REPUBLIC OF INDONESIA

MINISTRY OF MINES

GEOLOGICAL SURVEY OF INDONESIA

REPORT ON GEOLOGICAL SURVEY OF CENTRAL KALIMANTAN

PHASE I

LANDSAT DATA ANALYSIS

PHASE II

AERIAL PHOTOGRAPHY AIRBORNE MAGNETIC SURVEY

JAN. 1977

METAL MINING AGENCY OF JAPAN
JAPAN INTERNATIONAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

P R E F A C E

The Government of Japan, in response to the request extended by the Government of the Republic of Indonesia, decided to conduct an integrated geological survey for mineral exploration in central Kalimantan of Indonesia, and commissioned its implementation to the Japan International Cooperation Agency.

The Agency, taking into consideration of the importance of technical nature of the survey work, in turn sought the Metal Mining Agency of Japan for its cooperation to accomplish the task within a period of three years.

The Government of the Republic of Indonesia appointed the Geological Survey of Indonesia to excute the survey as the counterpart to the Japanese team. The survey has been carried out jointly by both governments' experts.

The first phase of the survey consists of Landsat data analysis; the second phase, aerial photography and airborne magnetic survey.

This report submitted hereby summarizes the results of both the first and the second phase surveys, and it will be also formed a portion of the final report that will be prepared with regard to the results obtained in the third phase.

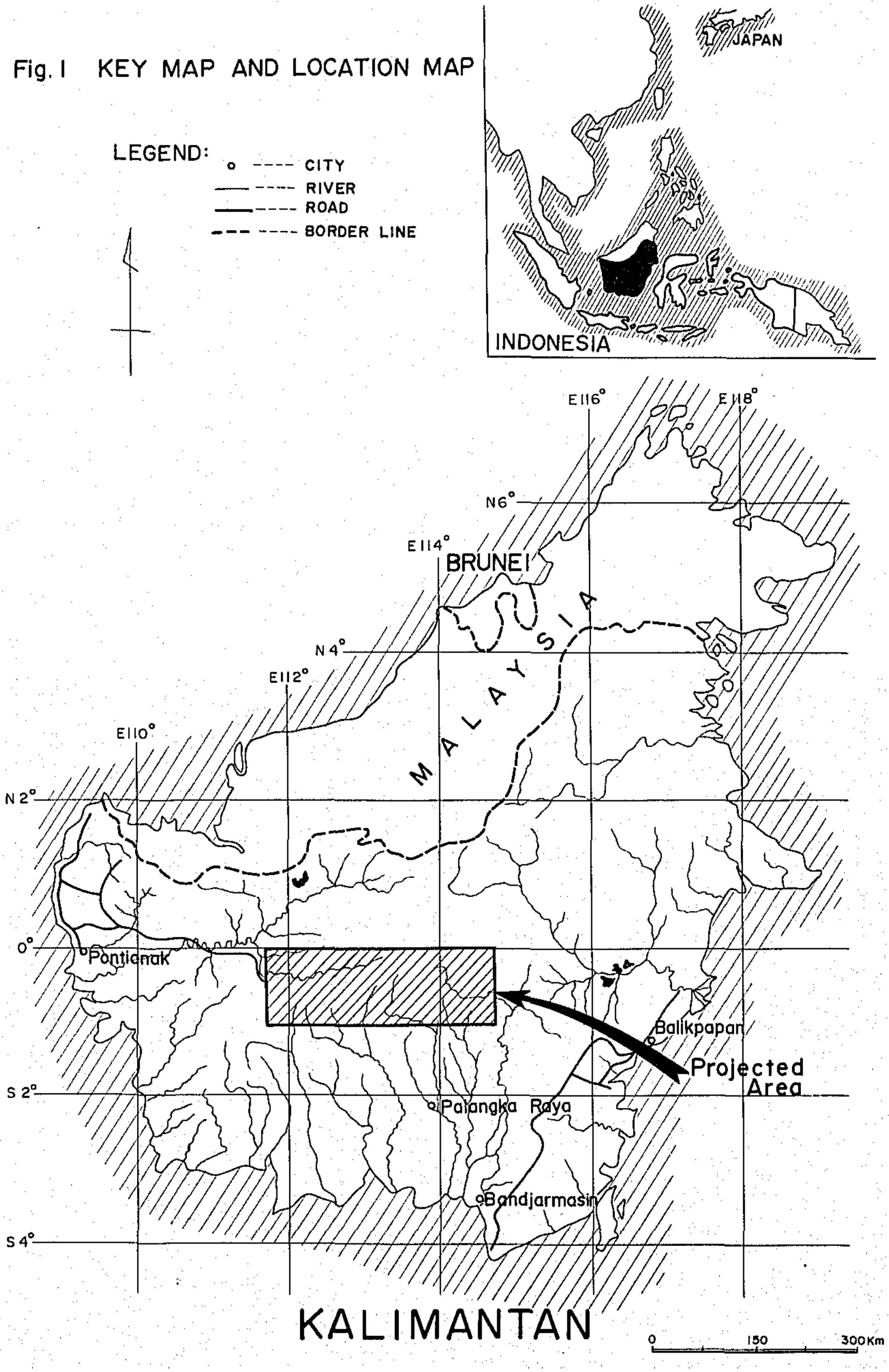
We wish to take this opportunity to express our gratitudes to all sides concerned with the excution of the survey.

January, 1977

Prof. Dr. J.A. Katili
Director General
Ministry of Mines
Republic of Indonesia

Shinsaku Hogen
President
Japan International Cooperation Agency

Fig. 1 KEY MAP AND LOCATION MAP



PHASE I

LANDSAT DATA ANALYSIS

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LIST OF ATTACHED DATA

1) Black and White Images 1/250, 000

	Band 4	5	6	7
E - 1356 - 02185	*	*	*	*
E - 1355 - 02131	*	*	*	*
E - 1355 - 02133	*	*	*	*
E - 1444 - 02054	*	-	*	*
E - 1246 - 02082	*	*	*	*
E - 1138 - 02080	*	*	*	*
E - 1138 - 02082	*	-	*	*
E - 1444 - 02061	*	-	*	*
E - 1372 - 02074	*	*	*	-
E - 1137 - 02022	*	*	*	*
E - 1443 - 02003	*	*	*	*
E - 1101 - 02023	*	*	*	*

2) False Color Compositive Images 1/250, 000

E - 1356 - 02185 E - 1138 - 02080 E - 1137 - 02022
E - 1355 - 02131 E - 1444 - 02061 E - 1443 - 02003
E - 1355 - 02133

3) Extracted Images on Lithological Units 1/500, 000

4) Geological Interpretation Overlay on LANDSAT-image 1/250, 000

5) Photo-Mosaic of LANDSAT-imagery (Channel 7) 1/1, 000, 000

6) Photo-Mosaic of LANDSAT-imagery(Channel 7) 1/500, 000

7) 3 Dimensional Display from LANDSAT-imageries (Channel 7) 1/500, 000

8) LANDSAT-images of Additive Color Composition and Enhanced and Extracted Composition

Abstract

Pattern and spectral analyses of LANDSAT data were carried out for the project area with the purpose of obtaining basic information for further prospecting.

From the pattern analysis, data pertaining to geology and the geologic structure were obtained and the geology of the area was classified into 16 geological units. These units were further correlated to the existing geological maps, and the distribution of the various lithological units of the area was clarified. The geologic structure of the area is controlled by the uplifted belt extending from southwest to northeastern part of the area and the basins in both east and west of this belt. WNW-ESE folds are prominent in the western basin and NNE-SSW folds are developed in the eastern basin.

From the spectral analysis, mineral showings were extracted. Alluvial and diluvial deposits were found in localities shown as placer deposits in the map and two types of anomalies were observed for areas indicated to contain vein deposits. Porphyry copper type deposits are expected to be found in this project area, acidic plutonic bodies were extracted, and the occurrence of many granitic bodies was confirmed.

Data concerning the geology and mineral deposits of this area are scarce and thus the detailed study of the mineral showings and the results obtained by this work is difficult, and the accumulation of geological data is awaited.

GENERAL REMARKS

Chapter 1 Introduction

1-1 Objective of the survey

The objective of this phase of the project is to analyse the LANDSAT data in order to extract anomalies and delineate areas of possible mineralization and related alteration as well as to obtain basic information concerning topography, vegetation, geology and geologic structure. The results of these analyses will serve as the basis for further phases of the project.

1-2 Outline of the survey

1-2-1 Project area

The project area is located in the central part of Kalimantan, Republic of Indonesia and is bounded by lines joining lat. 0° - 1°S., and long. 111°45' - 114°45' E. The total area is 36, 300 km^2.

1-2-2 Period of survey

December 1, 1975 to February 20, 1976

1-2-3 Analytical methods

The following 15 scenes of LANDSAT imagery were used during the work (12 scenes within the project area and 3 scenes outside of the said area).

Western zone

Image number	Latitude /	Longtitude of the central point
E-1356-02185	N00-05	E110-42
E-1355-02131	N00-04	E112-08
E-1355-02133	S01-23	E111-49

Eastern zone

E-1444-02054	N00-01	E113-42
E-1246-02082	S00-08	E113-35
E-1138-02080	S00-08	E113-39
E-1138-02082	S01-34	E113-19
E-1444-02061	S01-26	E113-22
E-1372-02074	S01-20	E113-17
E-1137-02022	S00-07	E115-05
E-1443-02003	S01-32	E114-47
E-1101-02023	S01-29	E114-47

Neighboring area

E-1051-02240	N01-24	E109-47
E-1051-02242	S00-03	E109-26

The vicinity of the Mamut mine

E-1173-02001	N05-43	E116-34

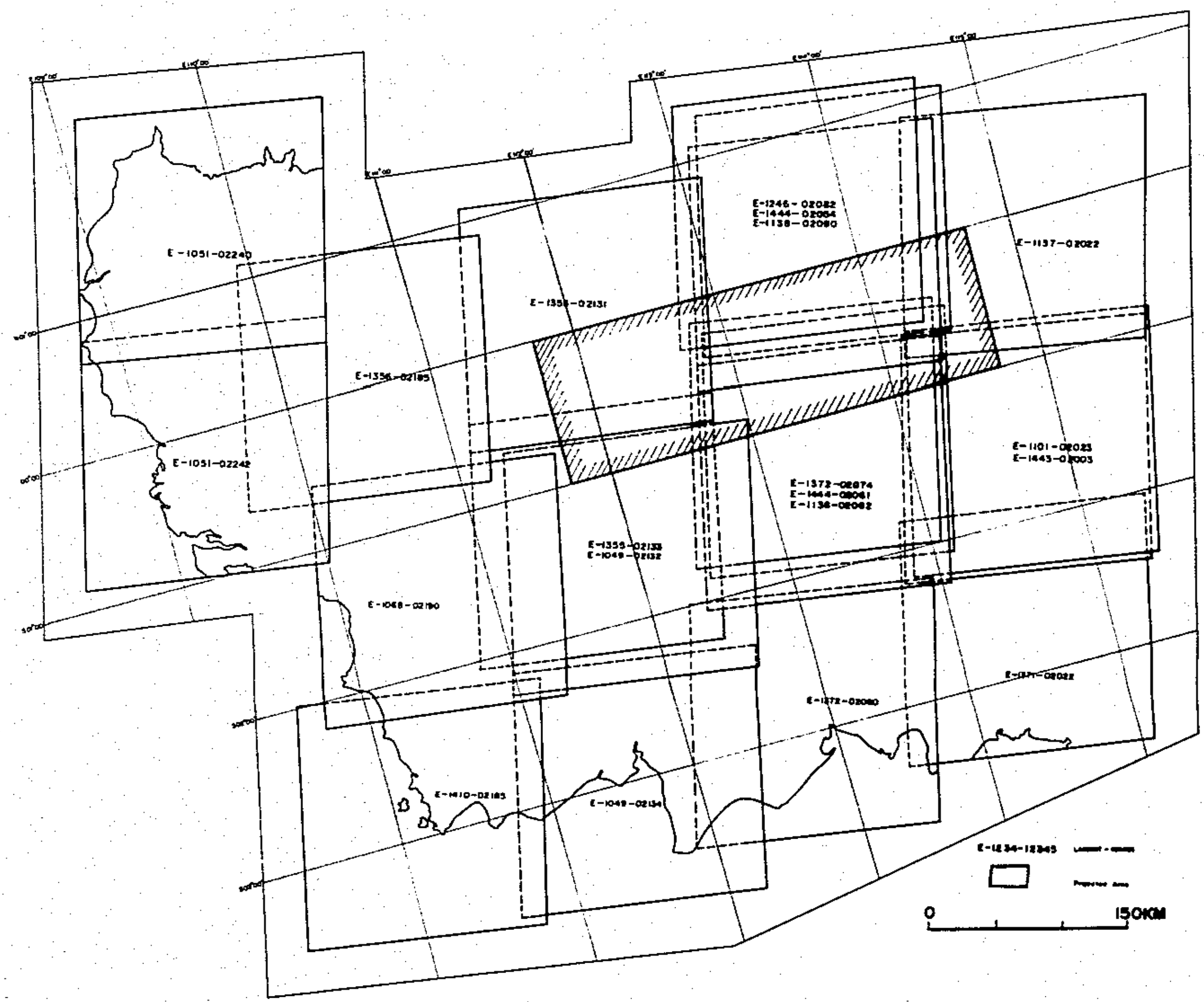


Fig. 2 INDEX MAP OF LANDSAT - IMAGES

(1) Geographical analysis

Topography, density of forests, savanna, human population, transportation network (roads, waterways) were classified by additive color composites, edge enhanced images, three dimensional display images and other methods.

(2) Geological and structural interpretation

Geological patterns were read directly from five types of positive images; namely, black and white images and false color compositive images of each band. Geomorphological characteristics such as density, lengths, and pattern of the drainage systems; resistance to erosion, cross section of valleys, forms of ridges; density, direction, and lengths of fissure systems as well as the tone and texture were considered in determining the lithological distribution. Also geological structural analysis was carried out by referring to the trends of bedding, schistosity, and the pattern of linear systems.

(3) Extraction of anomalies (mineralized and alteration zones)

These works are done by employing additive color method, color enhancement and extraction, and print out method.

(a) Additive color analysis

The negative and positive films of each band were studied by using additive color viewer under various combinations of the lights of three primary colors. The combination by which the alteration haloes of the known mineralized zones (including those not in the project area) stand out most conspicuously were selected. Additive color images were then prepared by this combination and similar anomalies were delineated.

(b) Color enhancement and extraction analysis

Combinations of the lights of the three primary colors and the negative and positive films of each band were produced by the multi-color data system. The color patterns which indicated the mineralized zones and the activation of the vegetation in the vicinity were extracted and used in identifying mineralized zones.

(c) Print out method

For the zones which were delineated from the operations explained above, more detailed, accurate, and objective data were printed out by CCT (Computer Compatible Tape) and analysed.

(4) Interpretation

All images prepared by the above procedure were studied, topographic, tonal, hazy, and geobotanical anomalies were correlated and their significance to geology and geologic structure was analysed.

Also during the analysis and interpretation mentioned above, various geological literatures concerning the vicinity of the project area were fully utilized and the data obtained by the Geological Survey of Indonesia during reconnassance survey were of great value.

(5) Map preparation

The results of the analysis of the images were compiled into a geological interpretation map.

(6) LANDSAT images

In selecting the LANDSAT images, attention was given to obtain the combination with the smallest amount of cloud over the total project area. And mosaic of the entire area by using the 7 band was prepared.

