THE REPUBLIC OF INDONESIA
REPORT ON THE COOPERATIVE MINERAL EXPLORATION
OF
SOUTHERN SUMATRA

PHASE I

FEBRUARY 1986

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

The Government of Japan, in response to the request extended by the Government of the Republic of Indonesia, agreed to conduct a metallic mineral exploration survey in the Southern Sumatra , and commissioned its implementation to the Japan International Cooperation Agency.

The agency, taking into consideration the importance of the technical nature of this survey, sought the cooperation of the Metal Mining Agency of Japan in order to accomplish the contemplated task.

The Government of the Republic of Indonesia appointed the Directorate of Mineral Resouces to execute the survey as a counterpart to the Japanese team. The survey is being carried out jointly by experts of both Governments.

The initial phase of the collaboration survey consists of geological and geochemical surveys for metallic mineral exploration.

This report summarizes results of the initial phase of the survey, and it will also form a portion of the final report that will be prepared with regard to the results to be obtained from the completed survey.

We wish to take this opportunity to express our gratitude to both sides concerned in the execution of the survey.

February , 1986

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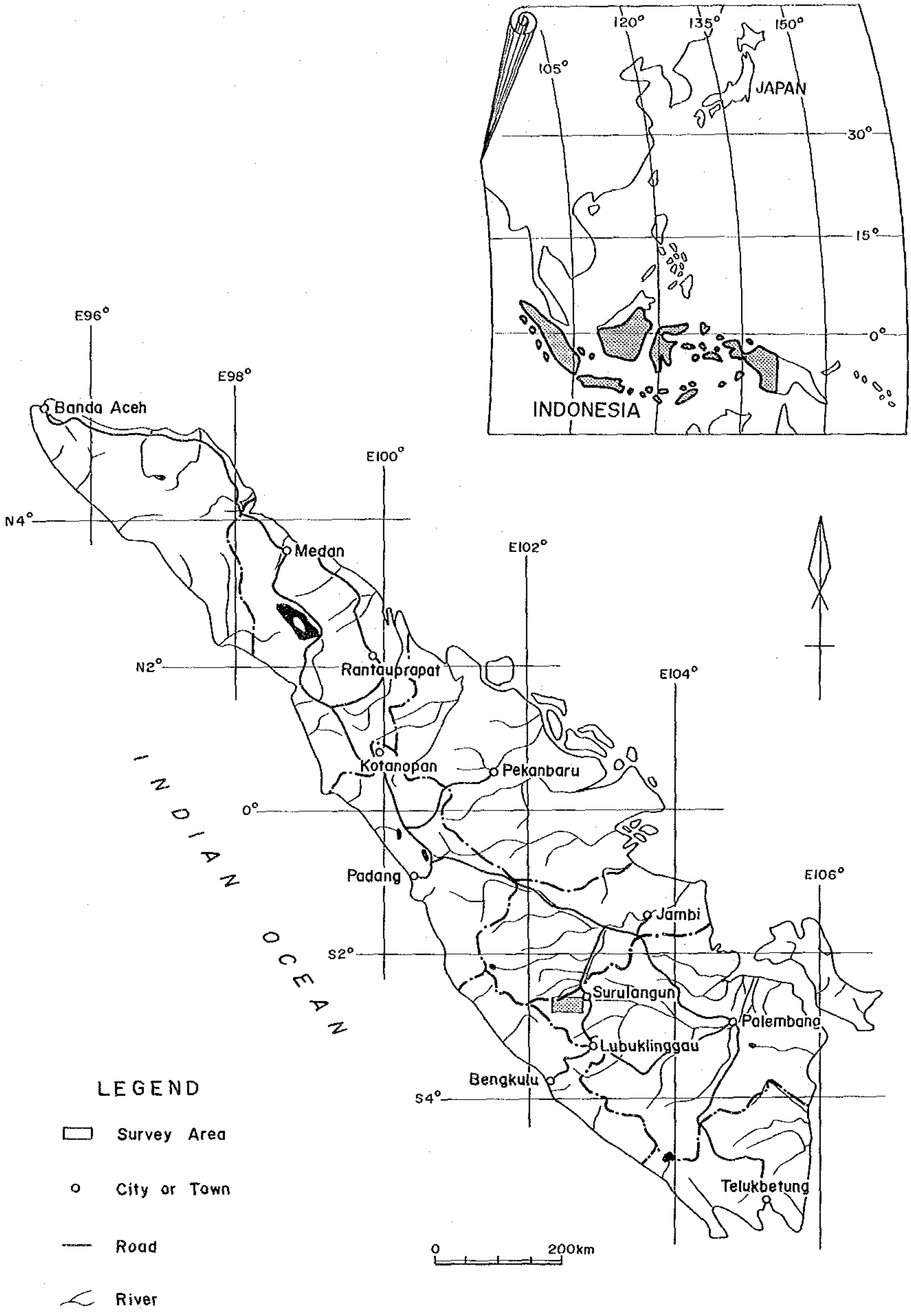

Fig. 1 Index Map of the Surveyed Area

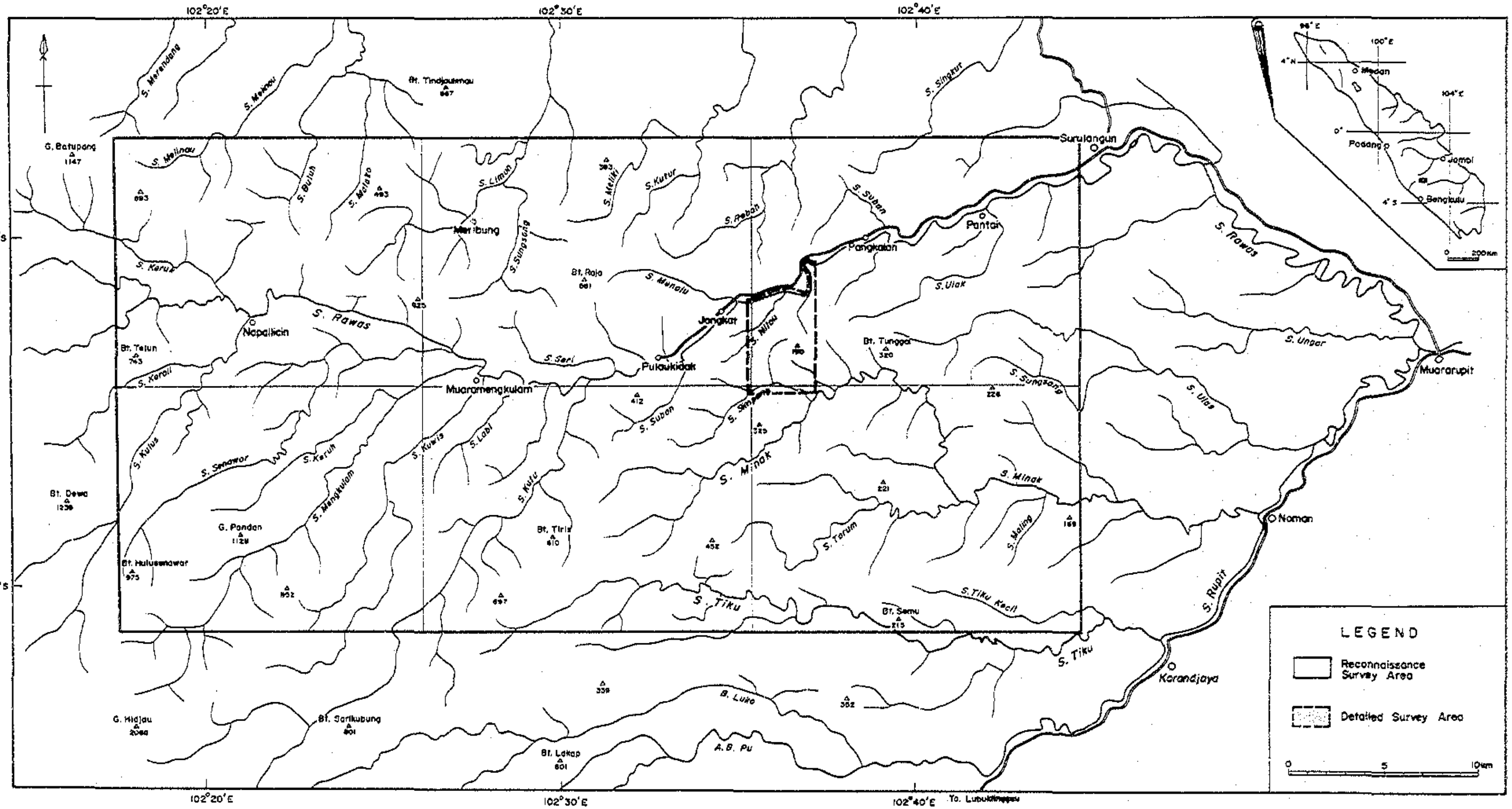

Fig. 2 Location Map of the Surveyed Area

SUMMARY

The initial phase survey consisting of geological and geochemical surveys was extensively conducted in area of 1,250 km^2 to aim at unraveling occurence and emplacement condition of non ferrous metallic ore deposits in a part of South Sumatra. As the result, following two areas have been selected successibly for the promising area.

1 The S.Tuboh area : Lead-zinc-copper-silver ore bearing skarn deposits are expected.

2 The Bt. Raja area : Iron-copper ore bearing skarn deposits are expected.

The project area of South Sumatra is composed of Mesozoic and Cenozoic Systems, and granitoids have intruded into them.

Sedimentary facies are divided into S.Rawas Formation of Jurassic-Cretaceous, S.Kuwis Formation of Cretaceous, Napallicin Formation and Hulusimpang Formation of Miocene, S.Minak Formation of Pliocene, Surulangun Formation and alluvium as a terrace deposit of Quaternary in the stratigraphycally ascending order.

Intrusive rocks consist of middle to late Cretaceous quartz diorite, Paleogene granite, granite porphyry, granodiorite, and quartz monzonite, middle to late Neogene diorite porphyry, and post Jurassic volcanic rocks. The granitoids are distrributed at Bt.Raja and sporadically toward southeast, and are also exposed in S.Senawar area of the west part of the survey area.

Both systems of folds and faults tend predominately to NE-SW direction, and these are present remarkably in the Mesozoic Formation area. In the contrary, a NE-SW fault system exists predominately in the central to southeast part of the survey area. Distribution of intrusive rocks shows the close relationship between these two geological structures and emplacement of the intrusions.

Mineralizations of the survey area are mostly skarn type and some silicifications accompanying by a minor amount of pyrite. The mineral indications of skarn type mineralization are 18 locations in the survey area. Among of them, S.Tuboh indication is small scale/high grade lead-zinc-silver-copper type, and the indications in the Bt.Raja area are iron-copper, and copper- molibdenite and/or iron mineralization.

Ore minerals in the S.Tupoh mineral indication are composed of galena,sphalerite, chalcopyrite and pyrite with remarkable amount of secondary oxide and carbonate minerals. In the Bt. Raja area, magnetite, hematite and chalcopyrite are common, and galena-sphalerite-green skarn type and chalcopyrite-pyrite-molibdenite dissemination are also observed.

Based on the distributions and elongation mode of the intrusive bodies, the relationship between geological structure and mineralization in the survey area is inferred the following geological events ;

(early) formation of NW-SE and NE-SW tectonic lines ⟶ activity of granitoids along the tectonic lines⟶ mineralization related to the granitoid activity (late)

In the detailed survey area, geochemical anomalies largely correspond to the mineral indications. Among of 47 geochemical anomalies in the reconnaissdance survey area, gold geochemical anomamalies are most intensive, and are extensively distributed in the area, supporsing to be related to gold mineralization.

Among of second order anomalies, 4 anomalies of copper, zinc, and lead are corresponded with one pyrite dissemination and two skarn mineralizations, but the rest is not coincided to any mineralization.

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Part 1 INTRODUCTION

Part 1 INTRODUCTION

Chapter 1 Outline of the Survey

1-1. Introductory Remarks

During the past decades, cooperative exploration survey for mineral resources development in the Republic of Indonesia have been carried out in the following areas : North-western Sulauesi (1970~1974), Central Kalimantan (1975~1978), Western Kalimantan (1979~1981) and Northern Sumatra (1982~1985), and a number of basic data for development of metallic mineral resources in the country have been obtained. As a result, significant contribution has been made in improvement of survey techniques to the Geological Survey of Indonesia and Directorate of Mineral Reosources of Indonesia as well as in accumulation of important data for geology and ore deposits in the country.

The Indonesian Ministry of Mines and Energy proposed a new project of mineral resources exploration in South Sumatra to follow the previous project at Northern Sumatra, and requested the cooperation of the Japanese Government. The Japanese Government responsed to the request by dispatching a preliminary survey mission headed by Toshio SAKASEGAWA, Metal Mining Agency of Japan, to Indonesia in August,1985. The mission conducted a preliminary survey as to the proposed survey site, and after discussion with the Directrate of Mineral Resources, Indonesian Ministry of Mines and Energy, which is in charge of the project as the Indonesian counterpart, both side agreed to conduct the cooperative survey at the Southern Sumatra area.

The initial phase programme consisting of photo-geological interpretation, geological and geochemical surveys has been conducted to aim at aquiring some promising traget areas for nonferrous metallic ore deposits. The initial phase survey area consists of a reconnaissance survey area and a detailed survey area, covering 1,232 km^2 and 18 km^2 respectively.

1-2. Survey Schedule and Survey Members

(1) Preliminary Survey and Agreement Negotiation

A survey mission with following schedule was dispatched to Indonesia in order to participate in preliminary field survey and discussion for the planning of Southern Sumatra Cooperative Mineral Exploration Survey, and to make plan for the initial phase programme.

a) period of preliminary survey and agreement negotiation

August 26, 1985 ~ September 7,1985.

b) Member of the Japanese party

Toshio SAKASEGAWA	Metal Mining Agency of Japan
Shotaro KISHIMOTO	Ministry of International Trade and Industry
Atsushi OSAME	Metal Mmining Agency of Japan
Toshihiko HAYASHI	Japan International Cooperation Agency

c) Members of the Indonesian counterpart

Pro.Dr.J.A.KATILI	Director General; Directorate General of Geology and Mineral Resources. Ministry of Mines and Energy
Ir.Salman PADMANAGARA	Director; Directorate of Mineral Resources
Ir.P.H.SILITONGA, M.Sc.	Chief of Metallic Mineral Exploration Division; Directorate of Mineral Resources
Ir.Yaya SUNARYA	Chief of Precious Metal Section; Directorate of Mineral Resources

(2) The initial phase survey

a) Survey period

The initial phase survey was carried out from October 4,1985 to February 28,1986. In Table 1 shows the whole survey programme.

Table 1 Time Schedule of the Survey

Items	'85 Oct.	Nov.	Dec.	'86 Jan.	Feb.	Mar.
Photogeological Interpretation	4 – 12					
Mobilization	14 – 19		28 – 31	8 – 9, 31	1	
Field Survey	20 –	–	– 27			
Laboratory Work				1 – 30, 7 – 10 –	2 –	
Report Writing					– 28	

☐ in Japan ▩ in Indonesia

b) Organization of the survey team

Japanese member

Planning and coordinating	Atsushi OSAME (MMAJ)
Leader	Yoitsu OGUMA (NED)
Member	Hideya KIKUCHI (NED)
	Osamu MIYAISHI (NED)
	Tetsuo SATO (NED)
	Kazuyasu SUGAWARA (NED)

(MMAJ: Metal Mining Agency of Japan)

(NED : Nikko Exploration and Development Co.,Ltd.)

Indonesian member

Coordinator	Ir.Yaya SUNARYA (D.M.R.)
	Pudjo SUDJARWO (D.M.R.)
	Hendro WAHYONO (D.M.R.)
	Ir.Bambang PARDIARTO (D.M.R.)
	Danny Z.HERMAN (D.M.R.)
	Atok S.PRAPTO (D.M.R.)

(DMR : Directorate of Mineral Resources)

1-3. Survey Area

The survey area is situated in the southern part of the Sumatra Island, and is bounded by the following longitudes and latitudes.

Northern line: latitude 2° 36′south
Southern line: latitude 2° 50′south
Eastern line: longitude 102° 44′east
Western line: longitude 102° 17′east

The survey area is almost entirely included in the Province of South Sumatra, though the northwestern corner of the area belongs to the Province of Jambi as administrative division. The whole survey area is shown in Figure 2.

1-4 Methods and Procedures of the Survey

(1) Photogeological Interpretation

The photogeological interpretation employed are as follows. First, drinage pattern are interpreted and compiled on the maps from air- photos. Then geological divisions or tectonical features are interpreted by photo- geological annotation (geological boundry lines, bedding-trace etc.) on the basis of topographical characteristics such as drainage pattern; shape, density, length and resistivity (degree of undulation and erosion) of stream system; valley section, ridge pattern and other lineaments (direction, length, intensity etc.) as well as of some photographical characterisitics such as tone of colour and disposition.

