU
TELOK MELANAU
INDONESIA
SARAWAK
S. DAUN
G. SERASANG
G. PANGGI
K. CHAMAR BULAN
TG. SERASANG
SCALE 1:25,000
FIG. 7

GEOL. MAP I

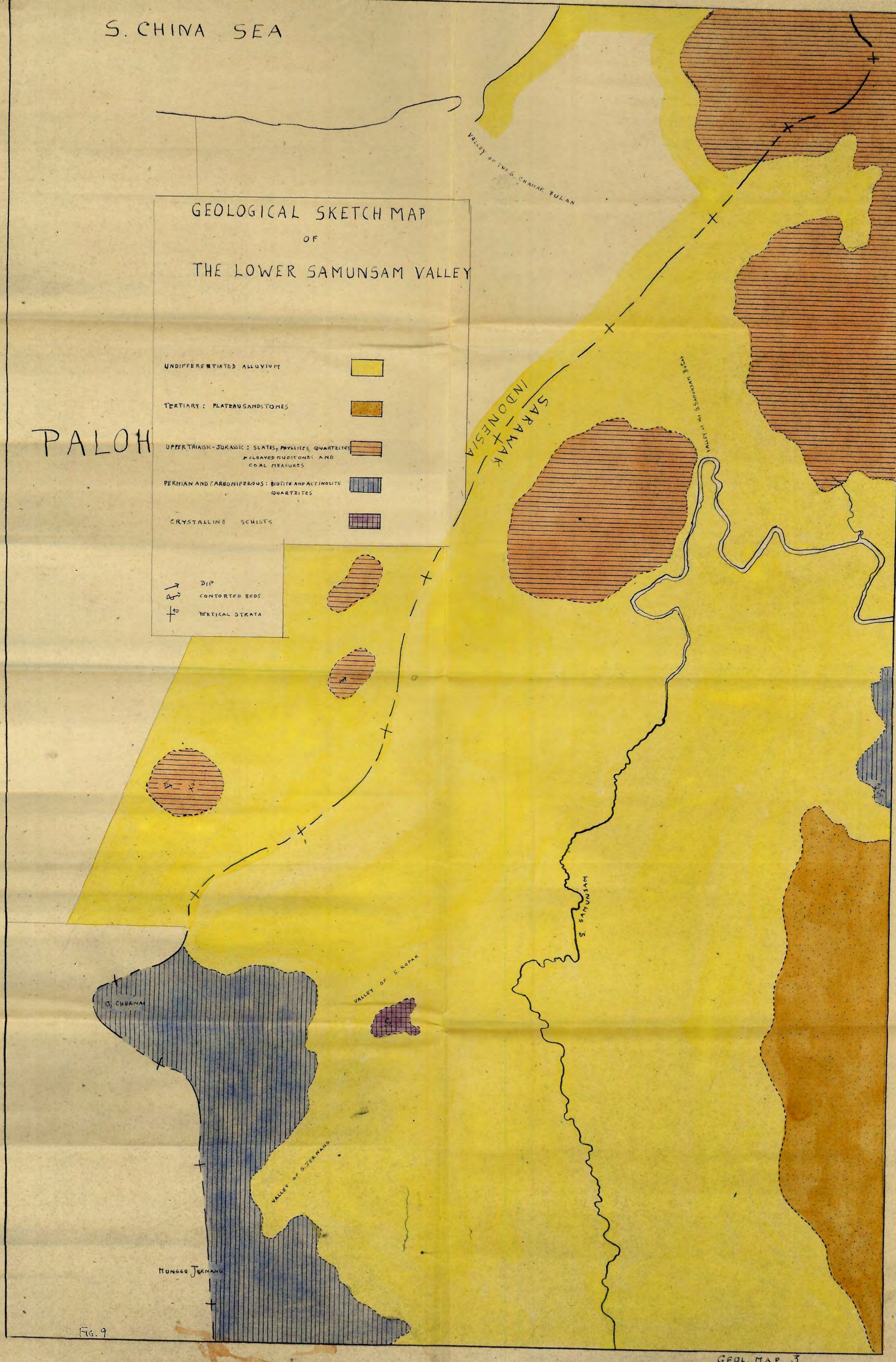


Fig. 9

GEOL. MAP 3

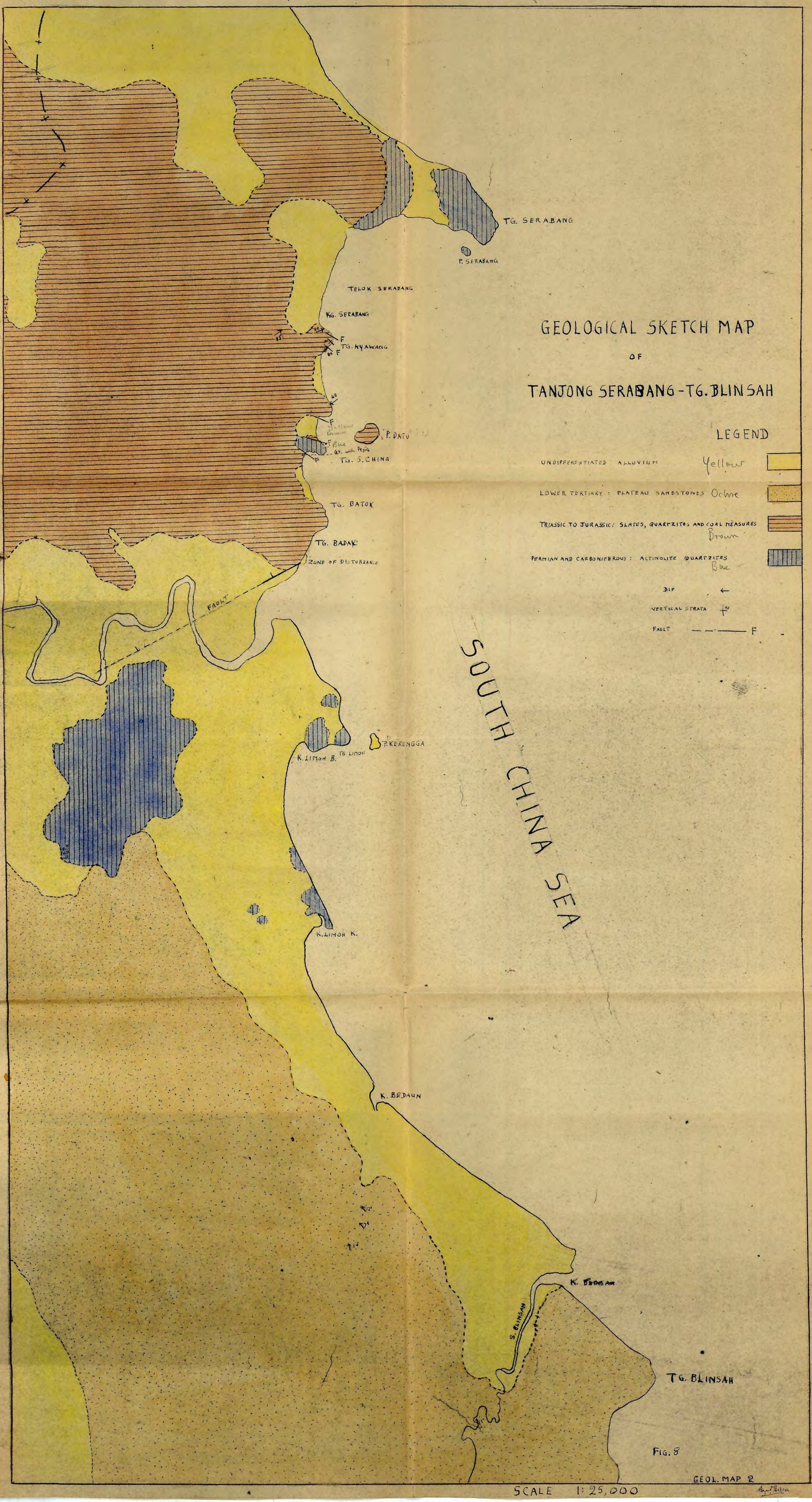


FIG. 8

SCALE 1: 25,000