1-2-4 Members of the survey team

Advance team

General services	Tsuneaki Mizuno	MMAJ
" "	Yuichi Kanita	JICA
" "	Teiichi Toda	MMAJ

Survey team

Coordinator	Haruhiko Hirayama	NED
Data analysis	Tokichiro Tani	NED
" "	Hiroyuki Fujioka	NED
" "	Teruo Takeyama	NED

Counterpart experts

	Adjat Sudradjat	GSI
	Turus Soejitno	GSI
	Sae'un Hardjoprawiro	GSI

1-2-5 The course of the survey

Actual negotiations concerning the details of the project was done by the advance team during the period of 10 - 29 October 1975. It was agreed at this time that the pattern information analysis was to be carried out in Indonesia and spectral analysis in Japan. As a result of this agreement, Japanese photogeologists were sent to the Geological Survey of Indonesia during 9 - 29 December 1975 then the Indonesia photogeologists to Japan to work on the project jointly.

Chapter 2 Summary of Results Obtained

The project area is geologically divided into the following three zones, namely southwest-northeast, northwest, and southeast zones.

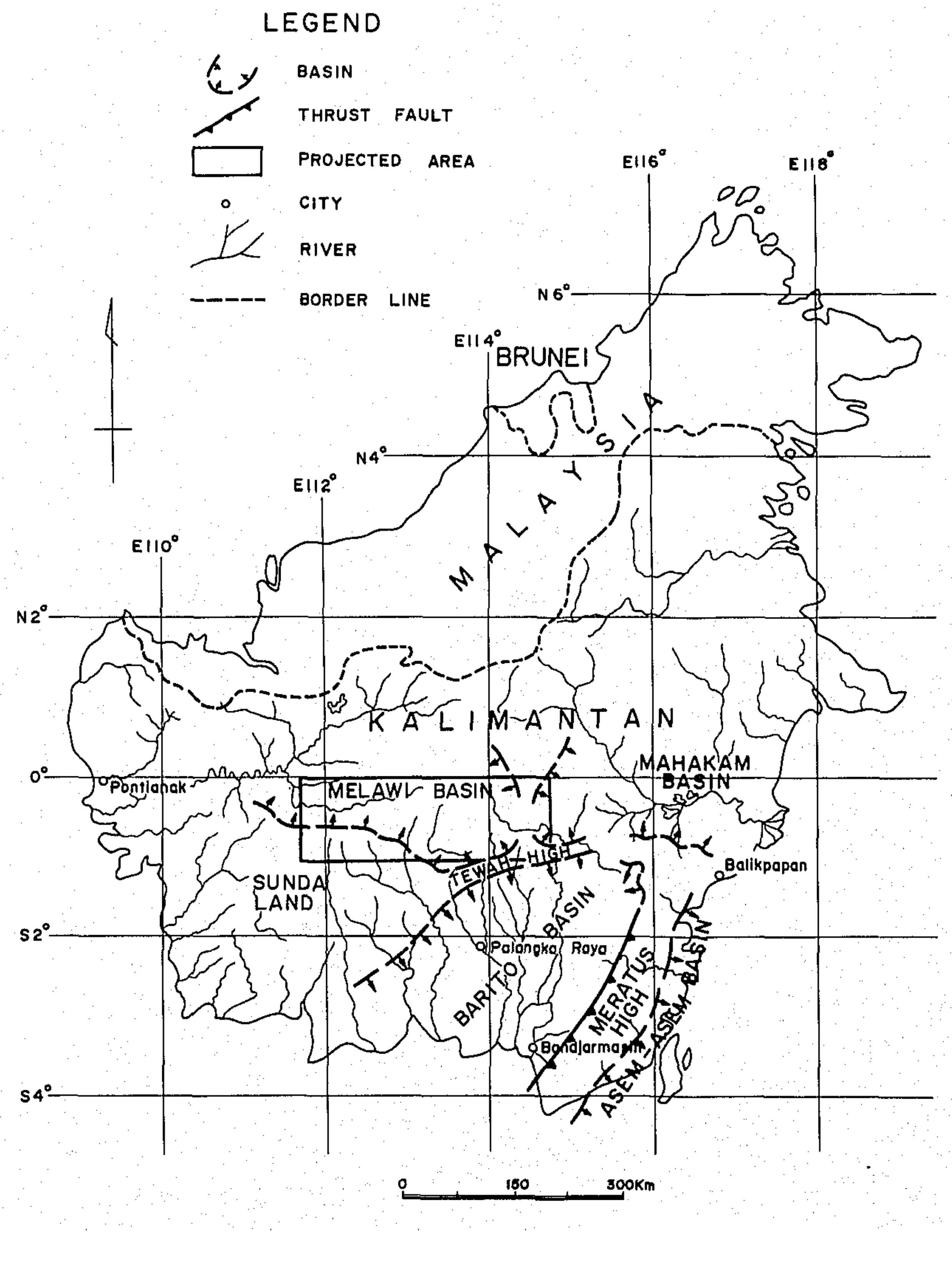
2-1 Southwest-northeast zone

This zone consists mainly of Units M and D (metamorphic rocks), N(andesitic rocks), and G (granitic rocks). These are correlated with Carboniferous-Triassic (metamorphics), Cretaceous (andesites), and upper Cretaceous (granites) of the geological map. Also this zone is situated in the northern part of the Sunda Land - Tewah High of the "Tectonic map of central and southeast Kalimantan" (Fig. 3), and forms the uplifted zone at the border between the Melawi basin and the Mahakam basin in the east.

The occurrences of Au, Cu, Pb, Mo, and other metallic veins have been reported in the granitic rocks.

From the results of the analysis, especially the pattern analysis and the color enhancement and extraction method, the granitic bodies are classified into relatively large bodies of different tone, texture, and resistivity to erosion. Also the major fissure systems trend in NNW - SSE direction and the metallic veins are believed to be controlled in that trend. The analysis by the print out method revealed the two types of anomalies which are shown in PL-IV-3 and -5. One type is developed in the vicinities of the granitic bodies and is characterized by clearly developed linear structures of NNW - SSE system. Thus these zones are considered

Fig. 3 TECTONIC MAP OF CENTRAL AND SOUTHEAST KALIMANTAN



to be promising for the occurrence of metallic veins from the development of fissures and its relation to igneous activities. The other type of anomaly consists of belts of relatively dark and light tones in single rock bodies. These belts occur in an echelon arrangement, and no vegetation difference is observed in these anomalous zones. This is believed to be caused by the difference in water content due to the silicification and argillization along the fissures.

Mineralization is not observed in the project area, but one of the types of mineralization which can be expected from this area is porphyry copper. One of the basis for this inference is the dissemination of chalcopyrite and pyrite in the granitic rocks found by the GSI to the south of the project area. Also one of the porphyry copper zones extending southward from the Philippines (Liddy, 1974) can be inferred to continue to the western part of Kalimantan via the Mamut deposit in the Malaysia side of the northern part of the island. With these facts in mind, we have extracted acidic plutonic bodies which are believed to be related to the above mineralization. Many granitic bodies were extracted as a result of the operation, but as there is no mineralization of this type known in this area, they could not be correlated and it is not yet clear as to which type of granites is related to mineralization.

2-2 Northwest zone

The major geologic units of this zone are T (Tuffs), H(sandstone-shale alternation), F and S (sandstones), B (basalts), and A (andesite dykes) which have been intruded into all of the above units. These units are correlated to Eocene - Miocene (tuffs and sandstone-shale alternation), and Pliocene - Pleistocene (sandstones, basalts, and andesite dykes) of the geological map. This zone is situated on the southeastern margin of the Melawi basin (Tectonic map).

These Eocene - Miocene series unconformably overlie the basement rocks and are controlled by the WNW - ESE trending folds. The Pliocene - Pleistocene sandstones occur almost horizontally and are not harmonious to the lower units.

Gold and diamond placer deposits have been reported from the project area. The distribution of alluvial and diluvial deposits was clarified by this analysis, but it was not possible to obtain information regarding the particulars of these deposits.

Other types of mineralization which can be expected to occur in the project area from geological and geologic structural considerations are .veins associated with andesite dykes, sedimentary uranium deposits, and epithermal syngenetic deposits.

Metallic veins associated with andesite dykes have been discovered by GSI to the south of the present area. Because of these informations,we have analysed the andesite dyke zones by print out method and this clarified the shape and distribution of these dykes, but it was not possible to study these anomalies concerning mineralization because of the lack of data.

Sandstone type uranium deposits occur in Tertiary or Quaternary systems which unconformably overlie granitic basement which forms basins (Hayashi, 1970, Katayama 1974). There are geologic environments suitable for the occurrence of this type of deposits in this zone.

Kuroko deposits have been reported to occur in the marginal parts of the Tertiary basins with intense igneous activity by the Society of Mining Geologists of Japan (1974). And there are geological conditions favorable for the occurrence of these submarine exhalative deposits.

2-3 Southeast zone

The major geological units of this zone are E (pyroclastic rocks), H' (sandstone-shale alternation), and C and S (sandstones). These units are correlated to Eocene - Miocene (pyroclastics and sandstone-shale alternation), and Pliocene - Pleistocene (sandstones) of the geological map. This zone is situated on the southwestern margin of the Mahakam basin (tectonic map).

The Eocene - Miocene formations unconformably overlie the basement and are controlled by the folds of ENE - WSW trend, and they are distributed in the Mahakam basin. The Pliocene - Pleistocene sandstones occur horizontally and are not harmonious to the structure of the Eocene - Miocene units as in the case of the northwest zone.

Geological and ore deposits data of this zone are very few. But from the general geological information now available, the zone is located at the marginal part of a sedimentary basin, and the pyroclastic formations are predominant, also there are possibilities of the occurrence of the Kuroko type deposits as in the case of the northwest zone. Unfortunately, LANDSAT images of this zone are somewhat cloudy and there are many parts where details could not be analysed.

2-4 Applicability of LANDSAT data analysis

2-4-1 Pattern analysis

LANDSAT analysis is very effective for topographic, geologic, and geologic structural analysis of unknown areas if clear and good images with small cloud cover are available. It is especially suited for tectonic studies. The age relationship, however, can only be determined by the vertical relationship of the geologic units, and from our experiences, the most detailed classification possible from the LANDSAT data is in the order of pre Tertiary, Tertiary, and Quaternary in most cases. If existing data such as geological maps are available, the analysis will be much more effective and the results will be in more detail. Therefore, this method will be a very strong weapon for completely virgin area or for areas with spotty and uncorrelated information.

2-4-2 Spectral analysis

(1) Analogue processing

There are two objectives for analogue process. One is to obtain objective data for pattern analysis and the other is for delineating the anomalies such as mineral showings.

In the former case, this is done in parallel with the pattern analysis or in a complementary manner only for specific problems of the analysis. The geologic units can be distinguished only by the density distribution of the film and geological consideration does not play important roles.

In the latter case, it is important that one or more known mineral showings exist in the same scene and that at least some information of these showings is available so that the anomalies can be compared and correlated. If there are no mineral showings in the same scene, the operation will be very difficult.

This method, therefore, is effective either during the pattern analysis or when a part of a scene has been geologically investigated and mineral showings have been located.

(2) Digital processing

Before attempting digital processing of LANDSAT images, the objective zones, for example the promising zones for mineral occurrences, must be delineated by some means. Also more accurate results can be obtained faster in proportion to the amount and quality of information obtained by other means.

For the delineation of the promising areas, pattern analysis and analogue processing of spectral information were combined in this case. Also analysis of reconnaissance aerial photographs will increase the accuracy of the work. The combination of studies of existing data, geological reconnaissance, and photogeological study would also be very effective.

This method, nevertheless, is not necessarily very effective in cases when other data are lacking, and should be used after accumulating certain amount of geological information.

2-4-3 Cloud cover in LANDSAT data

When clouds cover parts of the area in the LANDSAT images, several scenes will be necessary to analyse a single area. From our experiences, it will be possible to obtain results by combining several scenes if the cloud covers less than 30 per cent of the total area. The distribution of the clouds, however, greatly affects the accuracy of the analysis. For example, if the cloud occurs as masses in several parts of a scene, the covered parts can be complemented by studying scenes of other numbers or can be extrapolated from the geology of the visible parts. If, on the other hand, the clouds are dispersed throughout the area, analysis is impossible even if all the area became visible by combination of several scenes.

2-5 Conclusions and recommendations

2-5-1 Conclusions

The geology of the project area consists of the following 16 units in the ascending stratigraphic order. Carboniferous - Triassic metamorphic rocks, Cretaceous andesites, Eocene - Miocene tuffs and sedimentary rocks, Pliocene - Pleistocene sedimentary rocks and basalts, Recent sediments, and intrusive rocks such as Cretaceous granites and Pleistocene andesites.

The geologic structure is controlled by the uplifted belt in the southwest - northeast zone, by the Melawi basin to the west, and by the Mahakam basin to the east. Folds of WNW - ESE system is developed in the Melawi basin and NNE - SSW folds in the Mahakam basin.

Three systems of lineations NNW - SSE, NNE - SSW, and ENE - WSW are developed in the metamorphic rocks, but only NNW - SSE lineation is predominant in other units. The lineations of NNW - SSE direction gradually change from N - S to NW - SE direction as the formations become younger.

Placer and vein type mineralizations are known in this area. Placer deposits cannot be extracted from the LANDSAT images by any method, but alluvial and diluvial deposits were found in localities where placer deposits are shown in the geological map. Veins themselves cannot be extracted, but anomalies of linear structure and tonal anomalies were observed in the vicinity of the localities shown as vein occurrence in the geological map.

Mineral showings have not been found in the project area yet, but there are possibilities of porphyry copper, sedimentary uranium, and kuroko type exhalative deposits in the area from geologic and structural considerations.

Analysis was made of the area with porphyry copper in mind. The deposits in other areas were referred to. It was not possible to extract the mineral showings, but the distribution of the granites was determined fairly accurately.

2-5-2 Recommendations

The following surveys are recommended for future work in the area.

(1) Aerial photography

(2) Photogeology

(3) Air-borne magnetic survey

Further work should be considered after the execution of the above work.

The above work is recommended here from the following reasons.

(a) Regarding the geology and the geologic structure of the area, cloud cover is rather extensive from the central to the eastern part of the area, resulting in many unclarified parts. Thus reconnaissance aerial photography of the area is desired before carrying out ground surveys.

(b) Regarding mineral showings, reference data are lacking and thus the study of the relation between placer deposits and alluvial, diluvial sediments; veins and anomalies; porphyry copper deposits and granites are very difficult. Therefore, digital analysis and photogeological study of these problems are most desirable.

(c) The sedimentary uranium and Kuroko type deposits which are considered to have the possibility of occurring in this area cannot be analysed or extracted at this point because of the lack of any reference material. And the basin structure, the morphology of the basement surface and other salient features should be studied by airborne magnetic survey and other methods.

ANALYTICAL RESULTS

PART I

LANDSAT IMAGE PATTERN ANALYSIS

Chapter 1 Analytical Procedure

The LANDSAT images used in this study were 12 scenes in seven areas as shown in Fig. 2. The images of the western part were superior to those of the eastern half of the project area because of the cloud cover and the quality of the photographs.

Monochrome prints of 4, 5, 6, and 7 bands in the scale 1:250,000 and monochrome prints of bands 5 and 7 in scale 1:500, 000 and 1:1, 000, 000 of all the above scenes were used for photogeological study.

The reason for using larger scale prints of 1:500, 000 and 1:1, 000, 000 was the better quality of the images and the suitability for the observation of large tectonic features and linear structures. Band 5 images contained the largest amount of information concerning vegetation and band 7 images offered the best information on geology, topography, and water content.

The procedures of analysis and interpretation were as follows.

(1) Drainage systems and geological patterns were plotted by red dermatgraph pencil on 1:250, 000 black and white prints of each scene. Prints of band 7 were mainly used and other prints were referred to.