(2) Geological and Geochemical Surveys

Base camp was set at the Pulaukidak village situated in the central part of the survey area, and the survey was carried out by schedule of 7 to 12 days per a survey trip from the base camp. Topographic maps used were of scale 1:20,000 enlarged from maps of 1:100,000 in scale. As occasion demands, some route maps were drawn up by means of clinometer compass and of measuring by step distance. On the other hand, in the detailed survey area, enlarged maps of 1:5,000 provided from the maps of 1:20,000 as route-survey maps, and maps made by means of step distance or measure tape using clinometer compass, or traverse-survey method were used for detailed survey .

Stream sediments of the geochemical survey were systematically collected from under 80 mesh size, getting along with the geological survey. In the reconnaissance survey area the sampling was made at a rate of two samples per 1 km stream length (in traverse length), while in the detailed survey area at a rate of four samples per 1 km except portions with remarkable meandering. Some soil samples were also collected in the detailed survey area. The samples collected are listed in Table 2.

Some trenches and pits were also dug out to obtain more substantial information on geology and mineralization in the detailed survey area.

The geological data obtained were compiled principally on the maps of 1:20,000 in scale in the reconnaissance survey, and of 1:5,000 in scale in the detailed survey area.performed.

Table 2 Working Conducted

Reconnaissance area		
Surveyed area	1,232	km^2;
Traverse length	835	km
Rock sample * collected and selected	50	pcs(Whole rock analysis)
for laboratory analysis	5	pcs(age detrermination)
	50	pcs(thin section)
	30	pcs(x-ray analysis)
Collected and selected stream sediments	1,600	pcs(12-elements) * *
Detailed area		
Surveyed area	18	km^2;
Traverse length	40	km
Rock sample * collected and sellected	30	pcs(assaying,7-elements)
Stream sediment collected and selected	150	pcs(12-elements) *
Soil sample	65	pcs(2-elements) * * *
Dug pit	15	places(32.9m)
Dug trench	9	places(151.4m)
Soil stripped	17.5	m * (1 - place)
Cleaned up old trench	74.6	m * (5 - places)

* some number of samples from detailed area are included

* * Cu, Pb, Zn, Au, Ag, Hg, Mo, Ni, Co, Cr, As, Li.

* * * as small halo elements, Ag and Pb were selected.

Chapter 2 Outline of the Survey Area

2-1. Geography of the Survey Area

(1) Topography and Stream System

The survey area is situated at the transitional boundary zone between the Barisan mountain range being backbone range of Sumatra Island traversing in NW-SE direction and the Palembang basin field generally low in elevation. The western part of the survey area is high land (in general higher than 500 m above sea-level), while the eastern part is low land (in general lower than 100 m above sea-level). The highest point in the survey area is at the ridge of the G.Pandan, showing 1,445 m above sea-level.

In the central part of the survey area, S.Rawan runs from the southwest towards the northeast, and most streams in the area flow into the S.Rawas. The S. Rawas joins with S. Minak and S. Tiku running from the southeastern survey area,and becomes Air Musi at their downstream.

In the northwestern to northern part of the survey area, a river runs to north, and join with S.Tembesi at outside of the survey area.

(2) Climate

The Sumatra Island belongs to the tropical climatic zone and the annual climate consists of two contrasting seasons, namely rainy season and dry season. The rainy season is generally in months from October to March and the dry season from April to September. During the rainy season, the southwest wind flowing from the Indian Ocean to the East China Sea brings heavy rain-falls in the Sumatra Island. Even in the dry season, however, the northeast wind from the East China Sea to the Indian Ocean sometimes results in heavy rain-falls exceeding 150 mm, depending on geographic situation and topographic condition. It is said that the annual precipitation sometimes exceeds 4,000mm at Padang of the West Sumatra Province.

The atmospheric temperature is quite high in all the year, for example at Padang indicating constantly higher than 27℃.

(3) Transportation

Surulangun, main city of the survey area, reachs from Palembang, capital of South Sumatra Province, or Bungkulu, capital of Bengkuru Province, via Lubuklinggau by car. It takes about 10 hours to reach Lubklingau from Palembang through 380 km of Sumatra travers high way, or 4 hours from Bengkulu through 174km, and additionally 1.5 hours from Lubklingau to Surulangan through 92 km.

Commercial air way enters service daily to Palembang or Bengkulu from Jakarta.

(4) Field Condition

Small villages are sporadically distributed along S.Rawas in the survey area. All of them are thinly-populated, being less than 1,000 persons. Popuration of the inhabitants at Pulaukidak, where the base camp was set up, is merely about 250. There are no villages in isolated places of the mountain lands far from S. Rawas.

A undeveloped area in the survey area is typical tropical forest growing a number of huge trees exceeding 2 m in diameter and 15 m in height. An open lowland field is partly used as paddy fields and sometimes as residence places and as pastures for cattles.

In the survey area is accessible mostly by engine boat installed 12~45 HP engine or small rowing boat along main river, but only by foot in the mountain area.

Harvest of rubber and rice are main product in the area, Some vegitables and fruits are also cultivated, such as pepper, eggplant, yam, cassava, sugar cane, corn, bean, banana, pineapple, papaya, dorian, rambutan, and mango for consumption of local inhabitants.

Lumbering of lauan and rattan are small business by a company and local inhabitants.

2-2. Previous Surveys

BEMMELEN (1949) described and compiled complehensively on the geology and mineral resources of whole Sumatra Island including the survey area. After the publication, a few publication are available on the survey area as following ;

A geological map dealing with Surulangun area was compiled by Kartografi Directorat Geologi (1977) and another latest geological map dealing with the same area compiled by Geological Research and Development Centre (1984) * are available. Both are being prepared to published. Between the two works appears to exist some diffierence in stratigraphic division and notation as well as in exactitude.

As to ore mineralization, the oldest report by DIEKMAN (1917) and a more recent report by Kennecot Indonesia (1971) dealing with geological and geochemical investigations are available. In 1984, D.M.R. also compiled on their internal data on the geochemical investigation.

* In the following, this work is quoted simply as "the Existing Data (1984)".

(1) Description by BEMMELEN (1970)

BEMMELEN described on the general geology of Indonesia in Vol. I A and mineral resources of Indnesia in Vol II of " The Geology of Indonesia" published by him in 1949 and 1970. He briefly mentioned on the geology and mineral resources of the Sumatra Island in the paper. However, from his description in the Vol. I A is found out no detailed geological information directly related to this present survey area.

On the other hand, as to ore deposits (mineral indications), he describes four occurrences of lead and zinc. They are Sungai Tuboh, Aer Kulus, Aer Seri, and Bukit Rajah. Of these Sungai Tuboh belongs to the present detailed survey area and includes mineral indications at Sungai Kering and Sungai Sepan. These details will be described later in Part 3.

a) Aer Kulus: It is Situated at about 55 km SW of Surulangun. A large limestone boulder disseminated with sphalerite was found in Aer Kulus, the originated place of which could not be traced, but it presumably originates from the granite massif in the drainage area of the Aer ※ Kulus area or from the andesitic occurence situated from further up stream (※ The old spellings are used sometimes,i.e.,Aer,Songei,Rajah, but in present are used Air,Sungai and respesectivelyaccording the paper).

b) Aer Seri: It is situated at about 27 km WSW of Surulangun. During gold-panning, it was noticed that a remarkable amount of pyrite, black silver-free sphalerite occured as large fragment in the concentrates. By excavation, a vein or lens of small dimentions, of black, crumbly, pyrite bearing sphalerite was found in an entirely decomposed rock. However a following investigation was not carried out.

c) Bukit Rajah: It is situated at about 28 km SW of Surulangun. In the granite as well as in a contact-zone, veinlets of quartz occur, containing a more or less high percentage of sulphide minerals (pyrite, chalcopyrite, sphalerite, rich in silver). All these minerals occur in the gangue as a cource crystalline, irregular mass; banded structure can only seldom and indistinctly be observed. The galena contains a not unimportant percentage of silver. Sphalerite and galena occur only in a small quantities in a narrow vein on the contact of the granite and clay-schist on the Aer Tamiang, but veins of larger dimentions were not encountered.

(3) Prospecting by Kennecot Indonesia

Kennecot Indonesia carried out reconnassance geological survey and geochemical investigation over the area covering almost entirely the present survey area in 1970, and the final report on the project became available in 1971.
The outline of the report is as follows:

①	Survey period:	1970.4.1～1970.11.30 (8 months) Reconnaissance survey
②	Survey area:	23,000km^2 Block 10: N2° ～N3°, E102° ～103° Block 11: N3° ～N4°, West of 102° 45′
③	Surveyor: (Investigator)	Kennecot Indonesia Co.Ltd. 25 persons (geologic engineers・assistants)
④	Survey quantity:	6,000 samples of stream sediments /17,000km^2; Elements analyzed: Cu, Pb, Zn, Mo, pH value was measured at every sampling site
⑤	Products:	Sampling sites are plotted on a topographic map of 1:100,000. Geological map 1:250,000.

⑥ Survey results

a) In S. Tuboh, S. Kering and S. Sepan, Cu is at the background level, Zn sometimes shows high anomalies sporadically, Mo is not detected.

b) In the Bukit Raja granite, garnet and magnetite contain chalcopyrit e by less than 1 % in volume. According to geochemical prospecting, Cu contents ranges 40～60 ppm, Pb and Zn are at the background levels.

c) Zn anomaly (maximum 450 ppm) is detected at the upstream of S. Kulus, Cu and Pb at the background levels.

d) In Napallicin basin (extending over S. Rawas, S. Kerali, S. Kulus, S. Mengkulam, S. Kuwis), a weak anomaly of Cu (maximum 108 ppm) is detected, Pb and Zn at the background levels.

e) In S. Kutu, a high Pb anomaly reaching 630 ppm is detected, Zn and Cu at the background levels.

f) In the upstream of S. Kutu, weak anomalies of Cu, Zn and Pb are detected.

g) In S. Kuwis, a weak anomaly of Zn is detected.

⑧ Synthetic conclusion: There is no possibility to continue of the next phase.

(3) Survey by D.M.R. (I)

Survey by Danny et al of D.M.R.

Area:	230km^2, samples collected; 728 piecies
Period:	S. Tiku ; May ~June, 1984 (40 days)
	S. Mengkulam ; July ~October, 1984 (80 days)
	Topographic map used;1:50,000
Summary;	Sites of mineral indications 1:50,000
Conclusion;	Unknown

(4) Survey by D.M.R. (II)

Area;	615 km^2 and 330 km^2
Period;	October,1983
Samples;	147 pieces (stream sediments)
Conclusion;	Unknown

The data are reffered to report by Johnny R.Tampubolon after Prospeksi Logan Mulia dan Logan Dasar di Daerah Rawas Ulu, Sumatera.

(5) Survey by D.M.R. (III)

Most part of the area investigated is out of the present survey area, though in 1984 Yaya Sunarya and others made a local survey at a area including the stream basin of S. Tiku. Conclusion is unknown.

2-3. Geological Outline of the Survey Area

As mentioned above, no surveys have so far been carried out concentrating especially to the project survey area and/or its vicinity. Therefore, in the following is briefly reviewed the geological outline of the South Sumatra, on the basis of available descriptions by BEMMELEN (1970) and HAMILTON (1978).

" The oldest formation in the South Sumatra consists of crystalline schists, gneisses and granitic rocks, though their exact ages are still unknown. The oldest fossil-bearing formation in the Sumatra Island belongs to the Permo-Carboniferous System. Although the Upper Triassic System is widely distributed, neither middlen nor lower Triassic Systems have been recognized in the South Sumatra. (In the western part of the Central Sumatra, the Triassic System is considered to overlie conformably the Permian System.) The Jurassic System is distributed probably much more widely than currently recognized. The Lower Cretaceous System consists of two kinds of sedimentary facies, namely the deep-sea facies and shallow-brackish facies. The deep-sea facies includes thinly-laminated siliceous shales, tuffaceous sandstones, radioralian cherts and limestons containing *Orhitolina* sp. On the other hand, the shallow-brackish facies consists of volcanic rocks and pyroclastic rocks with intercalated reef limestones." On the basis of the above observations, BEMMELEN (1970) has reconstructed the pre-Tertiary geologic and tectonic development in the South Sumatra as follows.

" Geosynclinal sediments are predominated in the Upper-Paleozoic and Mesozoic formations, especially in the former. It thus appears that the South Sumatra at that time was a fore-deep formed in relation to the Malaya orogeny. In the fore-deep were then deposited a thick piles of deep-marine and shallow-marine sediments. A large-scale orogenic momvement brought about during the latest Mesozoic time, and the pre-Tertiary Systems were consequently folded and pushed up towards the southwest direction. These rocks consist mainly of phyllitic slates, quartzose sandstones and limestones, which are generally poor in fossils. The above folding activity was followed by the intrusion of granitic rocks to have resulted in the formation of a geanticline."

On the other hand, HAMILTON (1978) has described mainly on the developmental process of geologic structures, on the basis of chronological and marine-geological data. According to him, the time of tectonic movements is supposed to be somewhat younger than that suggested by BEMMELEN (1970). A brief review of the HAMILTON's idea is as follows.

" Structures in the present Sumatra Island are generally of the NW system. Such structures are not recognized in the pre-Tertiary basement rocks. The NW-trending structures are parallel to the arrangement of trench, fore-arc ridge and fore-arc basin. The Barisan mountain chain is a geanticline consisting of the old basement rocks, a part of which is covered by volcanic rocks derived from the active volcanoes at present. The northeastern side of this area constitutes a foreland basin. The further northeastern area, including some islands of Bangka and Belitung and also the Malaya Peninsula, is constituted by a craton. It thus appears that the above-mentioned NW trending structures overwhelming the Sumatra Island were due to tectonisms which probably started in late Oligocene."

It is not the purpose of this report to discuss the foregoing two different views. However, it should be pointed out that the time of formation of the NW-trending structures and the time of intrusion or emplacement of the granitoids are very important factors to evaluate the ore potentiality in the present survey area.

Palembang Province, in which most part of the present survey area is contained, has long been known as one of the oil fields, and recently the exploitation of coal is also being carried out. These oil and coal resources are emplaced in the Neogene Systems, especially within the Palembang Formation including lower-middle Miocene to Pleistocene formations. The Palembang Formation is sometimes subdivided locally into several members.

Rocks correlative in lithologic facies to the Palembang Formation are widely distributed over the eastern and southeastern part of the survey area through the Palembang open field. They are in general folded with folding axes mainly of N-S system.

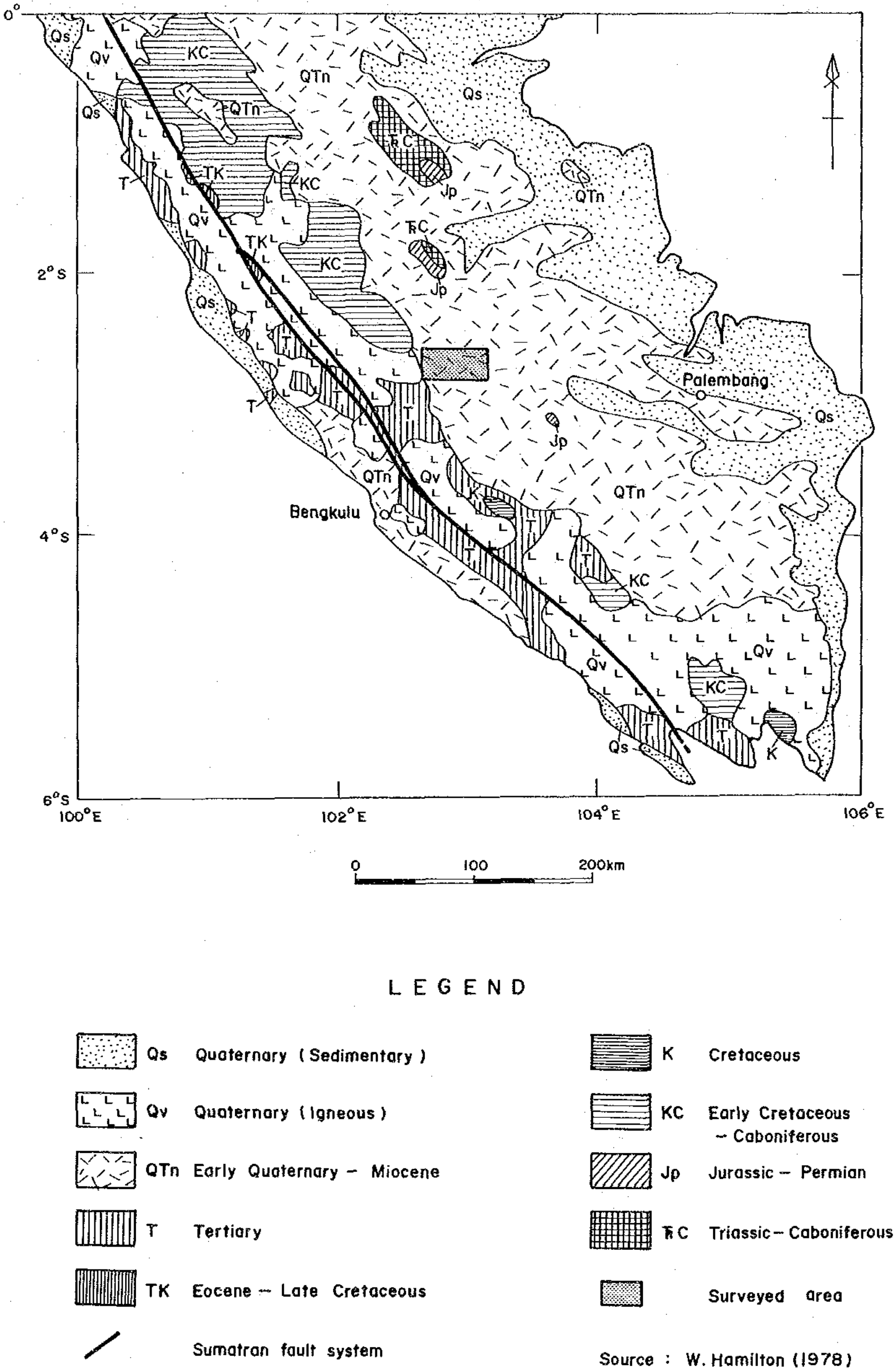

Fig. 3 Generalized Geologic Map of the Southern Sumatra

Part 2 PHOTOGEOLOGICAL INTERPRETATION

Part 2 PHOTOGEOLOGICAL INTERPRETATION

Chapter 1 Data Used and Methods

1-1 Aerial Photographs Used

The aerial photographs used for photogeological interpretation are of monochromatic prints of approximatry 1:100,000 in scale, and the total numbers used are 36 sheets. The list and the index map of the aerial photographs are shown in Table 3 and Figure 4.