Discrimination of geological units; relationship among these units; geologic structure such as trends of bedding and schistosity, folds, linear structure; topographic and other types of anomalies (e.g., tone anomalies due to alteration) were the major geological information obtained.

(2) In cases when 2 or more scenes were necessary because of the cloud cover, band 7 black and white prints with the least cloud cover and good quality were mainly used, and this was complemented by other scenes for parts covered by clouds.

(3) The photogeological characteristics of the geological units discriminated by the process mentioned above were listed in a table and the lithology of these units were analysed.

(4) The results of the above work were plotted on overlays and working copies were prepared. These interpretative works were also carried out by the Indonesian counterpart photogeologists. The results of the work of both groups together with data from previous works were correlated and final analysis map and report were prepared jointly by the Japanese and Indonesian members. In the preparation of the analysis map, the results of the Japanese work was used for the western part with lesser cloud cover and the Indonesian results were compiled for the eastern part with more cloud cover as the use of existing data was essential in this zone.

Chapter 2 Geology

2-1 General Geology

Geological map on 1:500, 000 scale published by the GSI is the only published geological data of the project area.

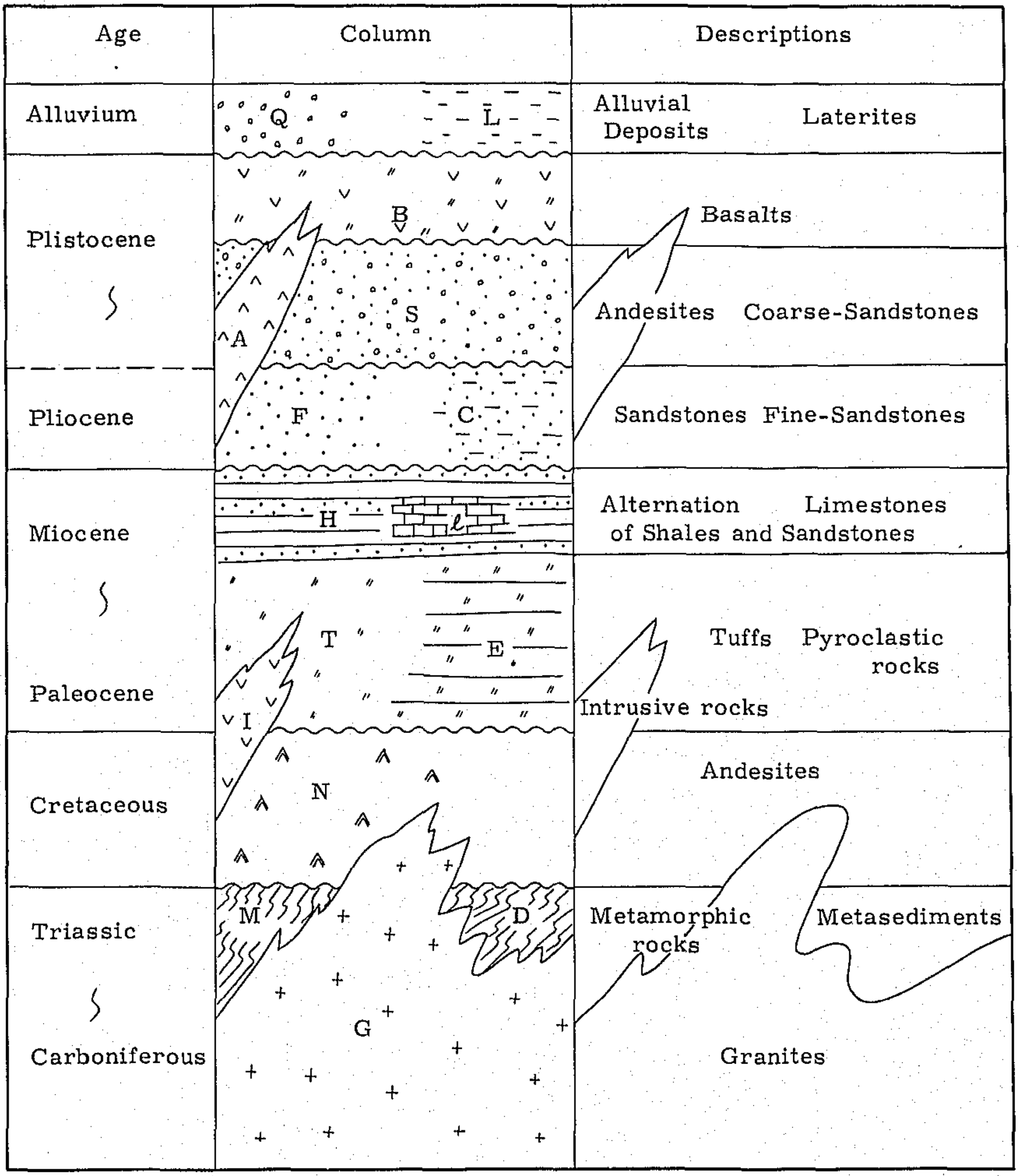
There are some blank areas in the eastern and southern parts of this map, but it is shown in this map that the southern part of the project area consists mainly of Carboniferous to Triassic formations with acidic to intermediate intrusive bodies, the northern part of Pliocene to Pleistocene units, and the southeastern part of Eocene to Miocene formations. Carboniferous to Triassic and Cretaceous units are shown in this map to the north of the project area. The lithology of these units, however, is not shown in this map. The geologic structure is not clear in the southern part, but the Pliocene to Pleistocene formations in the north are considered to be controlled by the east-west trending fold structure.

According to the GSI data, the geology of Kalimantan consists largely of Tertiary to Quaternary formations deposited on the Melawi basin in the west, Barito basin in the south, Mahakam basin in the east, and of the Carboniferous to Triassic units which form the basement of these basins together with the Cretaceous system (Fig. 3).

Although petroleum has not been found in the Melawi basin, large oil fields are known in both Barito and Mahakam basins.

The project area is situated at the northern margin of the

Fig. 4 MODIFIED GEOLOGICAL COLUMN



Notes :

1. Lineament patterns of Units M and D are different from Units N to B.
2. Folding structures are observed in Units E, T, H and ℓ.
3. Bedding planes of Units C, F, S and B are nearly flat.

Table 1. CHARACTERISTICS CHART OF LANDSAT-IMAGE, KALIMANTAN (7 BAND)

UNIT	PHOTOGRAPHICAL C.		TOPOGRAPHICAL CHARACTERISTICS									COMMENT	PROBABLE LITHOLOGY
			DRAINAGE			RESISTIVITY, SECTION			LINEARMENT, BEDDING				
	TONE	TEXTURE	PATTERN	DENSITY	PARAMETER	ROCK	VALLEY	RIDGE	DIRECTION	INTENSITY	KINDS		
Q	light	hazy	meander	rare	permanent	very weak	flat		-	-	-	swamp, oxbow rich, poor vegetation.	Quaternary Sediments
L	gray	fine	meander	rare	permanent	very weak	flat		-	-	-	well vegetation	Laterites
B	gray	coarse	dendritic	medium	very short	strong	∨	⌐¬	mainly 1	medium	joint	ditto	Basalts (Lava + Tuff)
S	very dark	fine	-	-	-	strong	–∨–	–√‾	rare	strong	bedding	dipping is nearly flat. F⌇S⌇B	Coarse Sandstones
F	dark	fine	-	-	-	medium	–∨–	–√–	rare	strong	bedding	dipping is very gentle H⌇F⌇S	Sandstones
C	dark	fine	dendritic	medium	short	medium	⌣	⌢	rare	weak	bedding	ditto H⌇C	Fine Sandstones
H(H')	light	coarse	-	-	-	medium	semi cuesta		rare	very strong	bedding	foldings are observed.	Alternation of Shales & Sandstones
ℓ	light	fine	-	-	-	very strong	-	⌐¬	rare	very strong	bedding	2 horizones T⌇ℓ /ℓ/ /H/E	Limestones
E	light	fine	-	-	-	medium	⌣	⌢	rare	strong	bedding joint		Pyroclastics
T(T')	light ~ dark	hazy	-	-	-	weak ~ strong	flat partialy	(T')	medium	weak	joint	characteristics are variable	Tuffs
N	light	coarse	dendritic	medium	very short	medium	⌣	⌢	mainly 1	medium	joint	resistivity is different in place by place	Andesites (Lava + Tuff)
D	gray	coarse	semi-dendritic	dense	short	medium	∨	⌐¬	many	medium	joint	overlain by S & C	Metasediments
M	gray ~ dark	fine	dendritic	medium	short ~ medium	strong	∪	∩	many	strong	joint	intruded by units G	Metamorphic rocks
A	very light	coarse	-	-	-	very strong	-	⌒	rare	weak	joint	intruded in units S & G	Andesites intrusive
I	dark	coarse	-	-	-	strong	-	∧	rare	weak	joint	intruded in units H & G	Intrusive rocks
G(G')	gray	rugged	rectangular	medium	medium ~ long	strong	∨	∧	many	strong	joint	characteristics are variable	Granites

Sunda Land and the uplifted belt and the margin of the Melawi and Mahakam basins.

The present study shows that the geology of this area consists of 16 geological units as shown in Table 1. These units are correlated with the geological map in the column laid out in Fig. 4. Units M (mainly metamorphic rocks) and D (mainly metasediments) are correlated to Carboniferous - Triassic; N(mainly andesites) to Cretaceous; H (mainly alternation of shale and sandstone), ℓ (mainly limestone), T (mainly tuffs), and E (mainly pyroclastic rocks) to Eocene - Miocene; B (basalts), S (mainly coarse sandstone), F (mainly sandstone), and C (mainly fine sandstone) to Pliocene - Pleistocene; Q (river sediments) and L (laterite) to Alluvium; and A (andesite), I (intrusive rocks), and G (granites) to acidic to intermediate rocks of the map.

The geologic structures of the eastern and western parts of the area differ greatly and the boundary of the two is the basement rocks of Units M, D, N, and G which are distributed from the northeast to the southwest part of the project area. Lineations with NNW - SSE, NNE - SSW, and ENE - WSW trend are developed in areas where the basement rocks are distributed. In the west, Units T, H, F, and S overlie the basement unconformably and the geology is controlled by the WNW - ESE trending folds, and in the east Units E, H, and C overlie the basement unconformably and are controlled by the NNE - SSW trending folds.

Anomalies which could be related to mineralization or alteration could not be found in this analysis.

2-2 Geological units

2-2-1 Unit M

This unit is distributed mainly from the southwest to the western part of the project area.

The features indicate fine-grained lithology, strong resistance to erosion, and linear structure with NNE - SSW, NNW - SSE, and ENE - WSW trend.

It is intruded by G and unconformably overlain by T.

The lithology of this unit is inferred to be schists, chert-quartzite, and metasediments.

2-2-2 Unit D

This unit is distributed mainly in the eastern part of the area.

The features indicate coarse-grained lithology, short and dense subdendritic drainage pattern, and lineations with NNE - SSW, NNW - SSE, and ENE - WSW trend.

It is unconformably overlain by C and S.

The lithology of this unit is inferred to be mostly metamorphic rocks of sedimentary origin.

2-2-3 Unit N

This unit is distributed mainly in the southwestern part of the area.

The features indicate coarse-grained lithology, very short dendritic drainage pattern, rounded valleys and ridges, and lineations with NNW - SSE trend.

It is intruded by G and overlain unconformably by C and B.

The lithology of this unit is inferred to be andesite lava and andesitic tuff.

2-2-4 Unit T (T')

This unit is widely distributed in the northwestern part of the project area.

The tone and resistance of this unit vary and the texture is hazy. Linear structure is developed in some parts of the unit.

Unit T' is somewhat more resistible than T, and it shows well developed linear structure, but the boundary of the two is gradual.

This unit overlies Units M, N, and G unconformably, is overlain conformably by H, unconformably by F and S, and is intruded by A and I. The boundary with B is often ambiguous, but it is believed that T occupies the lower stratigraphic horizon.

The major lithology of this unit consists of normal sedimentary formations of low resistivity such as tuff, siltstone, and marl. Lava is often associated with this unit. Unit T' is inferred to consist mainly of lava.

2-2-5 Unit E

This unit is distributed widely eastward from the southeastern part of the project area.

The tone of this unit is relatively variable and generally light, the texture fine-grained, and the resistance is not as low as T with fairly homogeneous dissection. It has clear bedding and folding.

It is overlain conformably by H and unconformably by S.

The lithology of this unit is inferred to be pyroclastic rocks, mainly stratified tuff.

2-2-6 Unit H (H')

This unit is distributed relatively widely throughout the project area.

The tone is light, texture coarse-grained, and cuesta is developed locally where this unit occurs. Clear bedding and folding are observed.

This unit conformably overlies T and E, forms alternations with ℓ, and is unconformably overlain by S, F, C, and B.

The lithology of this unit is inferred to be sedimentary rocks consisting mostly of alternation of sandstone and shale.

2-2-7 Unit ℓ

This unit is distributed in the southeastern part of the project area.

The tone is light, texture fine-grained, and the resistance is very high. Very clear bedding is observed.

This unit forms alternation with H.

The lithology of this unit is inferred to be limestone.

2-2-8 Unit C

This unit is distributed sporadically in a wide area from the central to the eastern part of the project area.

The tone of this unit is dark, texture fine-grained, drainage pattern dendritic, and the bedding is often observed though not very clearly.

It is overlain unconformably by S and B, and overlies D, N, T, H, and G unconformably.

The lithology of this unit is believed to be sedimentary rocks consisting mainly of fine-grained sandstone.

2-2-9 Unit F

This unit is distributed through the northwest and northern part of the project area.

The tone is dark, the texture fine-grained, and clear bedding observed.

It unconformably overlies H and is overlain unconformably by S and B, and intruded by A.

The lithology of this unit is believed to be sedimentary rocks consisting mainly of sandstone.

2-2-10 Unit S

This unit is distributed to the north from the northern part of the project area.

The tone of this unit is very dark, texture fine-grained, resistance high, and very clear bedding is observed.

This unit unconformably overlies D, N, G, T, E, H, C, and F, and is overlain unconformably by B and intruded by A.

The lithology of this unit is believed to be sedimentary rocks consisting mainly of coarse-grained sandstone and conglomerate.

2-2-11 Unit B

This unit is distributed northward from the northwestern part of the project area.

The texture of this unit is coarse-grained, it has dendritic drainage pattern with short parameters, the resistance high, and linear structure with NNW-SSE trend is developed.

It unconformably overlies N, T, H, C, F, S, and G, and is intruded by A.

The lithology of this unit is believed to be basaltic rocks, mainly lava flows.

2-2-12 Unit L

This unit is distributed in the southeastern and eastern part of the project area.

The texture of this unit is fine-grained, topography flat, vegetation dense, and drainage meandering.

This unit is inferred to consist mostly of laterite and other types of soil.

2-2-13 Unit Q

This unit is distributed along the large rivers of the project area.

The tone of this unit is light, topography flat, and meandering drainage, crescent lakes, and swamps are developed. This unit is inferred to consist mostly of alluvial sediments.

2-2-14 Unit G (G')

This unit is distributed westward from the southwestern part of the project area.

The texture of this unit is coarse-grained, it has rectangular drainage pattern, strong resistance and well developed clear linear structure with dominant NNW-SSE trend. Unit G' has somewhat lower resistance than G and thus is dissected further. The boundary between these two units is not clear.

This unit is intruded into M, and N, and is unconformably overlain by T (T'), S, and B, and is intruded by I and A.

The lithology of this unit is believed to be acidic to intermediate plutonic rocks consisting mainly of granitic rocks.

2-2-15 Unit I

This unit is distributed locally in the southwestern and northeastern parts of the project area.

The tone of this unit is dark, coarse-grained, resistance high, and the ridges are very steep.

This unit is intruded into G and T.

It is believed to be intrusive bodies, but the lithology is not clear.

2-2-16 Unit A

This unit is distributed sporadically and locally in the western part of the project area.

The tone of this unit is very light, coarse-grained, resistance very high, and it forms steep ridges.

It is intruded into N, T, H, C, F, S, B, and G.

The lithology of this unit is believed to be acidic to intermediate intrusive rocks consisting mostly of andesite.

2-3 Geologic structure

2-3-1 General structure

The project area can be divided from geologic structure into; (a) the uplifted belt extending from the southwest to the northeastern part where Units M, D, N, and G are distributed, (b) the margin of the Melawi basin in the northwest where Units T and H are distributed, and (c) the margin of the Mahakam basin in the southeast where Units E and H' are distributed.

The uplifted belt consists of metamorphic rocks, andesites, and granites which were intruded into the former rocks. Linear structure mostly of NNW-SSE trend is developed in these basement rocks.

The margin of the Melawi basin consists mostly of coarse-grained sedimentary rocks and is associated with tuffaceous material. These are controlled by the WNW-ESE trending folds.

The margin of the Mahakam basin consists mostly of stratified tuff and coarse-grained sedimentary rocks. These are controlled by the NNE-SSW trending folds.

Units S, B, L, and Q are distributed inharmoniously with the above-mentioned structure.

2-3-2 Folds

Fold structure is developed northwestward from the northwestern part and southeastward from the southeastern part of the project area.

The folds in the northwest are clearly identified in the photographs by following the key bed H. The folding is WNW-ESE trending synclinorium which disappears toward the east and peters out in the west. These folds mainly control the distribution of T and H, but these units are unconformably overlain by S and B and the eastern extension of the folds is not clear.

Those in the southeastern part are identified by following the key beds, H and ℓ. The structure is an anticlinorium with culmination and the trend is NNE-SSW. This structure mainly controls E, H, and ℓ.

The trends of these structures are almost perpendicular to each other. The relationship between the two folds, however, is not clear because the basement rocks M, D, and G are distributed between the two, and also Units S and L which overlie these structures unconformably occur almost horizontally in the belt which separate the two folds.

2-3-3 Faults

Faults large enough to control the geologic structure of the whole project area were not found in the present study. Small faults were found in many parts and their strike directions are variable. In the lineaments which will be mentioned later, however, NNW-SSE trend is predominant, and there are some linear structures which are developed over tens of kilometers. These are sharp linear structures and might very well be faults.

2-3-4 Lineament System

The system of linear structures in the project area are shown in Table 2 and Fig. 5 - 1～6. It is seen that the number of lineaments and the lengths of the systems are roughly proportional. More than half of these lineaments trend in directions between N40°W and N10°E. These trends can be further divided into more than 30per cent between N0°-30°W for Unit M, about 20per cent between N10°W - N10°E for D, more than 70per cent between N10°E and N40°W for N, approximately 70per cent between N10°E and N30°W for G, more than 50 per cent between N10°E and N30°W for T, and approximately 70per cent between N10°E and N40°W for B.

The concentration of the directions of the lineaments is very low for M and D. But as shown in Fig. 4-1, -2, this is caused by the existence of the NNE-SSW and ENE-WSW systems in these units. This is not observed in other geological units of the area. Other units, such as N, G, T, and B have NNW-SSE systems as shown in

Fig. 4-3 ~ 6

The above linear structure is analysed as follows.

(a) Linear structures of NNE-SSW and ENE-WSW trends were developed in Units M and D.

(b) During the phase of N, G, T, and B activity, lineaments with NNW-SSE trend were developed. This system gradually turned from N10°W to N30°W, in other words from N-S direction to NW-SE direction during the development of the geological structure of this area.

Table 2. LINEAMENT PATTERNS ON THE GEOLOGICAL UNITS

Directions	Unit M				Unit D				Unit N				Unit G (G')				Unit T (T')				Unit B			
	Number		Length		Number		Length		Number		Length		Number		Length		Number		Length		Number		Length	
	pcs	%	Km	%	pcs	%	Km	%	pcs	%	Km	%	pcs	%	Km	%	pcs	%	Km	%	pcs	%	Km	%
N 0° - 10°W	63	13	116.8	12	3	6	11.0	10	68	17	114.5	18	762	13	1,447.8	13	133	14	216.5	13	61	11	96.0	11
N10° - 20°W	51	10	90.3	10	0	0	0	0	71	17	106.0	17	894	16	1,635.8	15	157	16	273.5	16	83	15	125.0	15
N20° - 30°W	50	10	96.8	10	1	2	4.5	4	60	15	84.8	13	932	16	1,639.8	15	132	13	232.5	14	95	17	150.8	18
N30° - 40°W	26	5	49.3	5	0	0	0	0	42	10	75.5	12	751	13	1,448.3	13	94	10	162.0	9	89	16	121.3	14
N40° - 50°W	23	5	43.0	5	0	0	0	0	21	5	32.3	5	380	7	754.0	7	48	5	86.3	5	32	6	51.0	6
N50° - 60°W	25	5	43.3	5	0	0	0	0	8	2	15.3	2	217	4	399.8	4	22	2	40.8	2	14	3	23.8	3
N60° - 70°W	25	5	47.8	5	0	0	0	0	6	1	8.8	1	106	2	202.0	2	5	1	6.3	0	7	1	8.8	1
N70° - 80°W	16	3	31.3	3	0	0	0	0	1	0	1.8	0	51	1	112.3	1	3	0	4.5	0	6	1	9.3	1
N80° - 90°W	18	4	32.5	3	0	0	0	0	1	0	0.8	0	41	1	86.8	1	6	1	9.3	1	12	2	19.3	2
N90° - 80°E	24	5	44.8	5	0	0	0	0	1	0	0.8	0	27	1	59.3	1	6	1	9.8	1	1	0	2.0	0
N80° - 70°E	12	2	17.8	2	4	8	10.0	9	1	0	2.0	0	42	1	92.8	1	10	1	20.0	1	0	0	0	0
N70° - 60°E	12	2	23.8	3	4	8	7.0	7	1	0	3.8	1	39	1	74.8	1	19	2	34.5	2	2	0	3.0	0
N60° - 50°E	14	3	33.0	4	3	6	5.0	5	2	0	2.3	0	41	1	111.0	1	29	3	53.8	3	3	1	0.8	0
N50° - 40°E	11	2	17.8	2	6	13	11.5	11	4	1	10.8	2	61	1	158.5	1	44	4	79.8	5	6	1	9.5	1
N40° - 30°E	16	3	35.8	4	6	13	14.8	14	9	2	13.0	2	116	2	235.3	2	44	4	85.0	5	14	3	30.3	4
N30° - 20°E	43	9	90.0	10	14	29	26.5	25	21	5	36.5	6	244	4	572.0	5	61	6	114.3	7	34	6	50.0	6
N20° - 10°E	40	8	69.0	7	2	4	3.8	4	34	8	50.0	8	406	7	886.3	8	53	5	106.3	6	38	7	54.5	6
N10° - 0°E	32	6	59.0	6	5	10	12.0	11	55	14	82.5	13	636	11	1,266.8	11	119	12	174.5	10	62	11	88.8	11
Total	501		941.5		48		106.0		406		641.0		5,746		11,182.8		985		1,709.3		559		843.8	

Notes :
1 Lineaments of Unit D are observed partly due to much cloud cover and poor quality of images.
2 Lineaments of Unit T are observed mainly in the Western part of the area due to much cloud cover and poor quality of images in the Eastern part.

FIG. 5-1. ROSEGRAPH OF LINEAMENT ON UNIT M

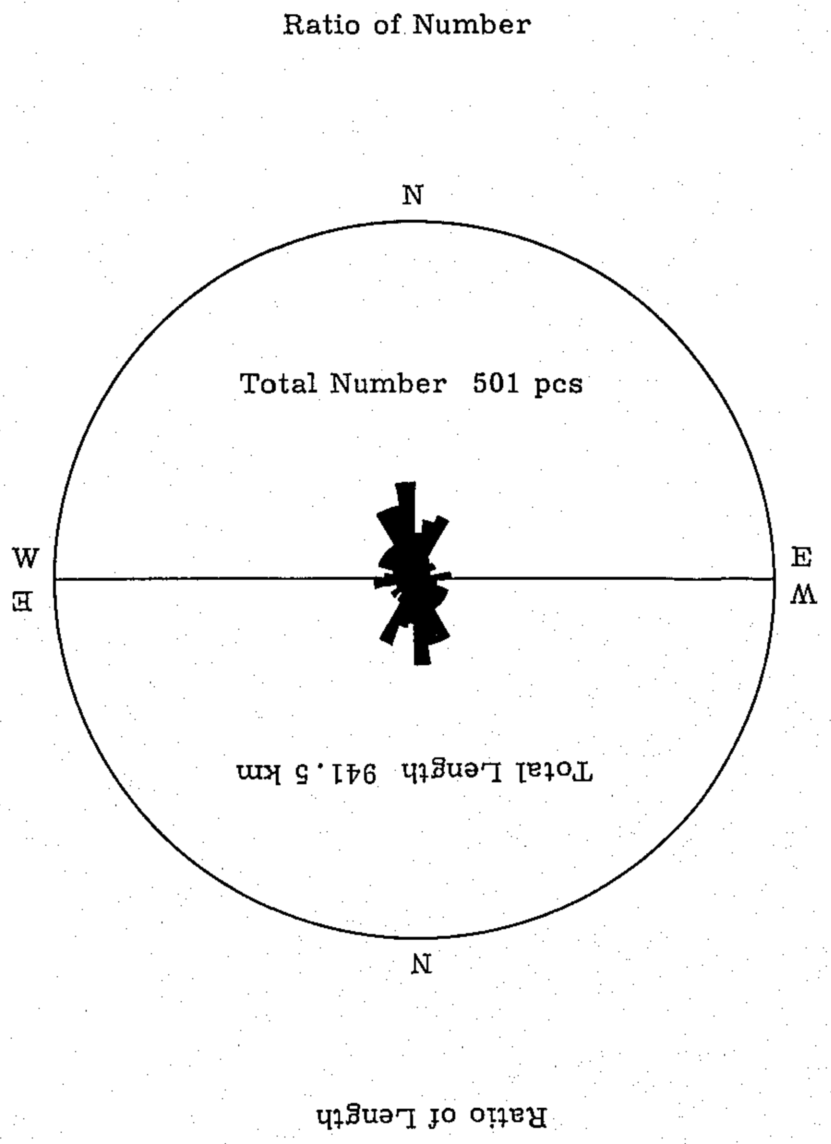
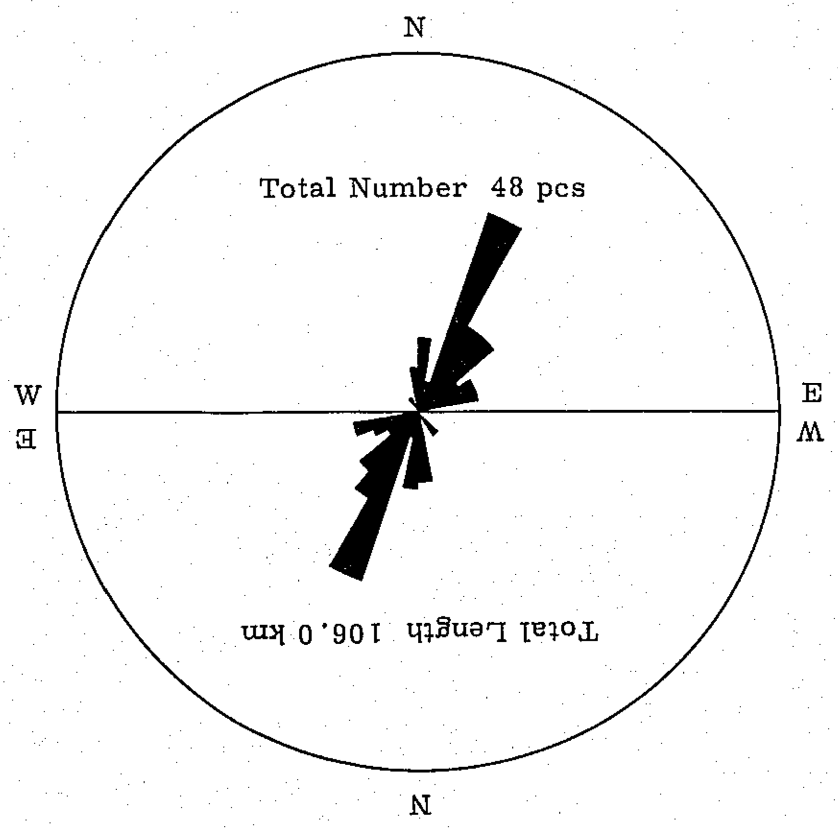


FIG. 5-2. ROSEGRAPH OF LINEAMENT ON UNIT D

Ratio of Number



Ratio of Length

FIG. 5-3. ROSEGRAPH OF LINEAMENT ON UNIT N

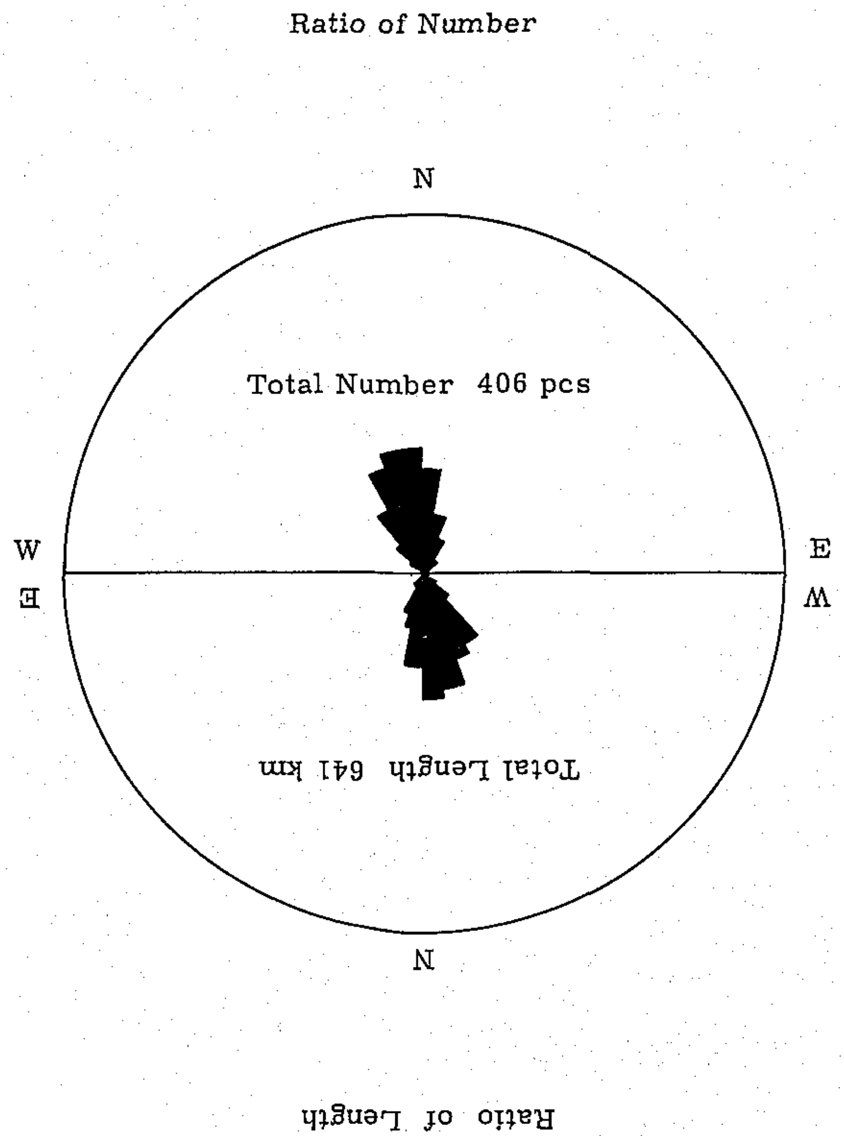
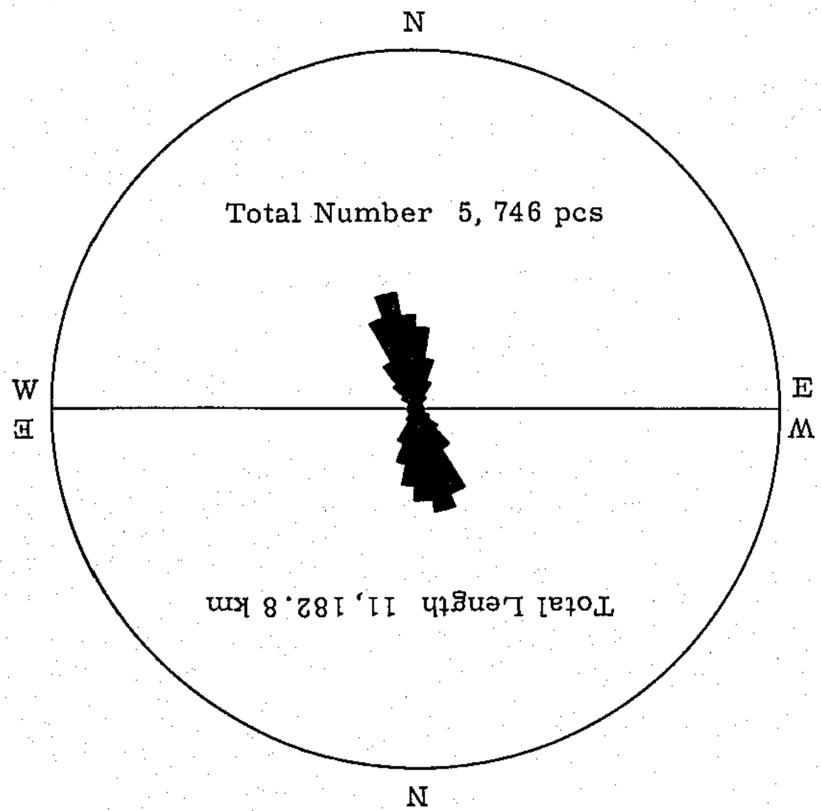