Table 3 List of Aerial Photographs

Course No.	Photo.No.	No. of Sheets	Fleight Direction
R38	222～228	7	North → South
R39	200～206	7	South → North
R40	218～224	7	North → South
R41	206～213	8	South → North
R42	148～154	7	North → South
Total		36	

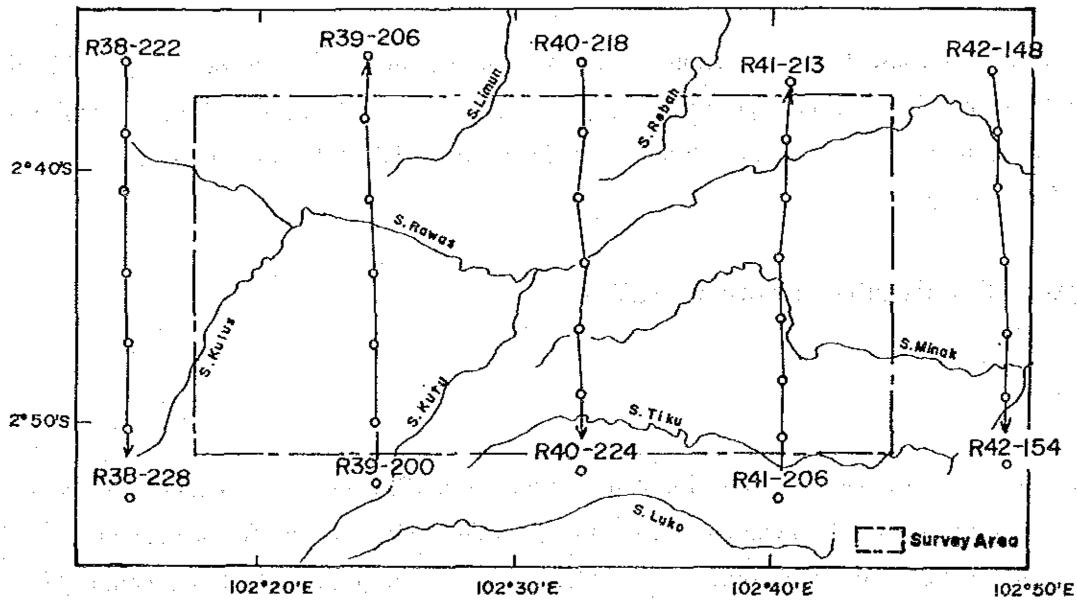

Fig. 4 Index Map of the Aerial Photographs for Photogeological Interpretation

1-2 Methods

The ordinary procedure of photogeological interpretation is as shown in Fig.5. This work is to compile photogeological interpretation map for preparation of the geological survey, and it has to be examined by reinterpretation after field-verification through reconnaissance aurvey. The photogeological interpretation map obtained is to be constracted as the final result map of respective surveys.

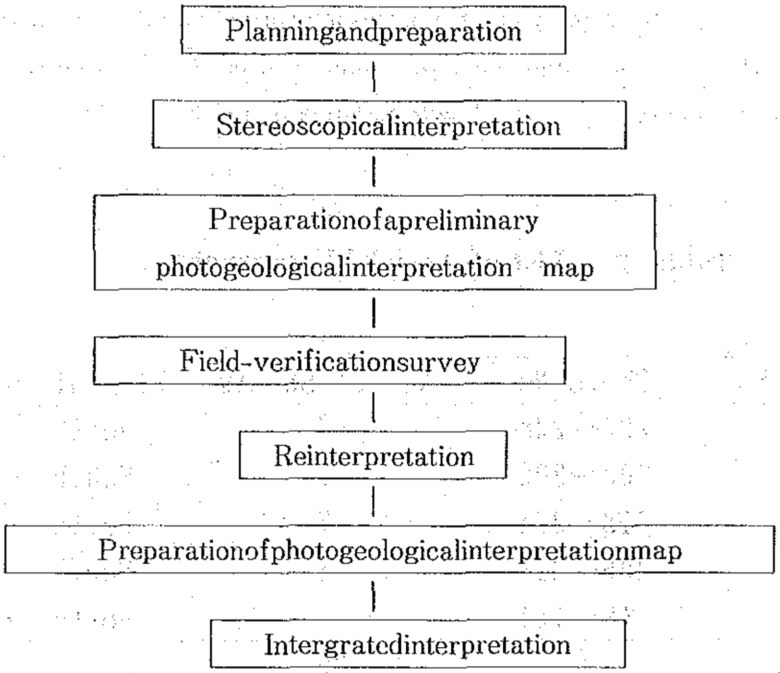

Fig. 5 Flow Chart of Photogeological Interpretation

1-3 Compilation of Interpretation

The stereoscopical interpretation results on geology and geological structures delineated on a film were transcribed onto a topographic map of scale 1 : 20,000 and then finally summarised, after synthetic examinations, onto topographic map of scale 1 : 50,000 which was reduced from a map of scale 1 : 20,000.

Chapter 2 Results of Interpretation

2-1 Outline

As the result of photogeological interpretation, the geological constituents of the reconnaissance area were divided into 10 geologic units (note : called 「Unit」 in the following) as listed in Table 4. They consist of sedimentary rocks (Units A~F), unconsolidated sediments (Unit Q) and intrusive rocks (Units I_1~I_3).

The formations generally trend NW-SE, and the existence of the folding strncture with the same direction is also inferred. The faults indicated as photo-lineaments are recognized from the central part to the eastern part of the reconnaissance survey area and are characterized by two predominant directions of NE-SW and NW-SE. Furthermore, no outcrops of rocks can be interpreted because of the dense vegetation in the area and also because the aerial photographs used are much smaller in scale than those used ordinarily in a interpretation.

2-2 Geoiogic Units

The division of the geologic units is as described in the preceding.

(1) Unit A

a) Distribution : The Unit is distributed in the area from the central northern part to the eastern margin of the reconnaissance survey area.

b) Photo-characteristics: It is dark greyish tone and medium-grained texture.

c) Morphological expression : It is Very high-densed dendritic drainage pattern, a moderate resistibility or undulation, and massive appearance. There are photo-lineaments of E-W directions in the central northern part and of NNW-SSE direction in the central eastern part , but they are very sparse in the distribution and their densities are low. Boundaries with other units are generally obscure. Above-mentioned characteristics interpreted that this Unit consists presumablly of clastic rocks.

(2) Unit B

a) Distribution : The Unit is distributed in the central to northwestern part of the reconnaissance survey area, elongating to WNW-ESE direction.

b) Photo-characteristic : It is generally dark grey tone and medium-grained texture, but, in the area from Napallicin on the right bank of S. Rawas to Muaramengklam, intermediate grey tone and fine-grained texture.

c) Mophological expression : It is generally very high-dense subdendritic drainage pattern, high resistibility, moderate to high undulations and massive appearance, but it is locally different characteristics such as a karst morphology around Meribung, and trellis drainage pattern in the vicivity of the S. Rawas basin, lower resistibility and lower undulation in the area from Napallicin to Muaramengklam. Well-developed beddings are interpreted in the S. Rawas basin, but these strikes and dips can not be always readed because of the small scale of the aeriel photographs used. Multi-directional photo-lineaments are especially recognized in the the karst region. The photo-linearment interpreted at boundary of this Unit and Unit I_1 along the mainstream of the S. Menalu is inferred to be a fault.

This Unit consists presumablly of clastic rocks accompanied by limestones. The Unit contacts conformablly with the Unit A, thongh it is partly bounded by a fault.

(3) Unit C

a) Distribution : The Unit is distributed in the almost central part of the area occupied by the Unit B and elongates in WNW-ESE direction.

b) Photo-characteristics : It is dark grey to intermediate grey tone and medium-grained to fine-grained texture.

c) Mophological expression : It is highly-dense dendritic drainage pattern , high resistibility or undulations, and massive appearance. It is almost similar to the Unit B, but is rather constant in wave pattern of valley cross section and has no morphological variation as compared with the Unit B. Boundary relation between the Unit and the Unit B is indistinct, but to the Units Q and I_2 is distinct.

The Unit is presumablly of clastic rocks. Relation between the Unit and the Unit B is conformable.

(4) Unit D

a) Distribution : It is distributed in the southeastern part of the reconnaissance survey area in the stream basin of S.Tarum.

b) Photo-characteristics : It is dark gray to intermediate grey tone and medium-grained to fine-grained texture.

c) Mophological expression : it is high-dense sub-dendritic drainage pattern, low to moderate resistibility, low undulations. and massive appearance. Two directional photo-lineaments (NW-SE, NE-SW) are observed but not very frequently. Boundary relations between the Unit and other Units are indistinct.

The characteristics suggests that this Units consists presumablly of clastic rocks and/or pyroclastic rocks. Its mophological pattern is very similar to the Unit F mentioned below, but it is also interpreted to be overlaid by the Unit E. Thus, the straigraphic relations between the Unit and the other Units are indistinct.

(5) Unit E

a) Distribution : The Unit is distributed widely from the southwestern part to the central southern part survey area and also narrowly in the ridge part of the northwestern margin of the reconnaissance survey area.

b) Photo-characteristics : It is dark grey tone and medium-graine texture.

c) Mophological expression : It is high-dense sub-dendritic drainage pattern, high resistibility or high undulations, and massive appearance. Three directional photo-lineaments (NE-SW, NW-SE > N-S) are recognized. Bounderies betweenthe Unit and other Units are generally distinct, but the boundary relation to the Unit B is indistinct in the northern marginal area.

Table 4 Photogeological Interpretation Chart

UNITS	Characteristics	PHOTO-CHARACTERISTICS: TONE: Vege-tation	TONE: Culti-vation	TEXTURE: Vege-tation	TEXTURE: Culti-vation	MORPHOLOGICAL EXPRESSION: DRAINAGE: External or Internal	DRAINAGE: Pattern	DRAINAGE: Density	DRAINAGE: Cross-section	ROCK PROPERTIES: Resis-tance	ROCK PROPERTIES: Bedding	ROCK PROPERTIES: Attitude	ROCK PROPERTIES: Lineament	ROCK PROPERTIES: Boun-dary	CONCLUSIONS: Lithology
Uncon-solidated Sediment	Q	medium grey	light grey	fine	speckled	external	meadering	low		Very low	none	horizontal	none	sharp	lluvium
Sedimentary Rocks	F	medium grey	light grey	fine	speckled blocky	external	sub-dendritic	very high		low	massive	gentle	none	vague	clastics
	E	dark grey	–	medium	–	external	sub-dendritic	high		high	massive	moderate	medium density three directions	sharp	pyroclastics
	D	dark grey to medium grey	medium grey	medium to fine	speckled blocky	external	sub-dendritic	high		low to moderate	massive	gentle	low density two directions	vague	clastics and/or pyroclastics
	C	dark grey	–	medium	–	external	sub-dendritic	high		high	massive	moderate	none	vague	clastics
	B	dark grey to medium grey	medium grey	medium to fine	speckled blocky	karst phenomena	sub-dendritic partly trellis	high		high to low	massive partly bedded	moderate to gentle	low density several directions	vague	clastics (partly well bedded)
	A	dark grey	medium grey	medium	speckled blocky	external	dendritic	very high		moderate	massive	gentle to moderate	low dencity several directions	vague	clastics
Intrusive Rocks	I_3	dark grey to medium grey	medium grey	medium to fine	speckled	external	radial	medium		very high	very massive	steep	none	sharp	acidic to intermediate intrusive rocks
	I_2	dark grey	–	medium	–	external	sub-dendritic	low		very high	very massive	steep to moderate	low density several directions	sharp	granitic rock
	I_1	dark grey	medium grey	medium	speckled	external	sub-dendritic	low		very high	very massive	moderate	low density several directions	sharp	granitic rock

The characteristics suggests that this Unit is presumablly of pyroclastic rocks. As to the relations to other Units, this Unit seems to overlays unconformably the Units A to D

(6) Unit F

a) Distribution : The Unit is distributed widely in the eastern part of the recconnaissance area.

Photo-characteristics : It is intermediate grey tone and fine-grained texture.

c) Mophological expression : It is very high-dense dendritic drainage pattern, low resistibility or undulations, and massive appearance. There are no characteristic drainage patterns and no indication of photo-lineaments. Boundaries of the Unit are indistinct.

The characteristics interpreted suggests that this Unit is presumablly of clastic rocks. This Unit seems to overlay unconformably the lower Units.

(7) Unit Q

a) Distribution : This Unit is mainly distributed in the stream basins of S.Rawas and S. Minaku.

b) Poto-charactaristics : It is dark gray tone and fine-grained texture.

c) Morphological expression: it shows meandering water systems and extremely low resistibility.

The characteristic reveals that this Unit is presumablly of clastic sediments distributed in the stream basins.

(8) Unit I_1

a) Distribution : The Unit is distributed in the vicinity of central part of the recconnaissance survey area.

b) Photo-chractaristics : It is dark gray tone and medium-grained texture.

c) Mophological expression : It shows sparsely-distributed sub-dendritic drainage pattern, very high resistibility, moderate undulations, and massive appearance. There are two main photo-lineaments of NE-SW and WNW-ESE directions (NE-SW > WNW-ESE). Its Boundaries are distinct, and occurs partly fault contact with other Units.

The characteristic interpreted suggests that this Unit is presumablly concomposed of granitic rocks. It is may be inferred that the Unit has intruded the Units A, B and C after the sedimentation of the Unit C strata.

(9) Unit I_2

a) Distribution : The Unit is stributed in a small scale in the southwestern and of the reconnaissance survey area .

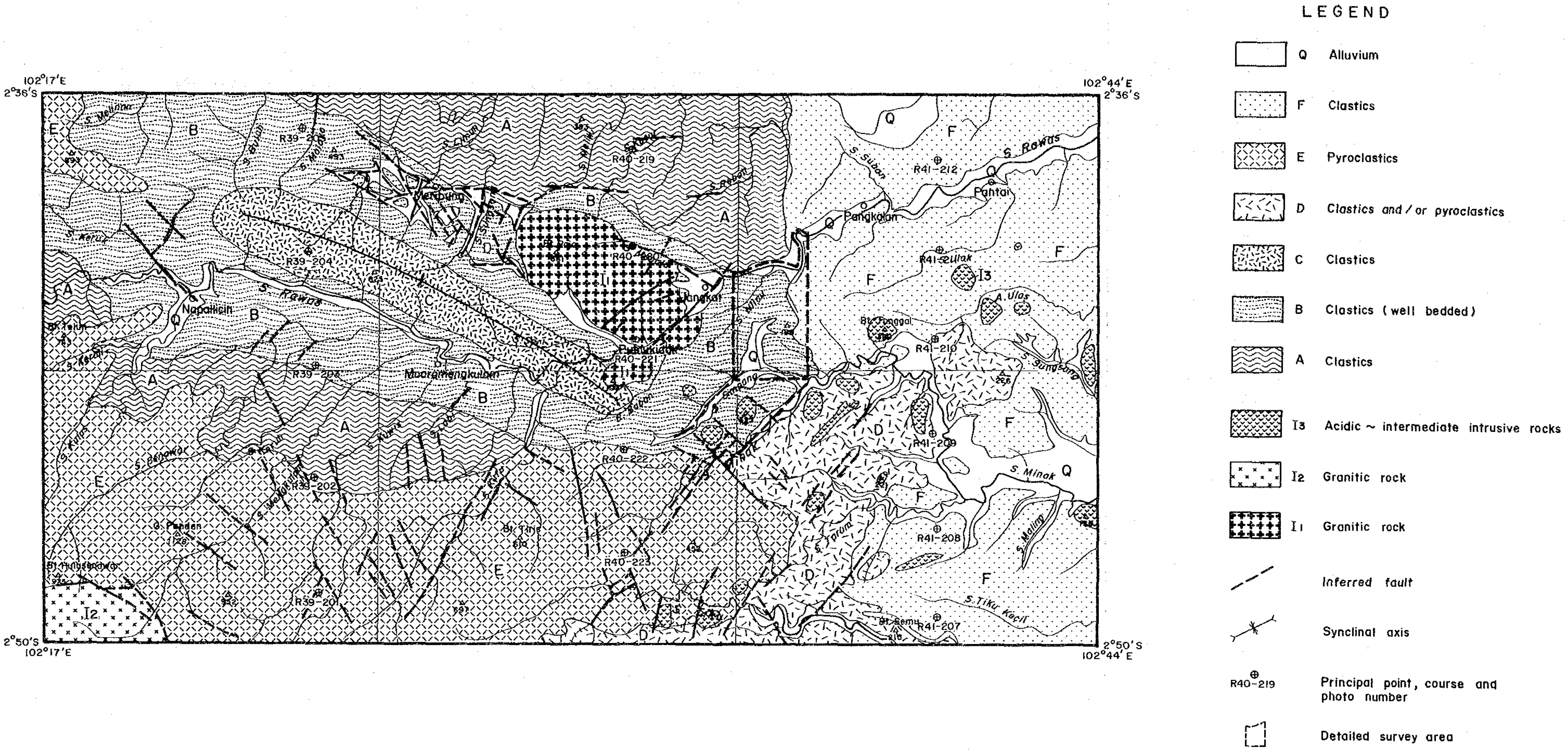

Fig. 6 Photogeological Interpretation Map

b) Photo-characteristics : It is dark grey tone and medium-grained texture.

c) Morphological expression : It shows sparsely-densed sub-dendritic drainage pattern, very high resistibility and massive appearance. A photo-lineament suggests that a fault exists along the boundary of the Unit and the neighbouring Unit E. Its boundaries are generally distinct.