FIG. 5-4. ROSEGRAPH OF LINEAMENT ON UNIT G (G')

Ratio of Number



Ratio of Length

FIG. 5-5 ROSEGRAPH OF LINEAMENT ON UNIT T(T')

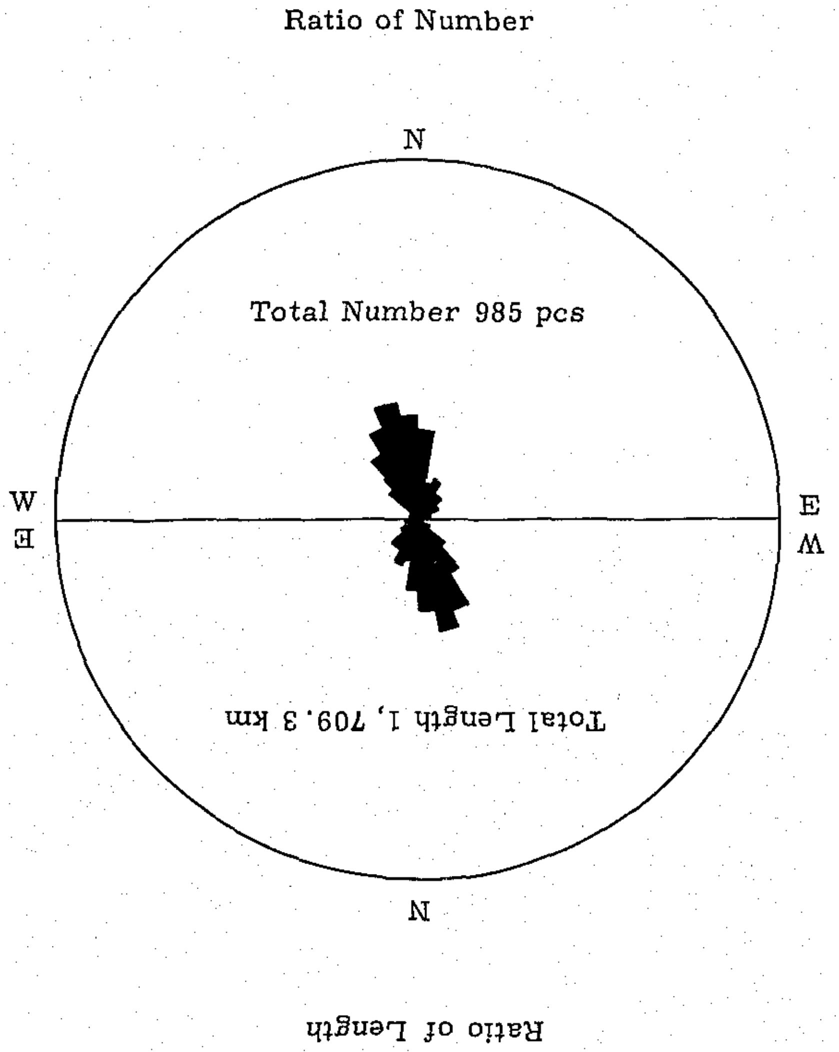
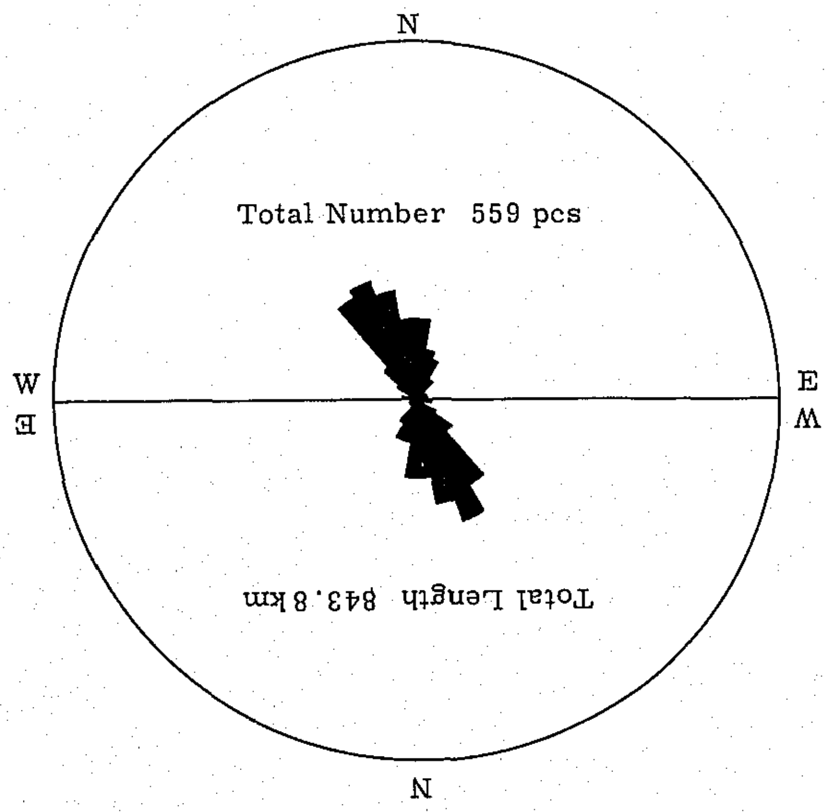


FIG. 5-6. ROSEGRAPH OF LINEAMENT ON UNIT B

Ratio of Number



Ratio of Length

PART II

SPECTRAL ANALYSIS OF LANDSAT DATA

Chapter 1 Introduction

Spectral information is those data which are related to the responding characteristics of the objects to the spectra of various wavelength range. Spectral data analysis can be done by digital processing which utilizes CCT (Computer Compatible Tape), and the analogic processing which utilizes images transformed into film base. The analogic method is further divided into photographic processing and electronic processing. The electronic process includes digital transform, but this is treated as an analogic process here because it is essentially the processing of the analogic data in films or prints.

The analogic processing involves the extraction of the objects by utilizing the difference of analogic quantity of the spectral intensities of each LANDSAT DATA band (bands 4 ~ 7; band 4, 0.5 - 0.6 microns; band 5, 0.6 - 0.7 microns; band 6, 0.7 - 0.8 microns; band 7, 0.8 - 1.1 microns) reflected from objects on land.

Digital method involves the processing of each sampling point of the scanner as image data symbols. In this case, it is possible to apply nonlinear functions or processing in multi-dimensional image space.

In the present study, geographic and topographic classification, discrimination of geologic units and geologic structure, and extraction of mineral showings were made by the methods described in Table 3.

Table 3. LIST OF SPECTRAL DATA ANALYSIS

Analytical Methods			Object			
			Geomorphology	Geological Units	Geological Structure	Ore Showings
Analogic Process	Photographic Process	False Color Composition	O	O	O	
		Additive Color Composition	O	O	O	
	Electronic Process	Color Enhancement & Extraction	O	O		O
		Density Measurement		O		O
		Edge Enhancement	O		O	
		Three Demensional Display	O		O	
Digital Process		Print Out Method		O	O	O

Chapter 2 Analysis

2-1 False color composition

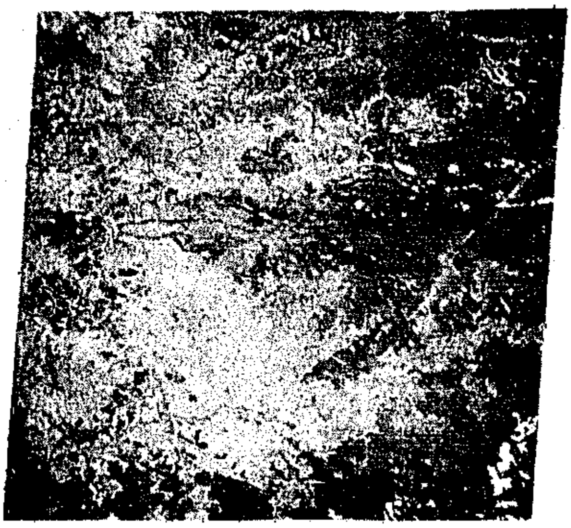
In the present study, natural type color composite images were prepared by the following combination of resulting color (filter). Band 4, yellow (blue); band 5, cyanine (red); band 7, magenta (green). Seven scenes of these images which cover the project area were made into 1:250, 000 scale in accordance with the black and white prints made for the pattern analysis. A part of this image is shown in smaller scale (1:2, 000, 000) in Fig. 6-2, Pl. 5.

In this composite, the activity and density of the forests are displayed by the difference of shades of green. Jungles are shown in dark green while the timbered areas are shown in various shades of yellow to yellowish green in accordance with the time of the timbering. Rivers, swamps, lakes and other areas of water are distinguished in black, semi-swamps in brown, and artificial constructions such as villages and roads in white. In some parts, false color composites of infrared type images which have the combinations of band 4, yellow (blue); band 5, magenta (green); and band 7 cyanine (red) were also prepared and used during the analysis. An example is shown in Fig. 6-2, Pl. 6.

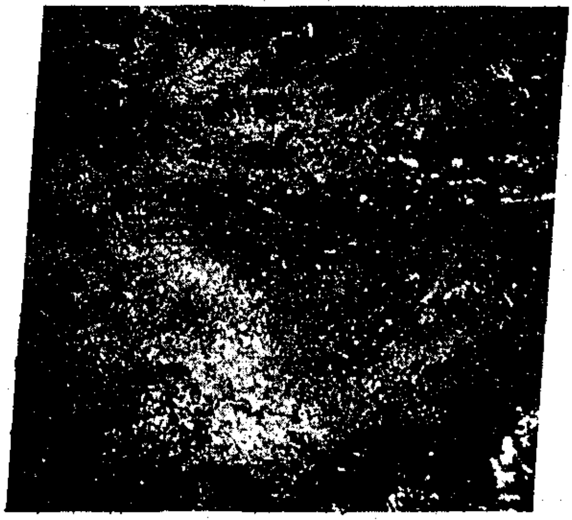
2-2 Additive color composition

(1) Equipment used

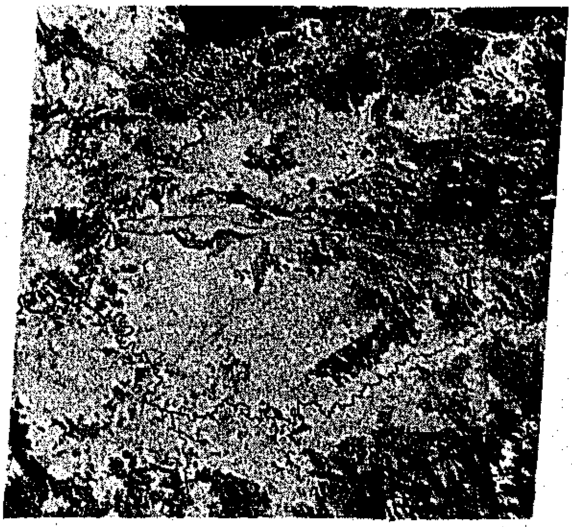
Mutiband Viewer Model 6000 (I^2S) was used for the present work.



Pl. 1



Pl. 2



Pl. 3

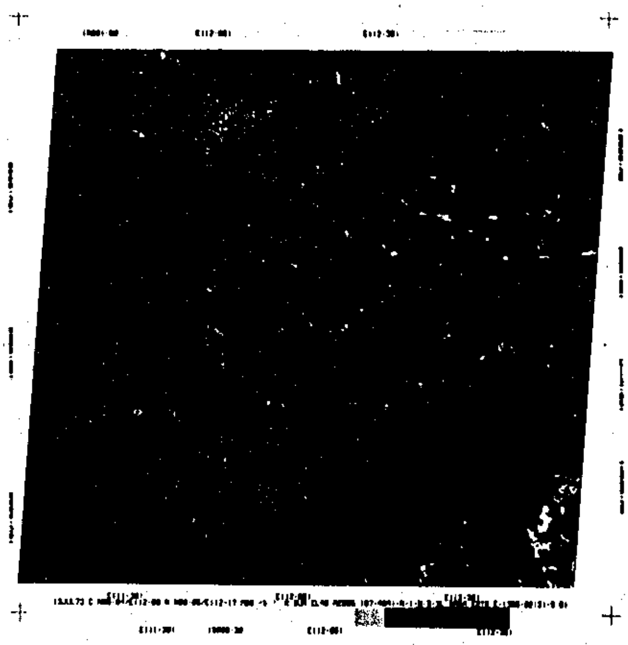
Pl. 4

Fig. 6 LANDSAT-IMAGES

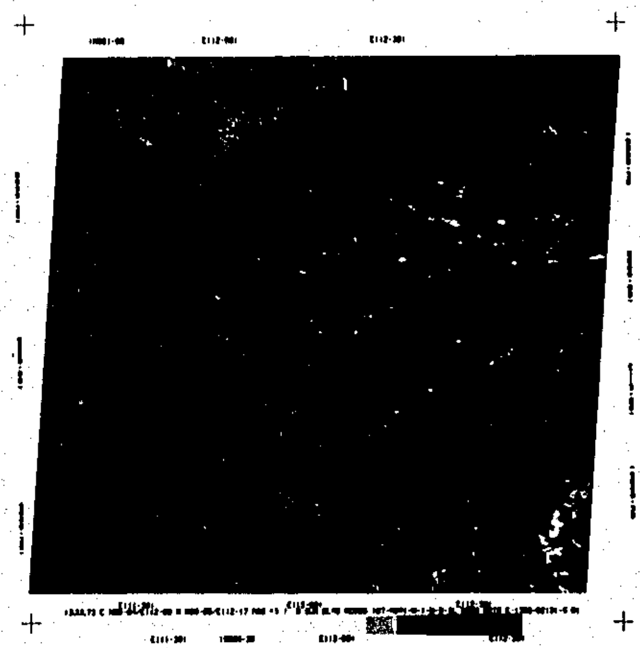
Fig. 6-1 B/W IMAGES (E-1355-02131)

Pl. 1, 4 Band (0.5 - 0.6 μm), Pl. 2, 5 Band (0.6 - 0.7 μm)

Pl. 3, 6 Band (0.7 - 0.8 μm), Pl. 4, 7 Band (0.8 - 1.1 μm)



Pl. 5



Pl. 6

Fig. 6 LANDSAT-IMAGES

Fig. 6-2 FALSE COLOR COMPOSITIVE IMAGES

Pl. 5, 4 Band - Yellow, 5 Band - Cyanine, 7 Band - Magenta

Pl. 6, 4 Band - Yellow, 5 Band - Magenta, 7 Band - Cyanine

The functions and the specifications of this model are as follows.

a. Function

Color composites are made from the combination of filters (three primary colors) and four films of each wavelength (bands 4 - 7 of LANDSAT images).