The characteristics interpretes that it is presumablly of granitic rocks. This Unit penetrate the Unit E, and thus it may have intruded after the stage of the Unit E. This Unit may be regarded as similar granitic rocks of the Unit I_1, but they are distinguished from each other in view of the possible difference in time of intrusion.

(10) Unit I_3

a) Distribution : The Unit is sporadically distributed in the eastern half part of the recconnaissance survey area.

b) Photo-charactaristics : It is dark grey to intermediate grey tone and medium-grained to fine-grained texture.

c) Morphological expression : It shows radial drainage pattern, very high resistibility, massive appearance, and cone-shaped morphology and its boundaries are always distinct.

The characteristics suggests that this Unit consists presumablly of acidic to intermediate intrusive rocks. This Unit thus may have intruded after the stage of the Unit F because it penetrates up to Unit F strata.

2-3 Geologic Structure

The stratum of the Units A to E and some folds generally trend in NW-SE direction, but only the Unit F is oblique to this general trend. Two unconformities are presumed to exist respectively at sedimentation stages of the Units E and F, the latter was relatively in a large time-gap of sedimentation. The distribution pattern of the photo-lineaments inferred as faults may reveal that the two directional fracture systems trending NE-SW and NE-SE are predominant in the recconnaissance survey area

Part 3 GEOLOGICAL SURVEY

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Chapter 1 Geology

1-1. Outline

The survey area is underlain by Jurassic to Cretaceous Systems, Cretaceous System, Tertiary System and Quaternary System. No pre-Jurassic System is recognized in the survey area, but Permian and Triassic Systems are exposed in the northwestern outside of survey area. Those pre-Jurassic stratum are regarded as basement of the area.

The Mesozoic System which is probably Jurassic to Cretaceous is divided into the S. Rawas Formation and the S. Kuwis Formation.

The S. Rawas Formation is widely distributed over the central part through the northwestern to northern part of the survey area, consisting mainly of phyllitic slates of pelitic rock origin. A limestone-dominant part in them is named the Mersip Limestone Member.

The Formation consisting of shales, pyroclastic rocks and andesitic to basaltic volcanic rocks is distributed in the south-side area of the S. Rawas and partly in the western part of the survey area, and the Formation is named the S. Kuwis Formation.

The S. Rawas Formation and the S. Kuwis Formation are evidently different each other in constituents and in degree of schistosity, though there is no outcrop contacted directly by both Formations

The Tertiary and Quaternary Systems are distributed overlying above-mentioned Formations. The Tertiary System is divided into the Napallicin Formation, Hulusimpang Formation and S. Minak Formation in the stratigraphically ascending order.

The Napallicin Formation occurs exclusively in the western part of the survey area and consists of sandstones and basaltic lavas. The Hulusimpang Formation is distributed widely in the southern half of the survey area and is dominated lavas and pyroclastic rocks. Lower half of the Formation is composed of andesitic, while the middle to upper part is generally dacitic. The S. Minak Formation occurs in the eastern to southeastern part of the survey area, consisting of sandstones, siltstones, tuffs and limestones with intercalation bed of lignite.

The Quaternary System is divided into the Surulangun Formation consisting of massive pumice tuff and the alluvium. The Surulangun Formation is present in a small distribution at the eastern edge of the survey area.

Various intrusive rocks are distributed penetrating the forgoing Formations. The intrusive activities have taken place at the following respective stages,namely granitic rocks at the S. Kuwis, post-S. Kuwis and S. Minak stages, dacitic rocks at the S. Minak stage, and andesitic rocks during the Napallicin to Surulangun stages, and basaltic rocks at the S. Kuwis, Napallicin and Hulusimpang stages. Emplacement, elongation, and arrangement of the intrusive rocks suggest that thses intrusions are structurally controlled by two predominant tectonic trends extensively distributed over the survey area.

One of the predominant tectonic trends is of NW-SE direction which is parallel to the elongation of the Sumatra Island. The other is perpendicular to the above trend, being of NE-SW direction. The S. Rawas Formation and the S. Kuwis Formation are often folded with axes of NW-SE direction. Elongation and distribution of granitoid bodies and faulting systems are also predominantly controlled by this direction. Foldings and faultings trending NE-SW direction are distributed in the detailed survey area and its southeastern vicinity, while the Tertiary and Quaternary Systems are sometimes loosely folded with N-S direction, but they usually lack in continuity.

1-2 Geologic Stratigraphy

As quite limited sedimentary rocks yield fossils, correlation and division of the geological stratigraphy are depended on continuity of rock facies, paying attentions to geological structure. The results obtained are significantly different, especially in geologic division from those of the Existing Data (1984). Therefore, some new Formation names are proposed and used.

(1) S. Rawas Formation (New Designation)

a) S. Rawas Formation

Definition: A pelitic rock-dominant facies with well-developed schistosity is distributed in the central part and the northeastern to northern part of the survey area, and it is newly named S.Rawas Formation. The limestone dominant facies within this Formation is also newly named Mersip Limestone Member.

According to the Existing Data (1984), a series of rock facies exposed along S. Rawas is named the Rawas Formation. However, the newly-named S. Rawas Formation also includes a part of the Asai Formation of the Existing Data (1984) which is assumed to be of Middle Jurassic and is distributed in the northeastern reaches of S. Menalu (a branch of S. Rawas). The "Asai Formation" in the northeastern reaches of S. Menalu is essentially of flysh type deposits composed dominantly of pelitic rocks with well-developed schistosity, and intercalated with subordinate amount of fine-grained sandstones, and often flute casts are observed in the Formation. The "Asai Formation" is thus quite similar in lithological charactristics to the previous Rawas Formation as well as in geological structure. Therefore, the report includes a part of "Asai Formation" in the previous Rawas Formation. On the other hand, no lavas and pyroclastic rocks are described from the previous Rawas Formation, and thinly-bedded andesite lavas and pyroclastic rocks are often observed in the stream basin of the S. Rawas. This part has been assumed to constitute upper horizone of the another Formation in Exsisting Data. However, the present survey unravels that these volcanic rocks are also an essential constituent of the "Rawas Formation". It is the reason to propose new name to "S. Rawas Formation".

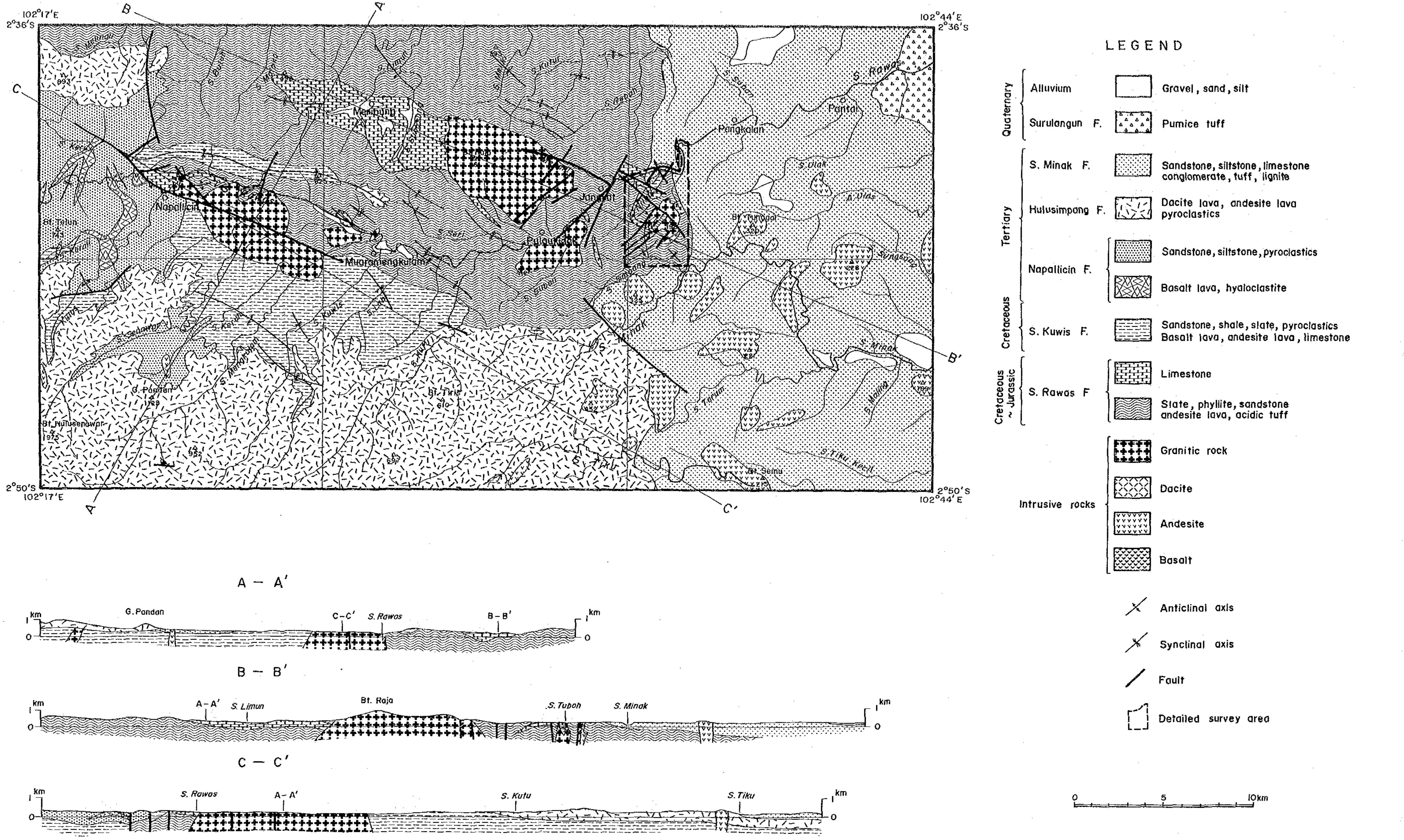


Fig. 7 Generalized Geologic Map of the Surveyed Area

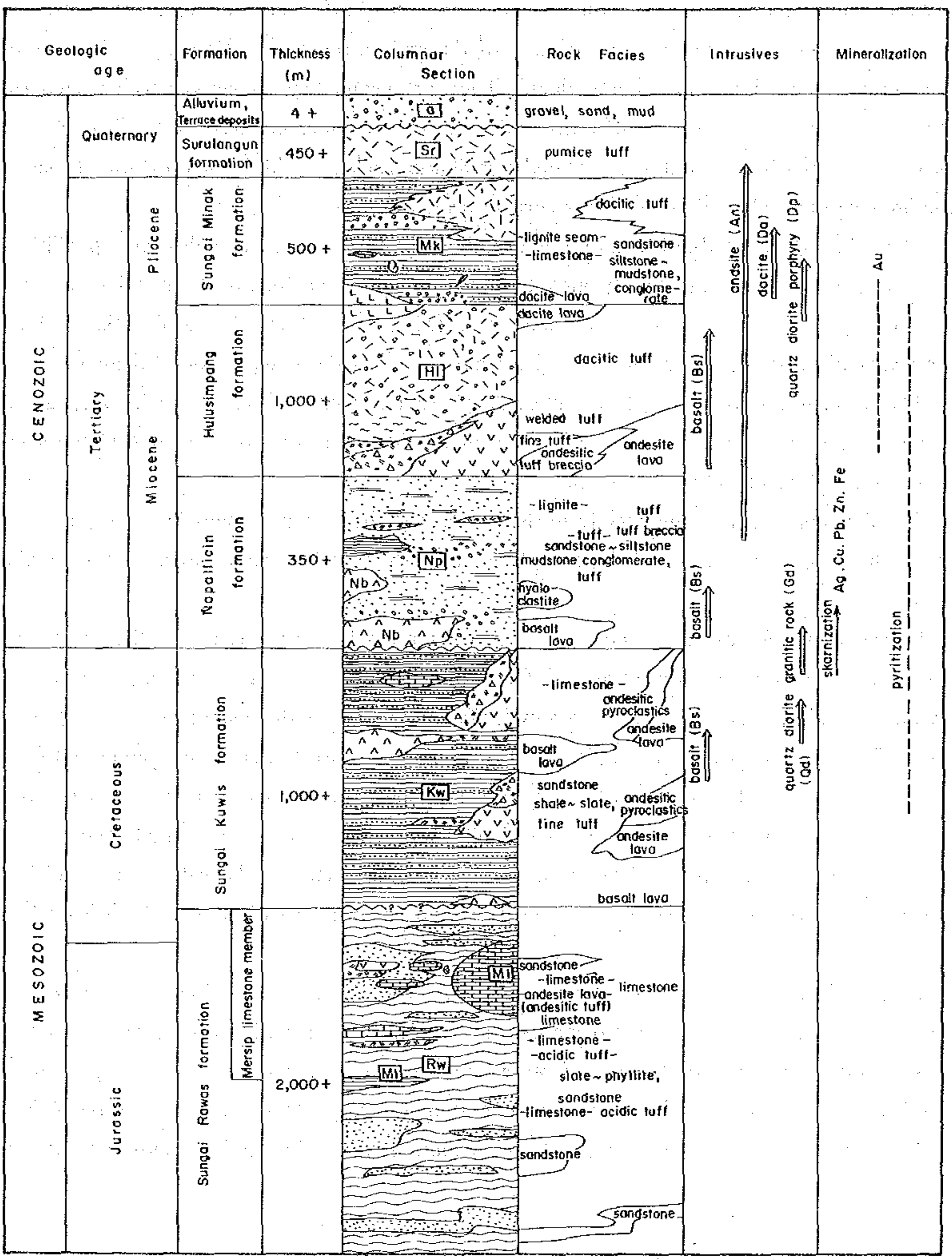


Fig. 8 Schematic Geologic Column of the Surveyed Area

Type locality; The main stream of S. Rawas, especially between Napallicin and Pulaukidak.

Thickness; 2,000 m or more.

Rock facies ; The pelitic rocks with well-developed schistosity are predominated,and accompany by subordinate amounts of sandstones, limestones, fine tuff and thin andesite lavas. The limestone are rather dominant in the vicinity of the main stream of S. Rawas. The sandstones are evenly distributed, though not abundant. The wacke sandstone consists of well-sorted andesitic tuffaceous materials. Fine tuffs are pale-green in colour, compact and siliceous rocks in appearance, and often contains alternated psammitic rocks. In a part of this Formation is sometimes recognized a white rock like sericite schist.

The pelitic rocks of this Formation is usually phyllitic , and may be called as " phyllitic slates" . They are classified into two groups depended on colour, namely, dark grey ones and greenish grey ones, the later being relatively sericitic and tuffaceous. Two types of lineation originated to intersecting of cleavage planes and flow lineations occur in those slate along S.Rawas.

The sandstones are irregularly intercalated within pelitic rocks. However, as already mentioned, flysh rhysmic altenations of a part of turbidite deposit are dominated in the area from the northeast of S. Menalu to S. Kutur.

The limestones vary remarkablly in thickness, and show oolitic facies in some part. The andesite lavas are dark greenish blue to dark greenish grey and some parts contain hyaloclastic facies.

Correlation: As already mentioned, this Formation is correlative with the previous "Asai Formation" and "Rawas Formation" of the Existing Data (1984). In the survey area, the previous both Formations are the same rock facies, and therefore the boundary between them cannot be specified. Looking as a whole, the Formation in central area is characterized by rather frequent occurrence of limestones, tuffaceous sandstones, fine tuffs and andesite lavas, while that in the northern area by the predominance of alternation of sandstone and mudstone. And the facies changes evidently-gradual between the two Formations. Therefore, no significant age difference is expected between them. There would be no problem in the newly defined "S.Rawas Formation".

Age: No fossils are reported to specify the age of this Formation. According to the Existing Data (1984), the Asai Formation and the Rawas Formation are correlated with middle Jurassic and upper Jurassic to lower Cretaceous Systems, respectively. In the present survey, referring to the above data, this Formation is assumed to range from Jurassic to Early Cretaceous.

Relation to underlying formation: This Formation constitutes the lowermost Formation in the survey area.

b) Mersip Limestone Member

Definition: It is a member of the S. Rawas Formation. The Member is named for a limestones strata distributed from Meribung to Mersip in the survey area.

Type locality: The Member is distributed at area from Meribung village to Mersip village.

Thickness: 400 m or more.

Rock facies: The limestone is dark grey to greyish white, partly white coloured and saccharoidal, and generally massive and homogeneous in structure. Parallel arrangement of flat ellipsoidal structures are sometimes observed in the rock.

Sample No.	SiO_2 %	Al_2O_3 %	Fe_2O_3 TOTAL %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	MnO %	LOI %	BaOppm (ICP)	FeO %	Fe_2O_3 % as Fe (III)
	0.60	0.28	0.16	0.32	54.21	0.03	<0.01	0.030	0.04	<0.01	42.75	<20	0.03	0.13
ER-07	1.64	0.79	0.26	0.45	53.00	0.04	0.11	0.040	0.05	<0.01	42.12	60	0.06	0.19

Fossils: Abundant fossils indicated Late Jurassic are found in stromatolite and reef facies.

Correlation: The name of this Member is used in the Existing Data (1984) for a member of the Peneta Formation overlying the Rawas Formation. However, taking into considerations its distribution and geologic structure, it seems natural to regard as a member constituting the S. Rawas Formation.

(2) S. Kuwis Formation (New designation)

Definition : Among the pre-Tertiary Systems croped out at the both banks of S. Rawas, a strata of pelitic rocks with distinct schistosity has already been defined as S. Rawas Formation . The S. Kuwis Formation is named for a series of rocks, consisting mainly of shales with poor schistosity or slaty cleavage. The Formation is accompanied by more abundant basaltic to andesitic lavas or pyroclastics and acidic fine tuffs than those in the S. Rawas Fotmasion and has intercalated bed of sandstone and thin bedded limestone.

According to the Existing Data (1984), the Peneta Formation is set up above the Rawas Formation. The Peneta Formation, whose type locality is S. Peneta outside of the present sarvey area, is named for a strata consisting of slates, shales, siltstones, sandstone and limestones. In the survey area, the above-mentioned strata containing comparatively abundant pyroclastics is correlated with the Peneta Formation. But remarkable difference in the rock facies is quite recognised between them . Thus the S. Kuwis Formation is proposed new name in the present survey according to the rock facies.

Thickness : 1,000 m or more.

Rock Facies : Shales, slates, fine tuffs, sandstones, limestones, basalt lavas (including hyaloclastites and pillow lavas), andesite lavas and andesitic pyroclastic rocks are the constituents of the Formation.

The shales or the slates (of which the former is remarkably predominated) are dark brownish to black in colour, massive in structure and usually obscure in bedding. These rocks are sometimes calcareous in composition. Two or more directions of schistosities, cleavages and/or joints are observed in the strata. The sandstones are a sort of wacke sandstone coloured greyish green to grey , and are intercalated within pelitic or muddy rocks. The content ratio of sandstones to pelitic or muddy rocks is very low.

The fine tuffs are pale green in colour and siliceous in composition. Weak grade bedding structure is sometimes recognized. A coarse-grained part may be called as acidic coarse tuff.

The limestones usualy lack its continuity. The thickness of a single bed is generally less than 1 m. At the middle stream of S. Bunga, northeast of Napallicin, some limestone lenses or nodules ranged from 5 m × 0.8 m (max.) to 0.3 m × 0.2 m (min.) in size occur intercalated within fine tuffs. They are grey in colour and certain sedimentary structures preserved.

Pillow facies and hyaloclastic facies occur in basalt lavas along S. Senawar and its vicinity. At the area near S. Senawar, the basaltic rocks seem to constitute the bottom portion of this Formation.

The andesites are comparatively basic in composition and usually occur as dark grey to dark green coloured blocky lavas. At the S. Bunga a strata of andesitic tuff breccias and lapilli tuffs are exposed, intercalating coarse acidic tuff and shale beds. The occurrence suggests that andesitic volcanic activities have taken place at two staged at least.

Fossils : Fossils of Pelecypoda, Gastropoda, Ammonites and Corals are known in the limestone. They indicate late Jurassic to early Cretaceous to the Formation.

Correlation : This Formation constitutes a part of the Peneta Formation.

Age : This Formation is correlative with late Jurassic to Cretaceous in age by available fossil data. This Formation is relatively lower in degree of regional metamorphism in comparison with the underlying S. Rawas Formation, and it suggests that the former is younger than the latter. This fact in addition to the fossil data may support the possibility that this Formation is Jurassic in age. On the other hand, a quartz diorite mass exposing over the area from S. Rawas to the downstream reaches of S. Senawar gives 83.6 ± 4.2 Ma (DR-36) in radiometric age, and it strongly suggests that this formation is older than upper Cretaceous in age. Taking into considerations the fact above mentioned, the S. Kuwis Formation is included in the Cretaceous System in this report.

Relation to underlying Formation : Direct relation between the S.Kuwis Formation and the underlying S.Rawas Formation is not observed in the field. However, the structure of the S. Senawar Formation sometimes appears to be uncoinsized with the S. Rawas Formation, and the degree of regional metamorphism is rather clearly different from each other. These fact may be suggestive of the presence of unconformity between both Formations.

(3) Napallicin Formation (New Designation)

Definition : The formation is named for strata which is distributed over the downstream reach of S. Kulus up to S.Rawas and its northwestern vicinity in the western part of the survey area, and is characterized by sandstones and basalt lavas (hyaloclastics). This Formation is well correlative with the Papanbetupang Formation of the Existing Data (1984).

Thickness : 350 m

Type Locality : The type locality of the Formation is located at Napallicin to upper reach of S. Rawas.

Rock Facies : The Formation is mainly composed of gray to purplish coloured sandstone and siltstone, and basalt lavas, accompanied by tuffs, conglomerate, and lignite beds.

The sandstones and the siltstones are more or less basaltic, and hence sometimes are greyish green to gray in colour. Its consolidation is usually not strong. The sandstones are massive while siltstones is fine well-beding and laminae in texture, suggesting sediment in a lake basin.

The basaltic lavas are divided into at least two flow units with 15 m ~25 m in thickness, and most part of them consists of hyaloclastites. These rocks sometimes contain blocks of conglomerates and sandstones derived from the underlying Formations and also intensely coalified-wood fragments (anthracite). It is generally soft or brittle.

The tuff may be correlative with marginal facies of hyaloclastites. They are green to purplish green in colour and coarse-grained sandy rocks in appearance.

The conglomerates consist of medium-sized gravels of granitic or quartzose rocks.

They are poorly sorted, and mostly resemble sandy conglomerates or conglomeratic sandstones. Lignite beds are usually associated with siltsones.

Fossils : No fossils are found in the Formation of the survey area.

Correlation : Existing Data (1984) correlated this Formation with the Papanbetupang Formation and with the Kasiro Formation. The Kasiro Formation yields some fossils of *teleostia.*

Age : Although no conclusive evidence is available, taking into considerations the age of the overlying Hulusimpang Formation described in the next section and its distribution relation, this Formation may be correlated with a part of the Miocene series in the Neogene Tertiary System. However, according to the Existing Data (1984), this Formation is correlated with the upper Pliocene series.

Relation to the underlying Formation : This Formation overlies unconformably the S. Rawas Formation and the S. Kuwis Formation with long time gap.

(4) Hulusimpang Formation

Definition : The Formation consists mainly of lavas and pyroclastic rocks and is widely distributed in the southwestern part to southern margin of the survey area. The Formation name follows the previous one.

Thickness : 1000 m or more

Type Locality : The stream basin of S. Kutu to the upstream of S. Mengkulam in the survey area.

Rock Facies : The andesitic lavas, the andesitic pyroclastic rocks, the dacite lavas and the dacitic pyroclastic rocks are the major constituents of the Formation. Andesitic volcanic rocks are predominated in the lower part of this Formation, while dacitic volcanic rocks in the middle to upper parts.

The andesite lavas are generally autobrecciated and greenish blue to green in colour. They are accompanied by tuff breccias and lapilli tuffs, and mostly massive and no flow banding, but their bedding is ecognizable by the presence of intercalated fine tuffs.

The dacite lavas occur at the uppermost part of this Formation and usually are hyaloclastic .

The dacitic pyroclastic rocks consist mainly of tuff breccias, and those at the lower portion are converted to weak welded tuffs.

The rock facies suggests that sedimentation basin must have been quite shallow, even if the rocks were formed under subaqueous conditions.

Fossils : This Formation yields no fossil.

Correlation : This Formation is correlative with the Hulusimpang Formation of Existing Data (1984). However, the former Hulusimpang Formation is exclusively composed of andesitic rocks, differed from present survey result.

Age : This Formation is regarded as a Miocene series on the basis of the Existing Data (1984).

This Formation and its extensions are supposedly distributed along the Barisan mountain range, and it is important host rocks for gold mineralization.

Relation to Underlying Formation : The Formation overlies conformably the Napallicin Formation, though a slight time gap may exist in some places.

This Formation is not present in the eastern part of the survey area, where the S. Minak Formation described next overlies directly the S. Rawas Formation. This fact suggests that the center of the sedimentary basin of the Hulusimpang Formation is located at the southwestern part of the survey area, and the localization of the sedimentation basin may be due to certain tectonic contorol as discussion next, rather than considering that the Hulusimpanf Formation had been eroded before sedimentation of the Minak Formation.

(5) S. Minak Formation (New Designation)

Definition : The S.Minak Formation is named for a strata exposed exclusively in the eastern side of the N-S line passing through near the detailed survey area, and is characterized by calcareous to tuffaceous sandstones, limestones, lignite beds and dacitic tuffs. This Formation may be correlated to coal-and oil-bearing Formations distributed in places over the Sumatra Island such as the Palembang Formation and the Muara Enim Formation. However, there is no correlative Formation with the Formation in the vicinity of the survey area, thus new Formation name, Hulusimpang Formation, is proposed in the survey area.

Thickness : 500 m or more (?)

Type Locality : The stream reach of S. Minak in the eastern part of the survey area.

Rock Facies : The Formation composed mainly of conglomerates, sandstones, siltstones, claystones, limestones, tuffaceous sandstones and tuffs with intercalated lignite beds. As a whole, the siltstones with intercalated lignite beds tend to be predominant at the lower part, thin bedded mudstones (claystones) and tuffs at the middle part, and tuffs at the upper part in the Formation.

The conglomeretes are locally distributed with less than 50 m in thickness and occur essentially as intrafomational conglomerates. They are mostly of granule in size and sometimes grade into sandstones via sandy-conglomerate facies.

The sandstones are mostly calcareous and sometimes contain small-sized (ϕ 1cm or less) mollusca fossils (Pecten ?) .

The siltstones are poorly-sorted, bluish grey soft rocks. They are generally rich in organic matter and turn into brown to black in colour by weathering. Several tens of lignite beds with unit thickness of 5 cm to 1 m are intercalated. The claystones are bluish grey soft rocks and sometimes associated with thin glauconite-bearing beds.

The limestones show grey in colour and in general occur as comparatively thin beds less than 10 m in thickness.

The tuffs and the tuffaceous sandstones are generally pumiceous, but sometimes occur as crystal-tuffs rich in quartz grains. The vesiculation of pumice tends to increase towards the northern area.

Fossils : *Rotalia, Ostraea, Ostracoda, Pecten, Tarrietioxylon Sumatrensis* KRAUSS are known. No data are available concerning plant fossils and pollen fossils.

Correlation : This Formation is consistent in distribution with the Air Benakat Formation, the Muara Enim Formation constituting a part of the Papanbetupang Formation, the Lakitan Formation and a part of the Kasai Formation, all of which appear in the Existing Data (1984).

Age : The Formation is assumablly the Upper Miocene series to the Pleistocene series.

Relation to Underlying Formation : The Formation overlies probablly conformably the Hulusimpang Formation. At the S. Nilau in the detailed survey area, it overlies unconformably the Napallicin Formation with basal conglomerate. It also contact with the S. Rawas Formation by a N-S trending linear boundary, suggesting that certain tectonic line lies concealed.

(6) Surulangun Formation (New Designation)

Definition : This Formation is named for a strata of pumiceous tuffs distributed in the northeastern margin of the survey area.

Thickness : 450 m or more.

Type Locality : The type locarity is at the port of Surulangun and its vicinity out of the survey area a little to the northeast.

Rock Facies : The Formation consists of massive and non-bedded pumiceous tuffs associated with pale yellow, light grey and claystones. Pumice in tuffs is white in colour, well-vesiculated and not deformed.

Fossils : The Formation yield no fossil.

Correlation : The Formation is correlated with the Kasai Formation of Existing Data (1984)

Age : The Formation is assumablly Pliocene to Pleistocene. In this report, it is correlated to Pleistocene, since this Formation overlies the Minak Formation mentioned before.

Relation to Underlying Formation : The Foprmation overlies conformably the Minak Formation.

(7) Alluvium

Definition : Unconsolidated sediments is distributed in places over the low open fields in the survey area. Recent sediments forms river terraces, fans,swamps and so on.

Thickness : River terrace along the S. Rawas sometimes reachs 4 m in thickness.

Rock Facies : Unconsolidated deposits of gravels, sands, silts or mud are constitutes of Alluvium deposit, but no volcanic sediments is in the deposit.

Fossils : The sediment yield no fossil.

Correlation : No detailed investigations have been made.

Age : Holocene.

Relation to Underlying Formations: The sediment overlies unconformably all the underlying Formations.

1-3. Intrusive Rocks

Many kinds of intursive rocks ranging from granitoids (granite, granite porphyry, granodiorite, quartz monzonite, quartz diorite etc.) to basaltic rocks in the survey area. A special attention should be paid to the mode of distribution and elongated shape of granitoid rocks, since they tend to reflect the geologic structures and tectonic settings of the survey area and hence they have a close relation with mineralizations.

(1) Quartz Diorite

Quartz diorites are distributed in the western part of the survey area from the east of Napallicin through the S. Senawar up to the S. Mengkulam. In the above area, 13 their intrusive bodies crop out with various scales, but it seems that they have originated from a series of magmatism. There is an evidence that the quartz diorites have intruded into the S. Senawar Formation and the Hulusimpang Formation and they have a certain time gap of intrusion between both Formations, in observation at the upstream of the S. Mengkulam.

Some of the rocks are characterized by weak gneissose textures owing to arrangement of pinkish potassic feldspars and slightly chloritized mafic minerals. Some are leucocratic ones and some others are rather dark in colour. Thus, the rock facies vary quite significantly by places. Microscopic observations reveals the following mineral assemblages in the quartz diorite.

- plagioclase-augite-quartz
- plagioclase-augite-quartz-potassic feldspar
- plagioclase-hornblende-biotite-quartz
- plagioclase-orthopyroxene (?)
- Plagioclase-hypersthene-augite-hornblende-biotite

Their textures are mostly holocrystalline and equigranular, sometimes porphyritic. Secondary minerals consist of abundant chlorite, sericite, epidote, and a small amount of calcite.

Whole rock analysis of 5 samples indicates that they are generally very close in chemical composition to typical diorite, though some samples show comparatively high FeO */MgO ratio.

In this report, the rocks are identified as quartz diorite because of the common occurrence of quartz and potassic feldspar and of the comparatively high FeO *
/MgO ratio.

A hornfels is found at the contact margin of the granitoid bodies, and silicified zone is present accompanying by weak pyrite dissemination in the contact zone as discuss later.

The sample DR-36 collected from the down reach of the S. Senawar is a holocrystalline equigranular rock with mineral assemblage of plagioclase-quartz-hornblende-biotite associated with a small amounts of chlorite, sericite and epidote. The quartz diorite has been dated as 3.6 ± 4.2 Ma in radiometric absolute age (K-Ar method). This age indicates the quartz diorite to be Albian of Early Cretaceous, and it is consistent with the result the present geological survey.

* Total Fe as FeO.

(2) Granite, Granite Porphyry and Granodiorite

Large intrusive rock bodies distributed in the area from Bt.Raja to the vicinity of Pulaukidak consists mainly of granite, granite porphyry and granodiorite, of which granite porphyry is the most abundant. They are leucocratic, holocrystalline equigranular or porphyritic

Mineral composition is commonly plagioclase≦potassic-feldspar, though agioclase>potassic-feldsparin the some case. The central part of the Bt.Raja rock body is mostly composed of plagioclase ≦ potassic-feldspar and thus the part is identified as granite or granite porphyry. The marginal part of the intrusive rock body and other smaller rock bodies distributed in the southern area of the Bt.Raja are usually composed essentially of granodiorite, quartz diorite and diorite.