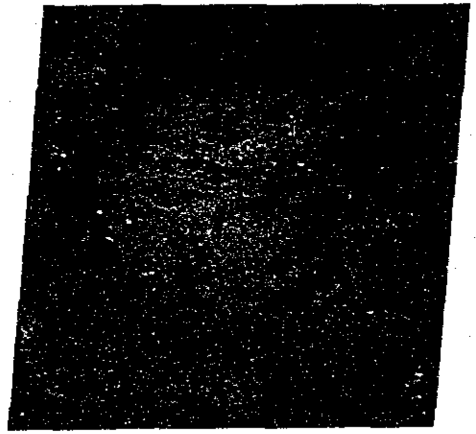
The position of lens and the intensity of light for filters and each lens can be selected independently for each channel.

b. Specifications

Registration	± 0.19 in. for X, Y co-ordinates
Screen	9 in. x 9 in.
Lens	150 m/m (4) f 5.6
Power supply	110 V, 50 Hz - 60 Hz, 25 Amp.
Size	30 in. W x 24 in. L x 44 in. H.
Weight	approximately 45 kg.

(2) Procedure

Negative and positive films were prepared for the LANDSAT images of each band covering the project area and the vicinity. Sets of four films were selected for each scene from the eight prepared films. These were set in the viewer, and the best combination of films and filters for each channel together with light conditions were determined by observing the conditions of the screen. For areas which necessitated analysis of higher accuracy, the same process was carried out for enlarged films.



Band - Film - Filter Light Strength
(4 ~ 7) (P : Positive, N : Negative) (R : Red, G : Green, B : Blue, X : None) (0 ~ 9)

Pl. 1

4 N R 6
5 N X 4
6 N G 9
7 N B 9

The acidic bodies exposed in the southern part are shown in white.
The river system and the swamps are emphasized in pale blue as negative film is used.
(see Table 4, No.10)

Pl. 2

7 P G 9
7 N X 9

The timbered areas are shown in dark green over yellowish background with *strong contrast*, and the boundaries of the rock units are clear.
(see Table 4, No.13)

Pl. 3

5 N R 9
6 N G 4
7 N B 9
7 P X 5

Information of bands 5 and 6 is added to 7 band negative and positive films. This combination is most suited for distinguishing the general geologic units of the total area. Water is bluish purple and the lithological difference of the normal sedimentary formations could be made easily.
(see Table 4, No. 14)

Fig. 7 ADDITIVE COLOR COMPOSITIVE IMAGES (E-1355-02131)

TABLE 4. INTERPRETATION CHART OF ADDITIVE COLOR COMPOSITION

	I.D. Number	Band (Channel)	Film Negative or Positive	Filter	Color Strength	Results
1.	E-1356 -02185	4 5 6 7	P P P P	B G R G	5 7 7 9	With this combination, the timbered open areas along the river which flows through the central part of the image are shown in light reddish brown, and other forests in dark reddish brown. The image is generally not clear because of the effect of bands 4 and 5.
2.	do.	4 5 6 7	P P P P	B R G G	9 9 9 9	In this combination with the filters of bands 5 and 6 exchanged from that of No. 1, the image is somewhat greenish and the difference of vegetation of the timbered open areas are distinguished.
3.	do.	5 6 7	P P P	B G R	9 7 9	In this combination with band 4 removed, the image is generally clearer with the effect of bands 6 and 7. Lake sediments in the center are identified. The linear structure of the acidic bodies in the south is clearer.
4.	do.	5 7	P P	B R	9 9	The image is generally reddish brown, but parts with bodies of water such as rivers are shown in bluish tone.
5.	do.	7 7	N P	X G	7 9	With this combination of negative and positive films of band 7, the drainage system is best shown. Peaks consisting of sandstone in the northwest and acidic bodies in the southeast are shown in white, and these bodies are distinguished from other geological units.
6.	do.	7 7	N P	B R	9 6	With this combination with different filters from No. 5, drainage and valleys which are shown in white in the negative film is shown in pale blue.
7.	do.	5 7	N P	R G	6 8	In this combination, the effect of band 7 is very strong, and the image has an orange tone. The green objects are clouds.
8.	do.	4 5 6 7	N N N N	R X G B	8 7 9 9	With this combination using only negative films, the timbered open areas are dark, and the forest light, the acidic bodies in the southeast are also shown in lighter tone.
9.	do.	5 6 7	N N N	B B X	8 9 9	This combination is best suited for the classification of general topography and geologic units. The sandstone in the northwest and the acidic bodies in the southeast are identified by the lighter tone, and the vegetation of the timbered open areas can be classified and the drainage is also clearly shown.
10.	E-1355 -02131	4 5 6 7	N N N N	R X G B	6 4 9 9	The acidic bodies in the south are shown in white. Only negative films are used and thus the drainage and swamps are enhanced and shown in pale blue.
11.	do.	7 7	R N	R X	9 9	This combination clarifies the general geologic units of the project area. The acidic rocks in the south is white with characteristic linear structures, and the anticlinal structure in the center consisting of sandstone has limbs with continuous bedding, and these can be distinguished from other units.
12.	do.	5 7	N P	X R	9 9	With this combination, the alluvial formations distributed along the meandering river are shown in tone lighter than the surroundings. Since red filter is used over band 7, the clouds are seen in red.
13.	do.	7 7	P N	G X	9 9	This combination is made by using green filter instead of red in No. 12. The timbered open areas are shown in dark green over yellowish background with strong contrast, and the boundaries of the rock units are clearer than in No. 12.

	I.D. Number	Band (Channel)	Film Negative or Positive	Filter	Color Strength	Results
14.	E-1355 -02131	5 6 7 7	N N N P	R G B X	9 4 9 5	This combination is obtained by adding the information of bands 5 and 6 to the negative and positive films, and it is best suited for general classification of the geologic units of the project area. The water zone is shown in bluish purple and the lithology of the sedimentary units can be distinguished easily.
15.	E-1355 - 02133	5 7	P N	R X	9 9	This combination is very good for extracting acidic bodies. They are displayed in the lightest tone and together with their characteristic linear structures, they can be clearly distinguished from other rock units. The open timbered areas are dark in this image and only those clouds which are colorless in band 5 positive film are shown in red.
16.	do.	7 7	P N	X G	9 9	This combination is also good for extracting acidic bodies. Acidic rocks come out in darkest green, other rocks in paler but dark green, and the timbered open areas and alluvial sediments are shown in yellowish brown.
17.	do.	7 7	P N	X R	9 9	The linear structure of the acidic bodies in the central part of the image is clearly shown by this combination, but only information similar to No. 16 can be obtained by this combination.
18.	do.	7 7	P N	X R	9 9	This is the same combination as No. 17, but the 7N film has been turned anti-clockwise in order to enhance the edges. The linear structures of the acidic bodies in the central part is emphasized.
19.	do.	4 5 6 7	N N N N	R X G B	9 3 9 9	The acidic bodies are shown in white. But the color in the southern and northern part is unstable due to photographic processing, and the margins of the rock bodies are not clear.
20.	do.	5 6 7	N N N	R G B	5 9 9	This combination was made by subtracting band 4 from No. 19. The shape of the rock bodies is better distinguished than No. 19. This fact shows that the noise level is high in band 4.
21.	do.	5 6 7	N N N	B B X	9 9 9	This combination is also good for extracting acidic bodies. Blue filter was inserted in bands 5 and 7, resulting in generally pale blue tone except for the acidic rocks. The distribution of open timbered zones and rivers can be clarified by this combination.
22.	E-1136 - 02080	4 5 7	P P P	B R G	7 9 9	This combination produces images closest to the natural tone. But since the films of bands 4 and 5 are generally dark, the tone of the image as a whole is dark greenish and is not suited for geologic classification.
23.	do.	4 5 7	P P P	B G R	8 3 9	This combination produces the so-called infrared type false color compositives, but the image is not suited for geological work by the same reason as No. 22.
24.	do.	7 7	N P	R G	6 8	Under this combination, all objects are displayed in orange with the exception of the clouds which are colorless in the band 7 positive film. The sandstones in the central part is shown in darker tone.
25.	do.	7 7	N P	X G	6 8	With this combination with the filter of the negative film removed from No. 24, the outline of the central sandstone and the drainage are shown in lighter tone, resulting in clearer information than No. 24.
26.	do.	7 7	N P	B R	9 9	With this combination, the clouds are displayed in red and the outlines of the formations which have lighter tones in the negative films are shown in intense blue together with the shadow of the clouds. Information generally obtained from this combination is less than from other combinations.
27.	do.	5 7	N P	R G	9 9	Under this combination, the clouds are displayed in green and the other objects in reddish hue. This is not suited for geological classification as the band 5 film has monotonous tone.

	I.D. Number	Band (Channel)	Film Negative or Positive	Filter	Color Strength	Results
28.	E-1138	4	N	R	8	This combination using negative film for all bands is
	-02080	5	N	X	6	*the best combination of this scene for topographic and*
		6	N	G	7	geological classification. The outline of the sandstones
		7	N	B	8	in the central and the northern parts are displayed in white and are clearer than those of other rock units.
29.	do.	5	N	B	9	Band 4 has been removed and the filter conditions have
		6	N	B	9	been changed from No. 28. The clouds are dark brown
		7	N	X	6	and other objects are light blue. The geological classification is even clearer than No. 28. This is because of the haziness of band 4.
30.	E-1444	7	N	X	8	In this scene, band 5 is lacking in the original film and
	-02061	7	P	G	7	the image quality of band 4 is very bad. Thus positive and negative films of band 7 were combined. The cloud is green and other objects are yellow, but as the atmosphere is hazy, the geologic units are difficult to distinguish in this image.
31.	E-1137	4	P	B	9	This combination positive films of all bands shows the
	-02022	5	P	G	7	clouds in white and other objects in dark brown. The
		6	P	R	9	bedding of the sandstone in the central and western part
		7	P	G	9	is distinguished, but the tone is generally monotonous.
32.	do.	4	P	B	9	This combination produces image with color close to
		5	P	R	7	natural light. But the tone is generally dark greenish
		6	P	G	9	and monotonous, and thus is not suited for geological
		7	P	G	9	classification. This is due to the dark and monotonous tone of the films of bands 4 and 5.
33.	do.	5	P	B	9	The tone produced from this combination is similar to
		6	P	G	6	No. 31. It is generally lighter because of the removal
		7	P	R	9	of band 4, and the bedding of the sandstone in central and the west is clearly indentified.
34.	do.	5	P	B	9	This combination with band 6 removed from No.33
		7	P	R	9	produces reddish tone in general, and the geological information available from the image is similar to those from No. 33. This indicates that bands 6 and 7 *contain approximately the same information.*
35.	do.	7	N	X	8	With this combination, thick clouds are displayed in
		7	P	G	9	green and other objects in yellow to brown. The image has lighter tone because of the use of negative *films and the bedding of the sandstone is clear.*
36.	do.	7	N	B	9	The filter conditions have been changed from No. 35.
		7	P	R	8	The thick clouds are shown in reddish brown and other objects in bluish color. The geological information available is inferior to that of No. 35.
37.	do.	5	N	R	6	The clouds are displayed in green and the ground in
		5	P	G	7	reddish color, but the color is generally monotonous and it is not suited for geological identification.
38.	do.	5	N	R	5	The band 5 positive of No. 37 has been changed to
		7	P	G	9	band 7. The tone is generally lighter than No. 37, and the bedding of the sandstone in the center and west is clearly observed.
39.	do.	4	N	R	9	This combination of negative films for all bands is the
		5	N	X	5	best for discriminating topographic and geologic units.
		6	N	G	9	The bedding of the sandstone is clearly identified and
		7	N	B	9	the alluvial deposits along the river is distinguished from other units by the brown color.
40.	do.	5	N	B	9	This combination provides good geological information
		6	N	B	9	similar to that of No. 39. Since the filter of band 7
		7	N	X	9	is removed, to ground is shown in lighter whitish color.

	I.D. Number	Band (Channel)	Film Negative or Positive	Filter	Color Strength	Results
41.	E-1443 -02003	4 5 6 7	P P P P	B G R G	4 6 8 7	With this combination, the effect of bands 4 and 5 is strong even with weak lighting through this band. Thus the general tone is monotonous and ground information is unavailable because of the thin overall cloud cover in this scene.
42.	do.	4 5 6 7	P P P P	B R G G	6 5 9 9	Color close to natural is obtained by this combination, the timbered areas along the river is shown in lighter color than the forests. Other objects are not very clear as in the case of No. 41.
43.	do.	5 6 7	P P P	B G R	9 5 9	This combination produces the so-called infrared false color. As the water is displayed in dark blue, the oxbow lakes along the river and swamps are clearly distinguished from the land which is red.
44.	do.	5 7	P P	B R	9 9	This combination produces images with slightly reddish tint compared to that of No. 43, and the available information is the same as No. 43. This shows that the information of bands 6 and 7 are almost the same in this scene.
45.	do.	7 7	N P	X G	9 9	This combination using negative and positive films of band 7 is least affected by cloud cover. The color is generally pale greyish green and the drainage is well identified. The bedding of the sandstone in the east is clearly identified.
46.	do.	7 7	N P	B R	9 9	Blue filter is inserted in the negative film of band 7 of the combination No. 45. The tone is generally red and the rivers and lakes are shown in blue. Available information is the same as No. 45.
47.	do.	5 7	N P	R G	7 9	Under this combination the cloud is shown in green and other objects in orange. Rivers, lakes, and swamps are displayed in intense red, but geological information available is not beyond that of Nos. 45 and 46.
48.	do	4 5 6 7	N N N N	R X G B	6 6 9 9	This combination was the best for identifying topographic and geologic units in other scenes. But for this scene, it is very poor with the exception of identifying drainage patterns. This is caused by the cloud cover over the scene and the haziness of the films of bands 4 and 5.
49.	do.	5 6 7	N N N	B B X	9 5 6	With this combination, the alluvial deposits in the north are shown in darker shade and are distinguished from other units. Other information is poor with the same reason as No. 48.
50.	E-1173 -02001	4 5 6 7	N N N N	R X G B	6 3 9 9	The acidic bodies which are displayed in darker colors in general color composites have enhanced lighter tone with this combination, and these bodies can be clearly distinguished from other rocks including those scattered around Mt. Kinabalu.
51.	do.	5 6 7	P P P	B G R	9 9 9	Positive films are used for all bands in this combination and the color is close to that of infrared false color composites. The acidic rocks are shown in reddish brown with redder tint than other units, and the structure near Mt. Kinabalu and Mamut mine is clear.
52.	do.	4 5 6 7	P P P P	B G R G	5 9 5 9	Color close to nature is obtained by this combination, and alluvial sediments which are white in the films of bands 4 and 5 are displayed in pale purple. The lineations cutting Mt. Kinabalu in NE-SW direction is clearly observed.

	I.D. Number	Band (Channel)	Film Negative or Positive	Filter	Color Strength	Results
53.	E-1173 - 02001	4	N	B	5	With this combination using negative films for all bands, the clouds and the alluvial sediments are shown in green and other objects in yellow - pale brown. The Tertiary sedimentary formations with clear bedding distributed along the coast are displayed in stronger brown than other units due to the effect of vegetation.
		5	N	R	5	
		6	N	G	8	
		7	N	G	9	
54.	do.	4	P	B	9	Color closest to the natural color is obtained by this combination for the project area with ACV. The acidic rocks with difference in vegetation are displayed in darker tone and the alluvium and open area near the Mamut mine is shown in lighter color.
		5	P	R	9	
		6	P	G	9	
		7	P	R	4	
55.	do.	7	N	X	9	Negative and positive films of band 7 are used. The darker tone of the films are weakened in this combination, and one side of the valleys is shown in green, thus the pattern of the lithologic units is very clear.
		7	P	G	9	
56.	do.	5	P	R	9	With this combination the parts which are displayed in dark tones in general color composites are shown in white. Therefore the acidic bodies are shown in lighter tone shown.
		7	N	X	9	
57.	do. (enlarged)	5	P	X	9	The effect of band 5 is strong in this combination and the roads, alluvium, open areas are identified clearly. The Tertiary sedimentary formations in the west show characteristic pattern with many white dots. The green tone is stronger to the north of this image, but this is believed to be due to the quality of the original film.
		7	P	G	9	
58.	do.	4	P	B	9	Color close to the natural color is obtained by this combination. It is seen that the vegetation of Mt. Kinabalu becomes darker green as the elevation increases. The roads and alluvium which are clearly seen in bands 4 and 5 are also identified clearly in this combination.
		5	P	X	8	
		6	P	G	9	
		7	P	G	9	
59.	do.	5	P	B	9	This combination produces color close to infrared false color. The acidic bodies of Mt. Kinabalu and the ultramafic bodies in the north are shown in tones darker than the surroundings. The lineation cutting the Mamut mine in N-S direction and that running in N-S direction to the northeast of the mine are observed clearly.
		6	P	G	7	
		7	P	R	9	

Color of the filters :

B : blue, G : green, R : red, X : colorless.

Color strength :

from 0 to 9 (max.)

(3) Results obtained

The results of the composition of the various combinations for each scene are listed in Table 4. Some of the composite images are shown in Fig. 7, Pl. 1~3. Large difference in shades of films was found in each scene, and thus combinations had to be selected for each scene according to the objective. But on the whole, the combination of negatives of bands 5, 6, and 7 was effective for the discrimination of geographic and geologic units, while negative and positive films of band 7 were the effective combination for geologic structure especially the lineaments.

2-3 Color enhancement and extraction

(1) Equipment used

Multicolor Data System Model 4200 C (NAC) was used.

This equipment is used with the purpose of determining the standard for extracting the necessary information. It transforms films recorded by each wavelength into electric signals and displays them on a color display panel. Electronic computation and human judgement are applied to obtain the optimum results.

The functions and the specifications of this equipment are as follows.

a. Function

i. Color composition

Three primary colors are applied to three filters of given wavelengths and the composed images are displayed on the color Braun tube. Also the results of addition, subtraction, multiplication, and division among the wavelengths can also be displayed.

ii. Automatic extraction of spectrum patterns

The spectral pattern of a given point of the display tube is automatically calculated and shown digitally.

iii. Classification

The distribution of objects with a given spectral pattern (point or range) such as that of a certain point on the display tube is automatically displayed.

iv. Area measurement

The ratio of the area occupied by the objects of a given spectral pattern which is classified by the above procedure to any given value (rectangular or any shape) is automatically displayed.

v. Calibration

Calibration for each of the three primary colors can be done by the grey scale attached to the system.

vi. Optional functions

Any given area can be extracted by pattern extraction control unit and the contours emphasized by the edge enhancer.

The grey level values and their distribution can be measured by the density control unit.

The measured values can be printed out by the digital printer.

b. Major specifications

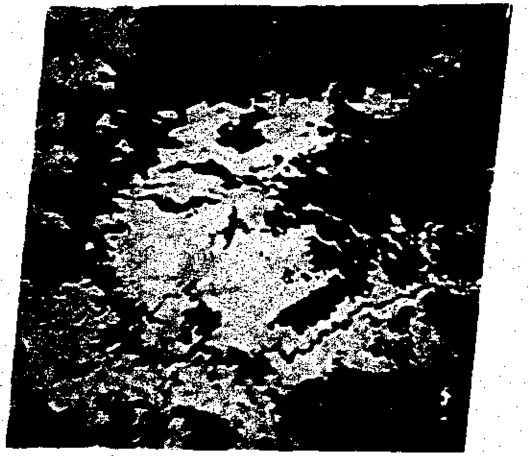
Camera system	TV camera (3 plan beacon)
Registration system	mechanical and electronic system
Intensity scale	64 steps for all 3 primary colors
Classification	full automatic system
Classification output	display on color CRT (cathod ray tube) in 5 modes, and print out of the grey level of 3 primary colors (optional)
Area measurement	digital percentage display on color CRT and print out (optional)

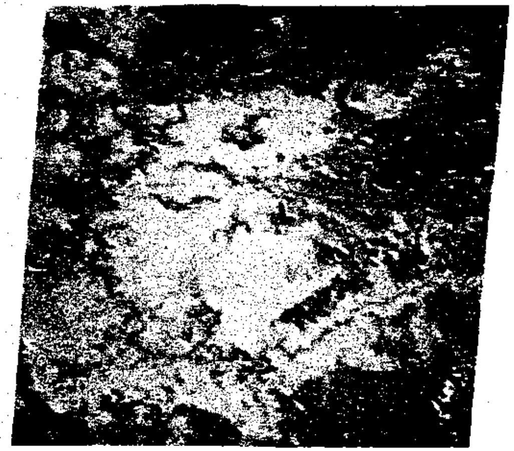
(2) Procedure

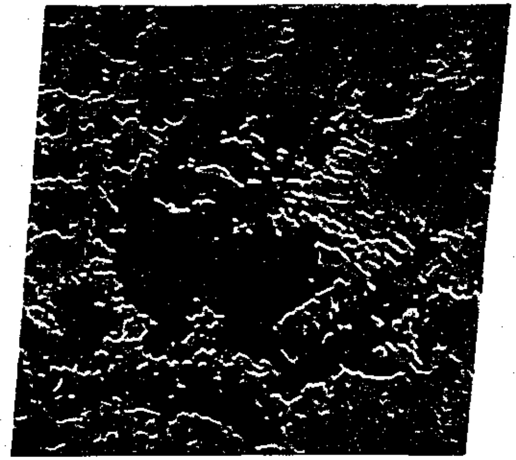
Three films were selected from the negatives and positives of each scene prepared for the additive color compositives. The optimum film combination, filter selection, and the light conditions were chosen for identification and discrimination of topographical and geological units by observing the display tube. The image was then fixed under the optimum conditions, the cross hair set on the object, the range of the channel intensity selected and the areas with the same intensity displayed in the color most convenient for discrimination.

(3) Results obtained

The results of the operation under various combinations are shown in Table 5. *And some of these images are shown in Fig. 8,* Pl. 1~3. In this analysis areas within a given intensity range were







Film Combination - Filter - Extraction Spectral Pattern (0 ~ 63) - Extraction Color

Film Combination	Filter	Extraction Color
4 ~ 7 Band	R : Red	Br : Brown
P : Positive Film	G : Green	R : Red
N : Negative Film	B : Blue	O : *Orange*
NR : Reserved Negative Film		

Pl. 1

6N	R	54-58	
7N	G	54-54	Br
7NR+7P	B	12-43	

The shale which is distributed in a continuous elongated shape on the limb of the syncline in the central part and zones of similar intensity are extracted. The continuation of this unit to the east is confirmed.
(see Table 5, No. 17)

Pl. 2

7P+7NR	R	34-39	O

Parts of sandstone and limestone are extracted from the other sedimentary rocks. But the granitic body located in southern-east is also extracted.
(see Table 5, No. 16)

Pl. 3

7NR+7P	R		
7P+5N	G		
7P	B	52-55	R

The open zones are clearly distinguished from other types of vegetation.
(see Table 5, No. 7)

Fig. 8 ENHANCED AND EXTRACTED IMAGES (E-1355-02131)

TABLE 5. INTERPRETATION CHART OF ENHANCED AND EXTRACTED COMPOSITION

	I.D. Number	Film Combi-nation	Filter	Extraction Spectral Pattern	Extraction Color	Results
1.	E-1356 -02185	6N 7N 7P	R G B	53~55	G	This combination is used for clarifying the outline of the open timbered areas.
2.	do.	6N 7NR+7P 7NR+7P	R G B	-	-	This is used for topographic classification.
3.	do.	6N 7N 7P	R G B	48~48	W	The cross hair was set on the granitic rocks with linear structures and distributed in the south. And zones of similar intensity were extracted. With a very narrow intensity range, it was possible to observe the continuation of these bodies in the direction of the lineation. Zones of similar intensity were observed in the swamps along rivers in other areas.
4.	do	6N 7N 7P	R G B	45~48 58~59	W	This is the same combination as No.3. Extraction was done with a wider intensity range. The granitic bodies in the south were extracted over wider areas, but with wider intensity range the Quaternary formations are included and it will be difficult to extract granitic rocks only.
5.	do.	6N 7N 7P	R G B	42~43 56~56	B	The cross hair was set on the limestone distributed in a small area in the northeast. Zones of similar intensity on negative films of bands 6 and 7 were extracted. The distribution of the limestone of this area identified by this method was the same as that obtained by pattern analysis. By this method the sandstone in the north-central part came out with the same intensity.
6.	do.	7NR+7P 7NR+7P	R -	33 ~ 44	B	The cross hair was set on the same limestone as No.5. Zones of similar intensity on "band 7 negative reversible+ band 7 positive" combination with intensity range slightly larger than No.5 were extracted. The distribution of the limestone in this area was clarified by this method. In other areas sandstone and some tuffs were extracted in the same intensity.
7.	E-1355 -02131	7NR+7P 7P +5N 7P	R G B	52 ~ 55	R	This combination was used with the purpose of clarifying the outline of the open timbered areas. Zones with intensities similar to that of positive film of band 7 were extracted. Most of the open areas were extracted by this method as in the case of No. 1.
8.	do.	7NR+7P 7N 7NR+7P	G R B	-	-	Topographic classification was done by this combination. There are many bodies of water in this area and they were shown in red and other objects were identified with the same tone difference as in the case of No. 2.
9.	do.	7N 6N 7P	R G B	52 ~ 52	W	The cross hair was set on the granitic bodies distributed in the southeast, and zones with similar intensity on negative film on band 6 were extracted. In other areas, however, the parts extracted by this combination were all of other geologic units and thus this is not applicable to other areas.
10.	do.	6N 7N 7P	R G B	36 ~ 39	R	The cross hair was set on coarse sandstone distributed in the east, and zones of similar intensity on negative film on band 6 were extracted. These zones agreed well with the results of the pattern analysis in this area. But in other areas most of the extracted zones consisted of other rock units.
11.	do.	6N 7N 7P	R G B	53 ~ 55 48 ~ 51 49 ~ 53	O	The cross hair was set on the sandstone distributed around the coarse-grained material mentioned above, and zones with similar intensities on negative film on band 6, negative film on band 7, and positive film on band 7 were extracted. These zones agreed well with the results of the pattern analysis in this area, but in other areas coarse-grained sandstone and tuff were also extracted by this combination.
12.	do.	6N 7N 7P	R G B	53 ~ 55 48 ~ 51	B	The cross hair was set on the same sandstone as above, and the combination with positive film of band 7 removed from No.11 was used. The zones extracted by this combination were approximately the same as in the case of No. 11.

	I.D. Number	Film Combi-nation	Filter	Extraction Spectral Pattern	Extraction Color	Results
13.	E-1355 - 02131	7P+7NR	R	37 ~ 39	B	The cross hair was again set on the sandstone. Extraction was done on "7 positive + 7 negative reversible". The results was unstable compared to the above two combinations and the information obtained was not more than those available by the above two.
14.	do.	6N 7P	R -	56 ~ 58	Pr	The cross hair was set on the basalt distributed in the eastern part of the image. Extraction was done by negative film on band 6. The results agreed well with those of the pattern analysis. Small basalt bodies were also extracted, but some of the sandstone and granites were also picked up.
15.	do.	7P+7NR	B	52 ~ 52	B	The cross hair was set on the andesite dykes in the central part of the image. "7 positive + 7 negative reversible" was used. Extraction was done with a very narrow intensity range. The dykes were shown as small dots and they agreed well with those of the pattern analysis.
16.	do.	7P+7NR	R	34 ~ 39	O	The cross hair was set on the sandstone and limestone distributed in a narrow area in the northwestern part of the image. "7 positive + 7 negative reversible" was used. Some of the sandstone and tuff were extracted in other area by this combination. The information obtained by this combination did not exceed those by pattern analysis.
17.	do.	6N 7N 7NR+7P	R G B	54 ~ 58 54 ~ 54 12 ~ 43	Br	The cross hair was set on the shale which is continuous along the limb of the syncline in the central part of this image and is used as a key bed. Negative films of bands 6 and 7, and "7 positive + 7 negative reversible" were used. Extraction confirmed the continuation of this shale bed to the east.
18.	E-1355 - 02133	5N 7N 7P	R G B	 53 ~ 55	R	The cross hair was set on one of the opened timbered zones which are distributed along the rivers. The extraction by positive band 7 distinguished these zones by the difference in vegetation.
19.	do.	7NR+7P 7N 7NR+7P	G R B	-	-	This combination was arrived at after a series of trial and error study for topographical classification of this area. The opened timbered areas are shown in white, the flat plain in pale red, and the mountains in red. The intensity difference of this combination is greater than others.
20.	do.	7N 6N 7P	R G B	51 ~ 63	W	The cross hair was set on the granitic body at the central part of the image. The extraction was done by negative film of band 6. The distribution of this body and those of similar lithology distributed in the north were extracted.
21.	do.	7N 6N 7P	R G B	54 ~ 54 46 ~ 46	B	The cross hair was set on the oval granitic body at the western part of the image and negative films of bands 6 and 7 were used. The bodies distributed widely in the east as well as this body has similar patterns to the granite of No. 20, but the density of the vegetation is somewhat different and they are shown in different intensity.
22.	E-1138 - 02080	5N 7N 7P	R B G	26 ~ 39	R	The cross hair was set on the sandstone in the northern part of the image. Negative film of band 5 was used. The metamorphic rocks in the vicinity of the sandstone were extracted together with the sandstone.
23.	do.	5N 7PR+7N 7N	R G B	25 ~ 38 12 ~ 12	W	Extraction was done with the input film of negative of band 5 and "7 positive reversible + 7 negative" with the same objective as No. 22. The conditions were narrowed and the metamorphic rocks of No. 22 were eliminated.
24.	E-1444 - 02061	6P 7P 7NR+7P	R G B	14 ~ 16 14 ~ 14	P	Cross hair was set on the laterite in the southern part of the image. Extraction was done with band 6 positive and "7 negative reversible + 7 positive" input film. Laterite was easily extracted by its dark and monotonous intensity in spite of the wide cloud cover.
25.	E-1137 - 02022	5N 7P 7N	R G B	 15 ~ 29	W	The cross hair was set on the shale-sandstone alternation in the west. Extraction was done with 7 negative input film. It was not possible to extract the objective formation because of the overall dark and monotonous tone of the image.