Biotite and hornblende are the principal mafic minerals in the rocks. Anaugite and a hypersthene are also observed in the Bt. Raja intrusive of the northwestern marginal part of the survey area. This part is granodioritic. Whole rock analysis data reveals that the rocks are in general slightly low in SiO_2 and K_2O, high in CaO and Na_2O and slightly high in FeO *, in *comparison with the average omposition of the typical granite.* The reason of high FeO * contentof the rocks may be due to the influence by some content of pyrite in the rocks.

Radiometric age data (K-Ar method) on the granite intrusion series are as follows:

AR-14 : 51.9 ± 2.6 Ma

BR-98 : 54.1 ± 2.7 Ma

Both data are fairly consistent with each other, and suggest that the rocks were derived from a granitic activity series which took place during the period from Paleocene to Eocene. The facts is not conflict with description on the granitic activity took place during this time by HAMILTON (1978), and the emplacement of these rocks might be largely controlled by the NW-SE structures mentioned in Part 1. Chapter 2, 2-2.

(3) Quartz Monzonite

This rock is exposed mainly in the detailed survey area, and is also distributed in the main stream of the S. Rawas between the S. Seri and the S. Menalu.

The rock in the detailed survey area is dark green, fine-grained and holocrystalline resembling diorite in appearance, while the rock of the S. Rawas is dark green, fine-grained and holocrystalline quartz diorite in appearance. The latter occurs as a body elongating N 60° E direction and has width of about 20 m. The rock is accompanied by quartz veins with the width of about 60 cm at its hanging-wall side (southeast side).

The rocks are favourablly named quartz monzonite rather than diorite or quartz diorite on the basis of microscopic observation and chamical assay results. Mineralogical constitution of rocks is plagioclase ≧ potassic-feldspar, and qartz is absent or quite few. Mafic minerals are biotite, hornblende and clinopyroxene. It is noted that the clinopyroxene is identified as aegirine augite, which suggests the rocks alkaline series.

On the other hand, results of whole rock analysis reveal that the $Na_2O + K_2O$ contents of the rocks are 10.26 % in average of 2 fresh samples. This value is considerably higher in comparison with 7.59 % of the average value of granite. This fact also indicates these rocks rather alkaline, and these above data suggest that these rock bodies are of quartz syenite or of quartz monzonite. In this report, on the basis of feldspar constitute of plagioclase ≧ potassic-feldspar, they are defined as quartz monzonite.

A similar small intrusive rock has intruded in the above-mentioned quartz monzonite bodies in the detailed survey area. The rock consists of plagioclase < potassic feldspar and is accompanied by a small amounts of quartz and mafic mineral which is probably aegirine augite. It is very coarse-grained, and potassic feldspar crystals in them sometimes exceeds 10 mm in size. Its intrusive activity stage might be very close to the mineralization stage in the detailed survey area. The radiometric age (K-Ar method) determination on the rock indicates 40.1 ± 2.0 Ma, and suggests that the intrusive activity of the rock took place during a period from late Eocene to early Oligocene.

(4) Quartz Diorite Porphyry

The rocks elongated almost N-S direction crop out at the main stream of S. Rawas in the northeastern margin of the survey area, intruding up to the S. Minak Formation. The rock is dark brown and fresh, and has columnar joints in vertical direction. Under the microcope, it is identified as a holocrystalline porphyritic rock consisting of plagioclase and orthopyroxene (hypersthene) associated with a small amount of quartz. Whole rock analysis suggests that it is more basic in composition than diorite. The Minak Formation in the surroundings has been undergone no apparent thermal alteration. The S. Rawas runs characteristically along hook-shape drinage in this area, and it means that the S. Rawas flows down along the western side of this intrusive rock body.

(5) Dacite

A small dacite body has intruded into the Minak Formation in the southern part of the detailed survey area. It is white in colour and contains small phenocrysts of quartz.

(6) Andesite

A number of andesite bodies are distributed into the area of the Tertiary System in the eastern part of the survey area, and also some small andesite bodies have intruded into the Tertiary and Mesozoic Formations in the western part of the same area. The former lines up with NE-SW direction. This arrangement seems to have a relation with the fault of NE-SW system predominated around there. They mostly occur as dykes, but some are of stock-like or more complex shapes and form high mounds in the western area. Most rocks are dark-green to black in colour and hard, compact, massive and generally basic in composition, and some rocks resemble dolerite or holocrystalline fine-grained diorite. As such example a rock body of the Bt.Ipuh can be called dorerite through microscopic observation, namely it is a holocrystalline rock and consists of plagioclase-augite-hypersthene-hornblende and is characterized by subophitic texture. The SiO_2 and Al_2O_3 contents are within the range of basic andesitic composition, while the FeO * content is higher and the MgO content comparatively low, also the FeO */MgO ratio is hence considerably higher, regarding as andesite, in composition by whole rock chemical analysis.

(7) Basalt

A basalt is distributed in the area of the Tertiary System in the western area, in the visinity of Meribung in the northern area and in the northern marginal part of the detailed survey area. The rock is usually dark green to black in colour, hard or compact. Among them, the rocks near Meribung have undergone intense chloritization, and some rocks in the western area has also undergone alteration. However, these rocks of the above area and the northern marginal part of the detailed survey area range in composition from andesitic basalt to basalt. The rocks in the detailed survey area are a stock-like body which has intruded into the boundary zone between the S. Rawas Formation and the S. Minak Formation.

1-4. Metamorphism

(1) Regional Metamorphism

The S. Rawas Formation consists generally of schistose pelitic rocks with pearly luster. Chlorites and plagioclases have extensively formed as altered minerals . It thus appears that they have undergone metamorphism of greenschist facies.

Psammitic rocks also have weak schistosity. They are green in colour and rich in chlorite.

Segregation veins of calcite occur extensively in the limestone.

Pelitic rocks often contain segregation veins of quartz. A number of spindle-shaped veins (1 m or more in length and 60 cm in width) are densely concentrated in places.

(2) Thermal Metamorphism

In the vicinity of granitic rocks, the S. Rawas Formation and the S. Kuwis Formation have been subjected to thermally hornfelsic metamorphism.

In the area of the S. Rawas Formation, biotite hornfels is extensively produced over about 10 km along S. Rawas, from 5 km up of Pulaukidak to around S. Menalu joins toward the downstream reach. Pelitic rocks are dark purple in colour, massive, and lose phyllitic texture. In psammitic rocks, their constituent minerals were recrystallized to coarse grains of granoblastic texture.

Hornfels of the S. Kuwis Formation is mainly dominated in the south side of the quartz diorite mass situated in the downstream of S. Kuwis. The hornfels is granoblastic in texture, but sometimes reserves schistosity. It consists mineralogically of hornblende, quartz, biotite and plagioclase. However, amphibole minerals are difficult to identify because of their extremely-minute grain size. The sandstones are recrystallized to meta-sandstones and limestones to marble.

(3) Alteration

The pyroclastic rocks and volcanic rocks of the S. Rawas Formation and a part of the S. Minak Formation have extensively undergone a green alteration. Such alteration is remarkable especially in the S. Minak Formation and the Hulusimpang Formation. These could be due to a hydrothermal activity during a regional metamorphism.

On the other hand, silicification zones are distributed at the south side of the quartz diorite of the western survey area and its eastern extension, at the marginal parts of the granitic rocks in the detailed survey area and its vicinity, significant silicification zones are recognized to be developed. As will be mentioned later, such silicification is presumablly due to alteration associated with mineralization.

1-5. Geologic Structures

Geologic structures in the survey area are characterized by the tightly-closed foldings of NW-SE direction predominated especially in the Mesozoic Formations and by the comparatively gentle foldings found in the Tertiary Formations overlaying unconformably the Mesozoic Formations. The latter are composed of two general directions of NW-SE and N-S, but they lack continuity.

Faults of NW-SE system, NE-SW system and N-S system are distributed in the Mesozoic and

Tertiary Formations. The NW-SE faults cut the NE-SW ones, and the N-S faults also appear to cut the NE-SW ones. On the other hand, the NW-SE faults are consistent in general trend of the "Great Sumatra Fault Zone" (KATILI, 1970). The "Great Sumatra Fault Zone" is passing through about 50 km southwest of the survey area and is associated with a number of "fault-branches" of WNW-ESE system. It is conceived that the NW-SE faults occured in the survey area have presumably a close relation to them.

(1) Folding Structure

Among the Mesozoic Formations, the S. Rawas Formation generally has distinct bedding and hence it is easy to measure its strike and dip. The most beds strike N 60° ~ 70° W and dip 60° or more in over the area. The beds dip south in the north area, while dip equally south and north in the south area.

The S.Rawas Formation seems to be holoclinal structure. However it is unravelled that the Formation is overturned and folded monoclinally, since upturned flute marks are observed on the bottom of a turbidite in the north area through the geological survey.

Along the S. Rawas, remarkable intrafolial folds are often recognized. The wave length of the folding in general ranges from 0.4 km to 1.0 km (in half wave length) except for the isoclinal folding and portions remarkably folded up.

The Tertiary formations generally show rather gentle dips (less then 30°) and are associated with foldings dominantly with N-S direction. In the southern area, foldings with 1~2 km in half wave length are observed, though the positions of folding axis are undeterminable in all the cases.

In the detailed survey area, some local box-type foldings are recognized in addition to the above mentioned regional foldings.

(2) Faulting Structure

The faults are grouped into NW-SE to WNW-ESE system, NE-SW system and N-S system in the survey area.

The NW-SE to WNW-ESE faults are distributed in the western and central to eastern areas and displace up to the Tertiary Formations.

The NE-SW faults are frequently found over the detailed survey area to its southeastern area, cutting the NW-SE to WNW-ESE faults, but they appear to be not large in scale. Most quartz monzonite intrusives arrange along this NE-SW direction without exception in the detailed survey area and its northwestern of S.Rawas, and the stratum are often displaced the both sides of the intrusive bodies The fact thus suggests that the NE-SW faults have certain relationship to the intrusion of those rock bodies.

The N-S faults are often recognized in the S. Rawas. If it is supposed that a hook shaped stream existed at S.Rawas in the detailed survey area is caused by the fault, the fault would be left-lateral fault with more than 2 km displacement.

Those fault systems all tend to be predominantly present in the areas near the S. Rawas, and they are hardly observed either in the S. Rawas Formation of the northern area or in the Hulusimpang Formation of the southern region.

The intrusive shape and distribution of granitic rocks are irregular, but they seem to be roughly consistent in direction with the NW-SE, NE-SW, and N-S fault systems. This fact may suggest that a tectonic lines of such directions lie concealed in the granitic intrusion area.

On the other hand, the andesitic rocks penetrating the Tertiary Formations arrange dominantly in E-W to NE-SW direction. The presence of tectonic lines in this direction would be possiblly expected. If it could be assumed that direction of fold axis in the Tertiary Formation is N-S and its tectonic commpression force worked from E-W direction, the dikes having E-W direction would be consistent in direction of a tention fracture caused by the compression stress.

Table 5 Results of Microscopic Observation of Thin Sections

凡 例

Q : Quartz
Af : Alkali feldspar
Pl : Plagioclase
Fd : Feldspar
Bi : Biotite
Ho : Hornblende
Au : Augite
Hy : Hypersthene
Cpx : Clinopyroxene
Opx : Orthopyroxene
Px : Pyroxene
Ol : Olivine
Maf : Mafic minerals
Op : Opaque minerals
G : Glass
Ch : Chlorite
Se : Sericite
Ep : Epidote
C : Carbonate minerals
Gar : Garnet
Py : Pyrite
Hed : Hedenbergite
Ac : Actinolite
Li : Limonite
Mt : Magnetite
He : Hematite
Cl : Clay minerals

Pu : Pumice
Ro : Rock

Gr : Granite
Gd : Granodiorite
Qd : Quartz diorite
Qm : Quartz monzonite
Di : Diorite
Gp : Granite porphyry
Gdp : Granodiorite porphyry
Qdp : Quartz diorite porphyry
Dp : Diorite porphyry
Dol : Dolerite
Da : Dacite
An : Andesite
Bs : Basalt
Sk : Skarn
Tf : Tuff
Tf bre : Tuff breccia
Tfa Ss : Taffaceous sandstone
Lap Tf : Lapilli tuff
Sdy Tf : Sandy tuff
Lith Tf : Lithic tuff
Ls : Limestone
Ss : Sandstone
Sl : Slate
Ca Sl : Calcareous slate
Si Ls : Siliceous limestone

Hol : Holocrystalline
Eqi : Equigranular
Por : Porphyritic
Inters : Intersertal
Interg : Intergranular
Suboph : Subophitic
Myrm : Myrmekite
Graph : Graphic
Amy : Amygdaloidal
pyrocl : Pyroclastic
Int : Intrusive rock
Hl : Hulusimpang formation
Kw : Sungai Kuwis formation
Ml : Mersip limestone member
Rw : Sungai Rawas formation

◎ : Abundant
○ : Common
□ : Few
△ : Rare
? : not specified

Table 5 Results of Microscopic Observation of Thin Sections (1)

Sample No.	Rock Name	Rock unit	Texture	Phenocryst										Groundmass											Altered Minerals									
				Q	Af	Pl	Bi	Ho	Au	Hy	Ol	Op		Q	Af	Pl	Bi	Ho	Cpx	Opx	Ol	Maf	Op	G	Q	Ch	Se	Ep	C	Gar	Py	K	Hed	Ac
AR 2	Dp	Int	Hol:Interg			○			□					□		◎		○	?○ (Cpx/Opx)				○			□	△		□					
AR 4	Di	Int	Hol:Eqi	□		◎		?	?○ (Au/Hy)			○														□	△?		◎					
AR 14	Ho-Bi-Gd	Int	Hol:Eqi	○	□	◎	○	□				□														□	□							
AR 19	Bi-Gr	Int	Hol:Eqi	○	○	○	□					□														□	□					?		
AR 24	Bs	Int	Inters			◎			○	?	?	□				◎			?○ (Cpx/Opx)				○	□					□					
AR 26	Q-Dp	Int	Hol:Por	□		◎		?	?○ (Au/Hy)					□		◎			?○ (Cpx/Opx)				□						○			?		
AR 27	Dol	Int	Hol:Interg			◎			○	?	?			□		◎			?○ (Cpx/Opx)				□			□?			□					
AR 34	Di	Int	Hol:Eqi			◎		○	?□ (Au/Hy)			□														□	□	□	△					
AR 37	Qm	Int	Hol:Eqi	□?	○	○	□		?□ (Au/Hy)			□														□		□						
AR 45	Q-Dp	Int	Hol:Por	□		◎		?	○	?				□		◎			□	?			□			□		□	□					
AR 58	Qm	Int	Hol:Eqi		○	○	□?	□	?□ (Au/Hy)			□																○						
AR 72	Dp	Int	Hol:Por			○		□?	?□ (Au/Hy)			□		□		◎						□	□		□	□			○					
AR 75	Dp	Int	Hol:Por			○			?□ (Au/Hy)			□		□		○			□			□?	□		□	□	□?				□?			
AR 76	Qm	Int	Hol:Eqi	□	○	□			?			□															□	□	□					
AR 79	Bi-Ho Qd	Int	Hol:Eqi	□	□	◎	□	○				□														□	□		□					
AR 81	Bi-Da	Int	Por	□		○	□					□		○		○	□						□			□			□					
AR 82	Bi-Ho-Px Qd	Int	Hol:Eqi	□	□?	◎	□	□	□	○		□																						
AR 85	Qm	Int	Hol:Eqi		○	◎		□?	○			□																						
AR 93	Di	Int	Hol:Eqi	□		◎			?○ (Au/Hy)			□														□	□		□					
AR 94	Qd	Int	Hol:Eqi Myrm	□	□	◎		?	○			□															□?					□?		
AR 122	Sk	—																							□	□			○		□		◎	
AR 125	Sk	—																							□	○		○	○					
BR 10	Ho-Qd	Int	Hol:Eqi	□	□	◎		○				□														□	□	□						
BR 31	Dp	Int	Hol:Por			○			?□ (Au/Hy)			□		□		◎			?□ (Cpx/Opx)				□		□	□	□		□					
BR 37	Dp	Int	Hol:Por			□		?	?□ (Au/Hy)					□		◎			?□ (Cpx/Opx)				□			□	□							□
BR 38	Bi-Gdp	Int	Hol:Por	○	○	○	□							◎	□?	○	□?						□			□	□	□						
BR 54	Dol	Int	Hol:interg			□			?□ (Au/Hy)							◎			?◎ (Cpx/Opx)		?		□			□			□					
BR 60	Px-And	Int	Crush			○			□?	?				□?		○			?□ (Cpx/Opx)				□			□		○						

Table 5 Results of Microscopic Observation of Thin Sections (2)

Sample No.	Rock Name	Rock unit	Texture	Phenocryst									Groundmass											Altered Minerals									
				Q	Af	Pl	Bi	Ho	Au	Hy	Ol	Op	Q	Af	Pf	Bi	Ho	Cpx	Opx	Ol	Maf	Op	G	Q	Ch	Se	Ep	C	Gar	Py	Li	Mt	He
BR 76	Bs	Int	inters			□?			?○ (Au–Hy)		□		□?		◎				?○ (Cpx–Ol)			□			□			◎					
BR 77	Qdp	Int	Hol:Por			○			?□ (Au–Hy)			□	○		○			?□ (Cpx–Opx)				□		□	○			○					
BR 94	Bi-Ho Qd	Int	Hol:Eqi	□		◎	□?	○				□													○	□	□	△					
BR 97	Bi Gp	Int	Hol:Por	○	○	○	□						◎	○	○	□						□			□	△							
BR 98	Bi Gp	Int	Hol:Por	○	○	○	□						○	○	○	□						□			△	△							
BR 100	Sk	—																						△					◎		□		
BR 103	Fe-Ore	Int																						△								◎	○
BR 105	Fe-Ore	Int																						△									◎
CR 12	Di	Int	Hol:Eqi			◎	□	□	□	○		□																					
CR 15	Bs	Int	Amy			□?			○	?	?		□		○			?○ (Cpx–Opx)				□			□			◎					
CR 44	Sk	Int																							□		□	□	◎				
CR 45	Gd	Int	Hol:Eqi	□	□	◎	□	□	□	□		□																					
CR 66	Dol	Int	Hol:Suboph			◎		□	○	□		□																					
CR 201	Qd	Int	Hol:Eqi	□		◎		?○ (Ho–Hy)				□													○	□	□						
DR 36	Bi-Ho Qd	Int	Hol:Eqi	○		◎	□	○				□													□	□	□						
DR 58	Dol	Int	Hol:Por	□		□?	?○ (Bi–Hy)								○?						○	□		□	◎?	□?		○					
DR 75	Gdp	Int	Hol:Por			○							○	□	◎	□	□					□			△	△							
DR 98	Qd	Int	Hol:Eqi	○	□?	◎	?○ (Bi–Hy)					□													○		◎						
ER 4	Bs	Int	Interg			□			□				□		◎			◎	?			○			□	?							
ER 6	Bi Da	Int		□		○	□						◎		□	□						□											
ER 26	Ho-Bi Gr	Int	Hol:Graph Eqi	○	○	◎	□	□				□													□	△							
ER 35	Qd	Int	Hol:Eqi	□		◎		○				□																					
ER 36	Ho-Bi Gr	Int	Hol:Eqi	○	○	○	□	△				□														△							

Table 5 Results of Microscopic Observation of Thin Sections (3)

Sample No.	Rock Name	Rock Unit	Texture	Rock Fragment		Mineral Chip									Matrix						Altered Minerals								
				Pu	Ro	Q	Af	Pl	Bi	Ho	Au	Hy	Mf	Op	Q	Fd	Mf	Op	Cl	C	Q	Ch	Se	Ep	C	Ga	Py		
AR 11	An Tf bre	Rw	Pyrocl		○			○					□?		□	□	?	□	○	○		○	□		○				
AR 16	Da Tf	Rw	Pyrocl		□			○					□?		○	○	□?	□	○	○	□	□	□		○				
AR 32	Tfa Ss	Rw			○			○					○		□	○	□?	□	○	□		○	□		□				
AR 55	Ca Sl	Rw				□									□			□	○	○			○		○				
AR 92	Ls	Ml													△			△		◎									
AR 97	Ss	Rw				◎		□						□	◎			□	○				□						
AR 98	Sl	Rw													○			□	◎										
BR 9	Sdy Tf	Kw	Pyrocl		◎			○					□?	□	□	○	?	□	□	□		□		□	○				
BR 11	An Sdy Tf	Kw	Pyrocl		◎	□		◎					□?	□	□	○	□?	□	□	○	□	○		○	○				
BR 26	Fine Tf	Rw						□?					□?	□	○	?		□	○	□		○	□		□				
BR 79	An Lith Tf bre	Kw	Pyrocl		◎			□					?	□	□	□?		□	○	○		□			□				
BR 90	Tfa Ss	Kw			◎	○		○					□?		□	○	?	□	○			□	□	□					
BR 92	Hornfels (Ss ?)	Kw	Granoblastic			○		□	□	○				□							□								
BR 95	Sl	Rw												□	□			□	◎					□					
CR 18	Lap Tf	Kw	Pyrocl	○	□			□?					□?	□	□	?	?	□	○	○	□	○	□?		○		□		
CR 20	Sdy Tf	Kw	Pyrocl		◎	○		○					□		□	□	?	□	○	□				□	□				
CR 31	Tfa Ss	Rw			◎			□					□		□	□	□?	□	○	□		○			□				
CR 51	Da Tf	Hl	Pyrocl	□?		○		□?	□?				□	□	□	?	?	□	○			?	□				□		
CR 54	Da Tf bre	Hl	Pyrocl		○	○		○	□				□		□	□	□	□	○	?		□	□						
DR 107	Si Ls	Rw													□			△	□	○									
ER 11	Lap Sdy Tf	Kw	Pyrocl		○			○					□	□	□	○	?	○	□		□	□	□	□					
ER 24	Ls	Ml																△	△	◎									
ER 27	Ls	Ml																△		◎									

Table 6 Results of Age Determination by K-Ar Method

Sample No.	Locality	Rock name	Isotopic age (Ma)
AR 14	South of Plaukidak	Granodiorite	51.9 ± 2.6
AR 76	S. Tuboh	Quartz monzonite	40.1 ± 2.0
BR 98	S. Menalu	Granite porphyry	54.1 ± 2.7
CR 66	BT. Ipuh	Dorelite	< 0.4
DR 36	S. Senawar	Quartz diorite	83.6 ± 4.2

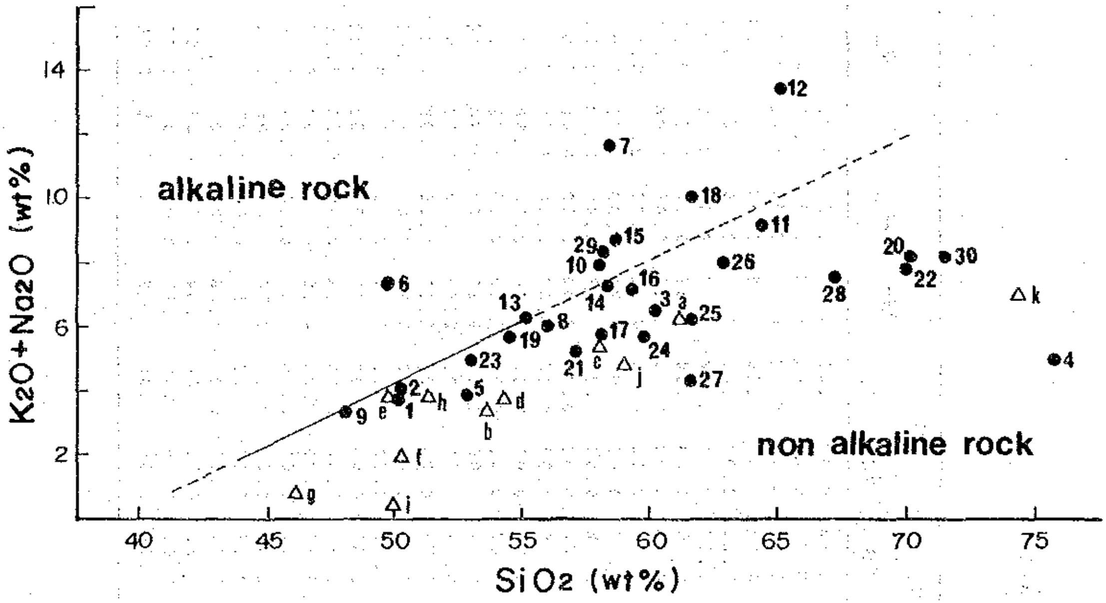
Table 7 Results of Whole Rock Analysis

(unit:% except ppm for BaO)

No.	Sample No.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	BaO	LOI
1	AR 2	49.98	20.75	2.41	4.97	3.92	8.88	3.34	0.46	0.62	0.09	0.14	360	4.03
2	AR 4	50.12	15.81	4.14	4.54	3.77	5.07	3.66	0.42	0.83	0.25	0.15	210	8.93
3	AR 14	60.10	16.26	2.77	3.41	1.88	4.84	3.93	2.51	0.75	0.40	0.15	540	0.95
4	AR 19	75.98	11.97	0.84	1.21	0.56	1.56	4.14	0.76	0.27	0.10	0.03	400	0.72
5	AR 26	52.80	15.52	2.01	6.12	2.92	6.75	3.03	0.93	0.81	0.30	0.16	240	7.61
6	AR 34	49.77	16.97	1.52	6.37	4.48	5.23	4.77	2.64	1.92	0.90	0.23	270	1.92
7	AR 37	58.51	18.01	1.78	3.31	0.87	1.99	6.46	5.32	0.86	0.43	0.05	550	0.92
8	AR 45	55.96	15.39	1.42	4.05	5.71	5.04	4.88	1.14	0.56	0.22	0.10	360	3.39
9	AR 58	48.04	17.38	6.43	5.80	5.37	9.62	2.91	0.41	1.10	0.06	0.17	110	0.72
10	AR 72	58.06	15.45	1.18	3.76	1.92	3.48	3.80	4.21	0.62	0.18	0.07	470	4.44
11	AR 75	64.35	16.46	1.33	2.29	0.92	0.90	6.39	2.91	0.49	0.26	0.15	510	1.84
12	AR 76	65.06	15.47	1.71	0.57	0.16	1.21	3.90	9.49	0.24	0.03	0.04	360	0.36
13	AR 79	55.18	17.01	2.50	4.72	1.83	6.29	4.11	2.24	1.04	0.35	0.21	330	2.36
14	AR 82	58.30	17.08	2.61	5.04	2.21	5.14	4.83	2.61	0.99	0.45	0.17	360	0.05
15	AR 85	58.66	15.67	1.95	3.07	1.91	7.95	5.85	2.89	1.10	0.49	0.11	310	0.78
16	AR 94	58.96	15.98	2.30	3.89	1.96	7.43	5.11	2.20	1.00	0.55	0.12	320	0.57
17	BR 10	58.08	16.02	1.70	3.73	4.31	6.28	4.29	1.50	0.59	0.37	0.10	300	1.54
18	BR 31	61.67	16.45	1.65	3.25	1.42	1.68	6.32	3.81	0.57	0.42	0.11	320	2.77
19	BR 37	54.52	17.64	0.56	7.98	2.94	6.84	4.35	1.33	0.99	0.59	0.19	180	1.18
20	BR 38	70.03	14.99	1.32	1.47	0.71	1.77	4.33	3.76	0.31	0.29	0.05	610	1.11
21	BR 94	57.07	16.74	2.16	3.89	4.22	6.36	4.32	1.03	0.79	0.30	0.12	200	2.09
22	BR 98	69.93	14.93	0.92	2.28	0.72	1.94	4.12	3.69	0.33	0.13	0.05	450	0.64
23	CR 12	53.07	17.50	3.35	6.83	3.64	7.87	3.71	1.01	1.07	0.48	0.20	260	0.31
24	CR 20	59.68	15.03	4.19	5.85	2.01	3.22	4.81	0.97	0.67	0.15	0.16	390	1.88
25	DR 36	61.30	16.05	1.89	3.16	3.24	4.83	4.57	1.70	0.56	0.18	0.09	310	2.00
26	DR 75	62.73	15.99	0.35	5.21	1.32	2.78	5.16	2.97	0.71	0.38	0.12	390	1.01
27	DR 98	61.47	15.08	3.35	5.88	1.24	4.81	4.20	0.14	0.54	0.29	0.13	120	1.96
28	ER 26	67.17	14.67	1.27	2.29	0.73	3.72	3.97	3.53	0.36	0.14	0.06	360	4.75
29	ER 35	58.06	16.28	0.46	4.34	2.49	6.90	5.81	2.56	0.57	0.41	0.15	650	1.54
30	ER 36	71.55	14.66	0.84	2.13	0.50	2.12	4.23	3.96	0.29	0.13	0.07	390	0.32
31	AR 24	61.38	16.27	3.43	3.12	0.68	4.56	3.87	2.53	0.73	0.27	0.30	400	1.85
32	AR 27	53.61	16.60	3.79	5.18	3.33	7.43	2.58	0.97	0.85	0.13	0.18	180	4.97
33	AR 81	58.07	13.75	1.24	3.76	4.53	4.15	3.20	2.21	0.45	0.27	0.12	450	5.55
34	BR 54	54.30	17.10	3.36	4.34	3.27	7.75	2.97	0.82	0.88	0.62	0.13	570	3.95
35	BR 60	50.18	18.53	3.16	6.07	4.98	7.61	2.90	0.95	0.70	0.41	0.17	140	3.43
36	BR 76	50.28	16.80	2.31	4.91	6.21	9.35	2.13	0.07	0.57	0.28	0.13	70	5.85
37	CR 15	41.15	11.55	5.97	4.02	15.03	7.55	0.68	0.22	0.56	0.15	0.14	70	11.18
38	CR 66	51.31	16.79	5.86	5.55	3.69	8.37	3.19	0.78	1.23	0.36	0.22	190	2.34
39	DR 58	44.98	9.92	1.01	6.14	12.94	7.99	0.46	0.01	0.48	0.43	0.16	690	13.03
40	ER 4	58.03	16.93	3.12	4.59	2.36	6.12	3.75	1.31	0.80	0.35	0.16	230	1.60
41	ER 6	74.23	13.30	1.29	0.45	0.28	1.26	3.53	3.66	0.18	0.06	0.05	550	1.33
42	AR 11	55.56	15.52	1.25	7.39	3.07	3.53	5.84	0.56	0.68	0.25	0.18	220	4.22
43	AR 32	51.62	16.46	1.34	7.57	4.10	6.48	4.71	1.31	0.67	0.20	0.17	160	2.24
44	BR 9	52.63	15.62	3.69	4.45	4.06	7.22	3.26	0.86	0.76	0.19	0.16	360	6.04
45	BR 11	49.07	16.91	4.00	4.91	5.65	7.50	3.36	0.08	0.96	0.16	0.19	40	5.14
46	BR 26	49.75	16.79	3.40	7.25	3.67	3.23	6.92	0.01	0.87	0.25	0.20	30	5.58
47	CR 20	59.37	15.25	2.89	4.84	3.12	6.58	3.11	0.32	0.47	0.01	0.18	140	3.21
48	CR 31	55.72	15.03	3.32	6.78	2.87	6.08	3.80	0.36	0.73	0.12	0.22	280	3.85
49	ER 24	0.60	0.28	0.13	0.03	0.32	54.21	0.03	0.01	0.03	0.04	0.01	20	42.75
50	ER 27	1.64	0.79	0.19	0.06	0.45	53.00	0.04	0.11	0.04	0.05	0.01	60	42.12

Table 8 Results of Normative Calculation

Sample No.	Q	C	or	ab	an	Ne	Di wo	Di en	Di fs	Hy en	Hy fs	Ol fo	Ol fa	Mt	Hm	Il	Ru	Ap
1 AR 2	1.97	0.00	2.72	28.25	40.27	0.00	1.36	0.78	0.51	8.97	5.86	0.00	0.00	3.49	0.00	1.18	0.00	0.21
2 AR 4	9.70	0.70	2.48	30.96	23.57	0.00	0.00	0.00	0.00	9.39	3.82	0.00	0.00	6.00	0.00	1.58	0.00	0.59
3 AR 14	14.66	0.00	14.83	33.24	19.32	0.00	0.92	0.53	0.34	4.15	2.67	0.00	0.00	4.02	0.00	1.42	0.00	0.95
4 AR 19	44.56	1.71	4.49	35.01	7.16	0.00	0.00	0.00	0.00	1.39	1.14	0.00	0.00	1.22	0.00	0.51	0.00	0.24
5 AR 26	10.96	0.00	5.49	25.63	26.00	0.00	2.33	1.06	1.25	6.21	7.29	0.00	0.00	2.91	0.00	1.54	0.00	0.71
6 AR 34	0.00	0.00	15.60	37.01	17.10	1.81	1.28	0.73	0.50	0.00	0.00	7.31	5.56	2.20	0.00	3.65	0.00	2.13
7 AR 37	0.00	0.00	31.43	46.78	4.45	4.25	1.15	0.46	0.70	0.00	0.00	1.20	2.00	2.58	0.00	1.63	0.00	1.02
8 AR 45	3.49	0.00	6.73	41.27	16.73	0.00	2.89	1.92	0.75	12.29	4.78	0.00	0.00	2.06	0.00	1.06	0.00	0.52
9 AR 58	2.43	0.00	2.42	24.61	33.15	0.00	5.93	4.20	1.21	9.17	2.63	0.00	0.00	9.32	0.00	2.09	0.00	0.14
10 AR 72	8.48	0.00	24.87	32.14	12.67	0.00	1.46	0.70	0.74	4.08	4.30	0.00	0.00	1.71	0.00	1.18	0.00	0.43
11 AR 75	12.29	1.75	17.19	54.04	2.87	0.00	0.00	0.00	0.00	2.29	2.58	0.00	0.00	1.93	0.00	0.93	0.00	0.62
12 AR 76	5.89	0.00	56.06	26.75	0.00	0.00	1.10	0.40	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.07
13 AR 79	6.72	0.00	13.23	34.76	21.36	0.00	3.19	1.47	1.70	3.09	3.58	0.00	0.00	3.62	0.00	1.98	0.00	0.83
14 AR 82	5.70	0.00	15.42	40.85	17.22	0.00	2.27	1.09	1.14	4.41	4.64	0.00	0.00	3.78	0.00	1.88	0.00	1.07
15 AR 85	0.00	0.00	17.07	49.41	8.52	0.03	7.63	4.76	2.41	0.00	0.00	0.00	0.00	2.83	0.00	2.09	0.00	1.16
16 AR 94	5.92	0.00	13.00	43.22	14.18	0.00	8.01	4.34	3.39	0.54	0.42	0.00	0.00	3.33	0.00	1.90	0.00	1.30
17 BR 10	8.32	0.00	8.86	36.28	20.03	0.00	3.67	2.38	1.03	8.35	3.62	0.00	0.00	2.46	0.00	1.12	0.00	0.88
18 BR 31	4.11	0.00	22.51	53.45	5.28	0.00	0.17	0.08	0.09	3.46	3.78	0.00	0.00	2.39	0.00	1.08	0.00	0.89
19 BR 37	2.05	0.00	7.86	36.79	24.69	0.00	2.28	0.84	1.48	6.48	11.42	0.00	0.00	0.81	0.00	1.88	0.00	1.40
20 BR 38	25.85	1.23	22.21	36.62	7.01	0.00	0.00	0.00	0.00	1.77	1.19	0.00	0.00	1.91	0.00	0.59	0.00	0.69
21 BR 94	8.36	0.00	6.08	36.54	23.25	0.00	2.67	1.76	0.72	8.75	3.56	0.00	0.00	3.13	0.00	1.50	0.00	0.71
22 BR 98	25.61	0.91	21.80	34.85	8.86	0.00	0.00	0.00	0.00	1.79	2.97	0.00	0.00	1.33	0.00	0.63	0.00	0.31
23 CR 12	4.56	0.00	5.97	31.38	28.12	0.00	3.28	1.66	1.54	7.40	6.84	0.00	0.00	4.86	0.00	2.03	0.00	1.14
24 CR 201	15.56	0.55	5.73	40.68	15.07	0.00	0.00	0.00	0.00	5.00	6.47	0.00	0.00	6.08	0.00	1.27	0.00	0.36
25 DR 36	12.94	0.00	10.04	38.65	18.27	0.00	1.91	1.24	0.54	6.82	2.95	0.00	0.00	2.74	0.00	1.06	0.00	0.43
26 DR 75	10.69	0.11	17.55	43.64	11.40	0.00	0.00	0.00	0.00	3.29	8.33	0.00	0.00	0.51	0.00	1.35	0.00	0.90
27 DR 98	21.83	0.00	0.83	35.52	21.89	0.00	0.05	0.01	0.04	3.07	7.34	0.00	0.00	4.86	0.00	1.03	0.00	0.69
28 ER 26	21.93	0.00	20.85	33.58	11.79	0.00	2.43	0.99	1.46	0.83	1.22	0.00	0.00	1.84	0.00	0.68	0.00	0.33
29 ER 35	0.00	0.00	15.12	48.33	10.79	0.44	8.73	4.08	4.55	0.00	0.00	1.49	1.83	0.67	0.00	1.08	0.00	0.97
30 ER 36	25.64	0.00	23.39	35.78	9.33	0.00	0.17	0.05	0.13	1.19	2.74	0.00	0.00	1.22	0.00	0.55	0.00	0.31



△ Volcanic rock

a: AR 24	f: BR 76
b: AR 27	g: CR 15
c: AR 81	h: CR 66
d: BR 54	i: DR 58
e: BR 60	j: ER 4
	k: ER 6

● Plutonic rock

1: AR 2	11: AR 75	21: BR 94
2: AR 4	12: AR 76	22: BR 98
3: AR 14	13: AR 79	23: CR 12
4: AR 19	14: AR 82	24: CR201
5: AR 26	15: AR 85	25: DR 36
6: AR 34	16: AR 94	26: DR 75
7: AR 37	17: BR 10	27: DR 98
8: AR 45	18: BR 31	28: ER 26
9: AR 58	19: BR 37	29: ER 35
10: AR 72	20: BR 38	30: ER 36

Fig. 9 SiO_2 - (K_2O + Na_2O) Diagram

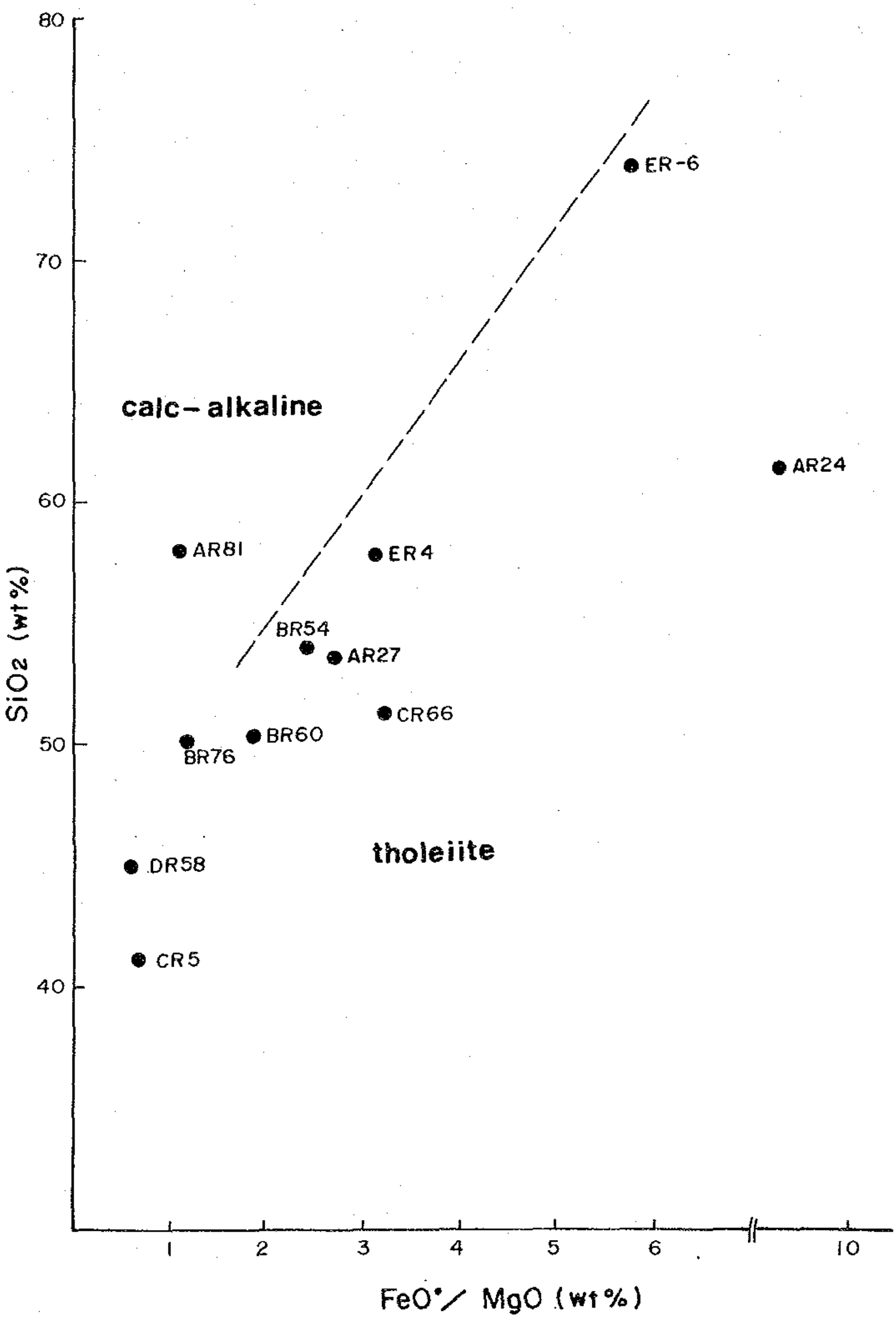
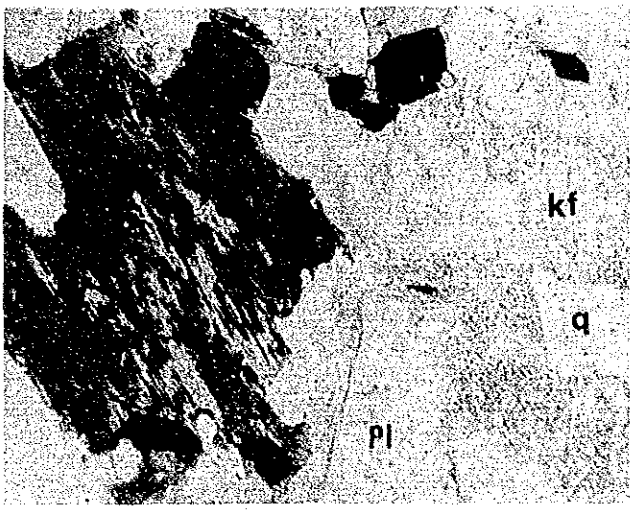
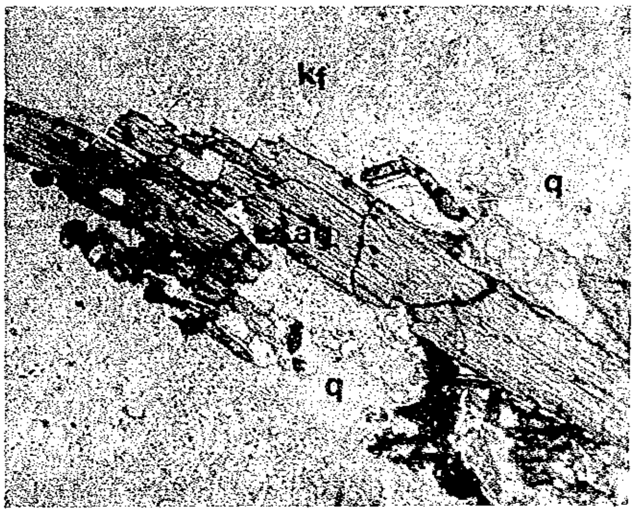


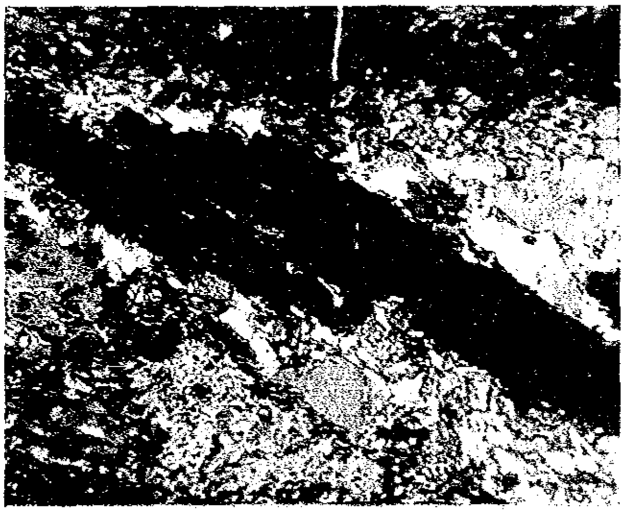
Fig. 10 **FeO $*$/ MgO - SiO_2 Diagram**

AR-14 Granodiorite

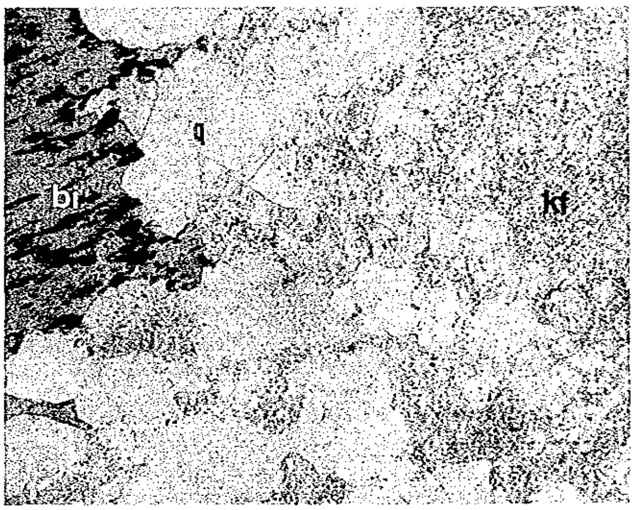


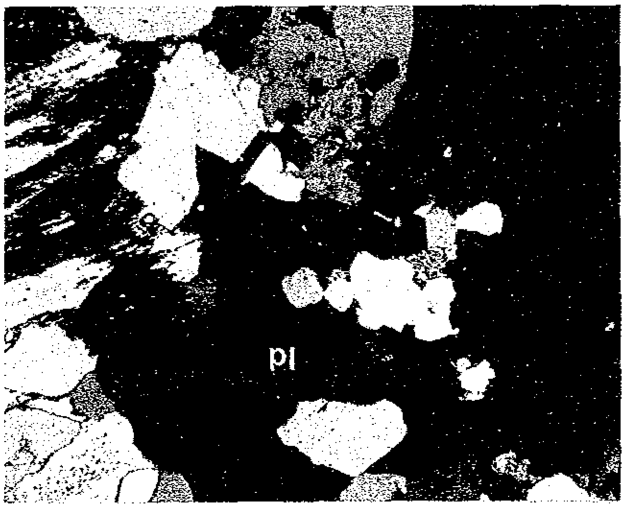
AR-76 Quartz monzonite





BR-98 Granite porphyry



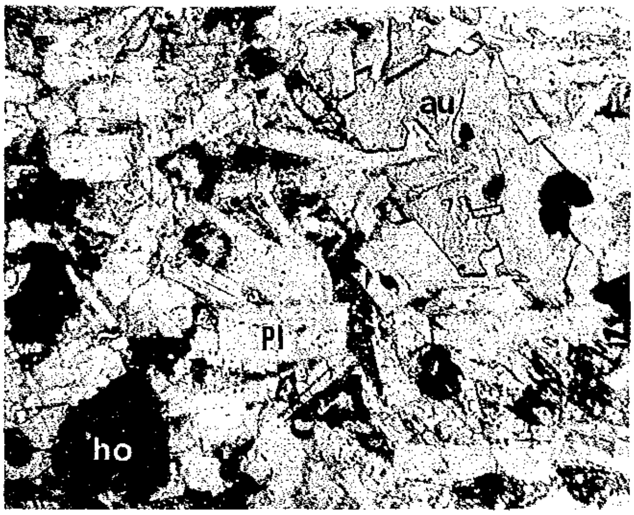


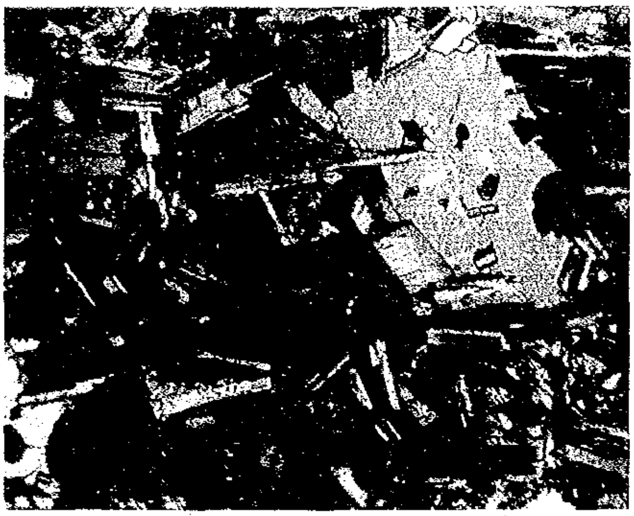
0 0.5mm Open

Closs

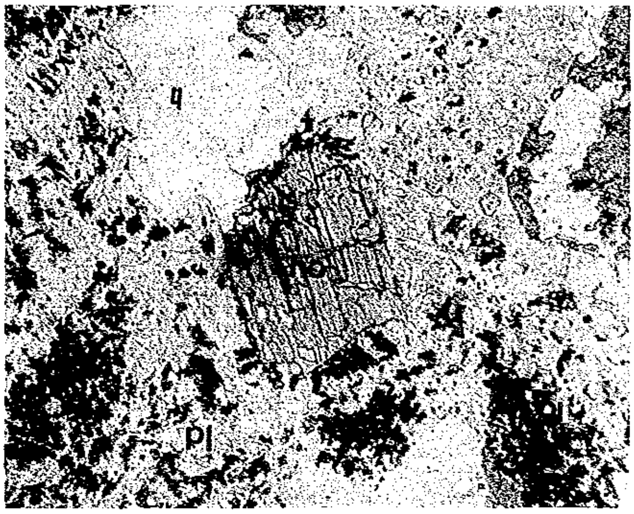
Photo.1 Microscopic Photograph of Rock (1)

CR-66 Dorelite





DR-36 Quartz diorite



0 0.5mm Open

Closs

LEGEND

q : Quartz
pl : Plagioclase
kf : Alkali feldsper
bi : Biotite
ho : Hornblende
au : Augite
ag : Aegirine augite
ep : Epidote

Photo.1 Microscopic Photograph of Rock (2)