	I.D. Number	Film Combi-nation	Filter	Extraction Spectral Pattern	Extraction Color	Results
26.	E-1137 - 02022	5N 7P 7NR+7P	R G B	25 ~ 46	P	Extraction was done with "7 negative reversible + 7 positive" input film. The extracted area was much smaller than No. 25, but the shade of the clouds were also extracted.
27.	E-1443 - 02003	5N 7P 7N	R G B	22 ~ 35	W	This combination was used with the purpose of extracting limestone and sandstone which are widely distributed in this area. Results were unsatisfactory because of the wide cloud cover of this image.
28.	do.	5N 7P 7NR+7P	R G B	19 ~ 37 17 ~ 17	P	This was attempted with the same purpose as No.27, but the results were disappointing because of the same reason.
29.	E-1173 - 02001	5P 7N 7P	R B G	24 ~ 32	R	Acidic rocks associated with the mineralization of the Mamut mine in the northern part of the area were extracted. The ultramafic rocks to the north of the mine, coast line, and the shade of the clouds were also extracted by this combination.
30.	do.	7NR+7P 7N 7NR+7P	G R B	22 ~ 23	W	This combination was used with the same objective as No. 29. The ultramafic bodies were not extracted by this method.
31.	E-1173 - 02001 (enlarged)	6P+7P 6P+7P 7P	B R G	18 ~ 30 17 ~ 32	R	Extraction similar to Nos. 29 and 30 was done with an enlarged film for the vicinity of the Mamut mine. With this degree of enlargement, the effect of the topography is large and it was difficult to extract all the acidic bodies under the same condition.

N : negative film, P : positive film, NR : negative films reversed by this equipment, PR : positive films reversed by this equipment.

Extraction Color : Br : brown, B : blue, G : green, R : red, W : white, Pr : purple, P : pink extracted for each band. Therefore, features with relatively simple intensity and those with relatively clear intensity difference such as rivers, lakes and swamps, artificial construction, and timbered areas were extracted easily. Of the geological units, sandstones and limestones which have relatively high resistance and form key beds, granitic rocks with well developed linear structure, andesite and other intrusive rocks with light tone and high resistance were extracted with ease.

2-4 Density measurement

(1) Equipment used

Density control unit, an optional function of the Multicolor Data System Model 4200C which was used in the color enhancement method, was used for this work. This unit reads out the intensity of given points of the images on the screen, displays the values digitally, and also graphically displays the intensity variations over a vertical line.

(2) Experimental procedure

Positive films of each band for 10 scenes excluding those with heavy cloud cover were prepared for the LANDSAT images covering the project area and the vicinity. These films were displayed on the Braun tube of this unit, and sections through the necessary geological units discriminated by the pattern analysis were selected, and the intensity variation over these sections were photographed and studied.

(3) Results obtained

An example of images obtained by this method and the intensity curves compiled from these images are shown in Fig. 9 and PL. - III.

The following intensity characteristics of the geological units identified by the pattern analysis were clarified by this method.

Unit Q : Although no difference from other units is noted in bands 4 and 5, this unit is dark in bands 6 and 7. The intensity fluctuates rather sharply due to the water content of this unit.

Unit L : The intensity curve is rather monotonous and dark.

Unit B : The intensity curves of each band show fine fluctuations.

Unit S : It is generally dark. The intensity curves of each band show large flucturations.

Unit F : The intensity curves are somewhat dark and fluctuate strongly. This unit occurs together with H and it is difficult to determine the boundary of the two units by this method.

Unit H : The marginal parts of this unit are dark. The intensity curves generally show remarkable fluctuations. But where it is distributed over wide areas in the east, the curves are monotonous.

Unit ℓ : Although no difference from other units is noted in bands 4 and 5, this unit is dark in bands 6 and 7.

Fine fluctuations of the intensity curve are observed in band 7, but the curve is monotonous in bands 4 and 5.

Unit E : The tone is somewhat lighter in bands 6 and 7, but the intensity is similar to that of neighboring Unit H in bands 4 and 5; and the discrimination of the two units is difficult.

Unit T : This unit is generally light. The intensity curves show fine fluctuation in bands 6 and 7, but they are monotonous in bands 4 and 5. This unit in the eastern part shows monotonous curves for all bands.

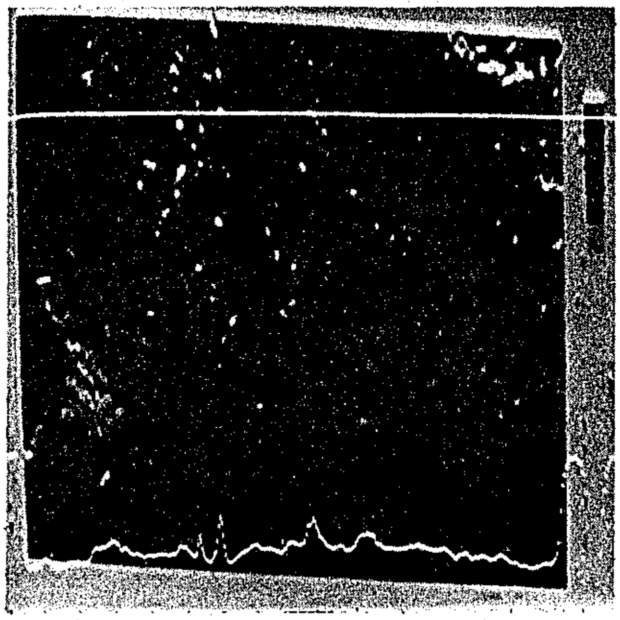
Unit N : The intensity curves are monotonous for all bands. The curves show fine fluctuations in bands 6 and 7 in some areas, but this is due to the effect of clearing operations.

Unit D : The intensity curves are generally monotonous for all bands, and show fine fluctuations in some areas.

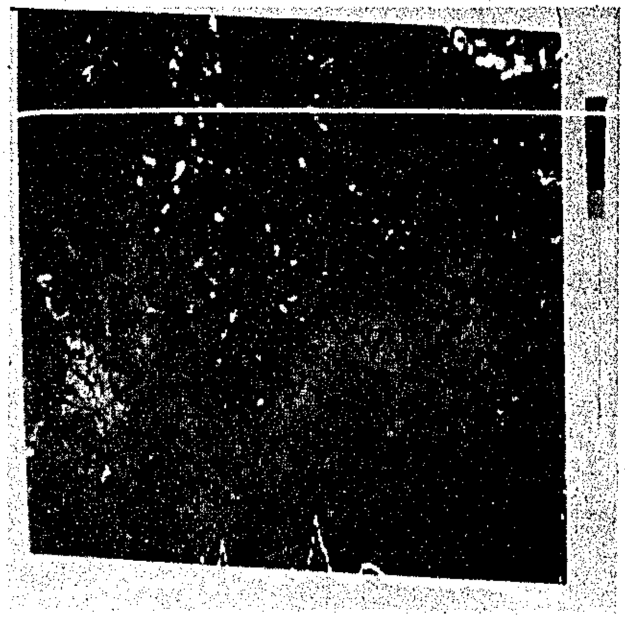
Unit M : The intensity curves are somewhat dark, and monotonous for all bands. It is difficult to distinguish this unit from other bodies by this method because of the narrow distribution.

Unit A : The intensity curve show conspicuous peaks.

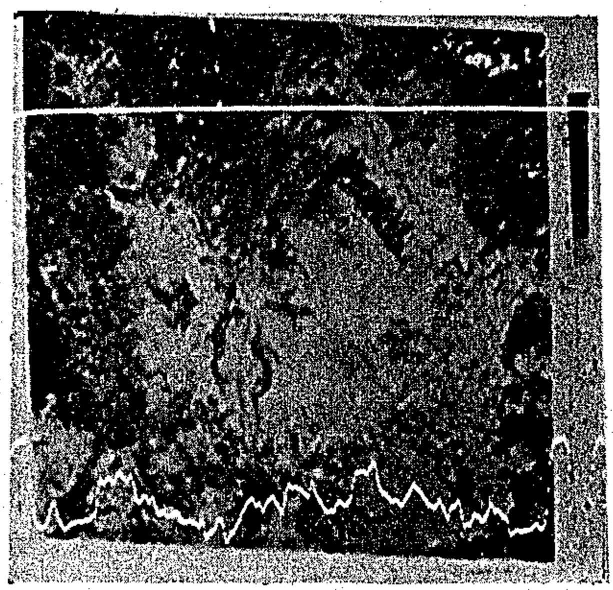
Unit G : The intensity in the timbered areas is lighter than other units. It is generally dark in other areas. The intensity curves, of bands other than 4 show fine



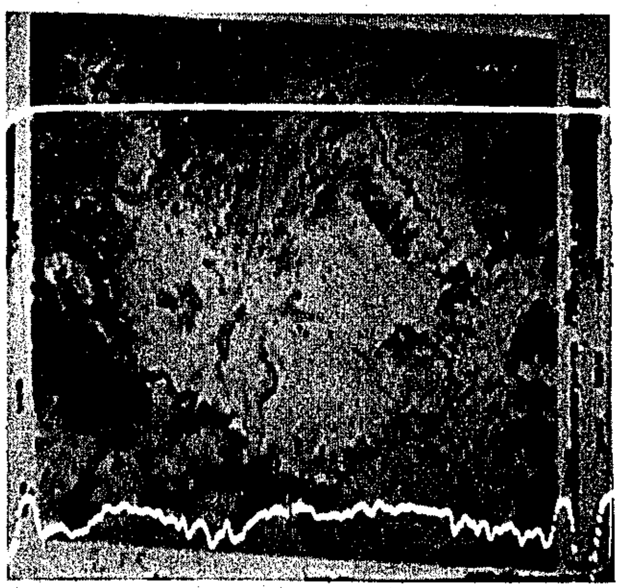
Pl. 1



Pl. 2



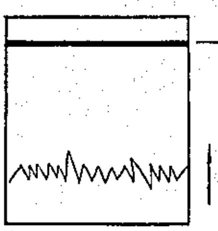
Pl. 3



Pl. 4

Fig. 9 DENSITY PROFILE (E-1355-02131)

Pl. 1, 4 Band
Pl. 2, 5 Band
Pl. 3, 6 Band
Pl. 4, 7 Band



fluctuations.

2-5 Edge enhancement

(1) Equipment used

Pattern extraction control unit which is an optional function of the Multicolor Data System 4200 C used in color enhancement analysis was used for this work. This unit displays information from a single film on a Braun tube doubly with a time lag. This enhances the contours of the images and hidden information of monotonous and low contrast films can be thus extracted.

(2) Experimental procedure

Positive films of band 6 or 7 which reflect the nature of the geologic units are selected. The direction and time lag which enhance the linear structure in the images of these films on the display tube are selected. And these images are photographed.

(3) Results obtained

A mozaic of the images obtained by this method is shown in Fig. 10. Acidic intrusive bodies with well developed lineaments, sandstones developed as key beds, and andesite dykes with very high resistance to erosion are displayed by this method as images with enhanced edges and are clearly distinguished from other units.

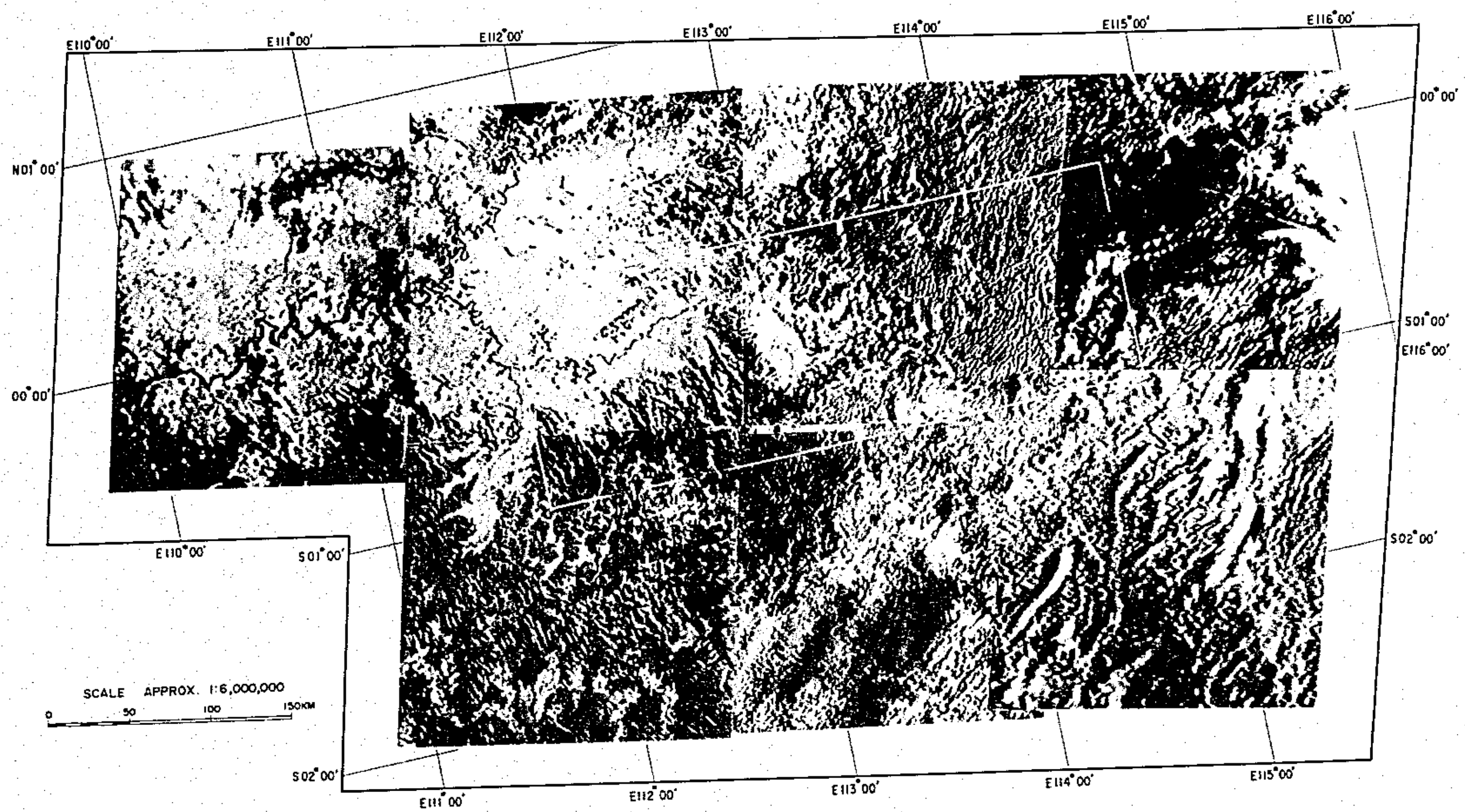


Fig. 10 PHOTO - MOSAIC OF EDGE ENHANCED IMAGES

2-6 Three dimensional display

(1) Equipment used

Photo Digitizing System Model 200 (PDS and NAC) was used for this work.

The functions and the specifications of this equipment are as follows.

a. Function

This system digitizes images (analogue values). The pattern discrimination is all computer controlled. This equipment can be used for a very wide range of purposes. During the present study, three dimensional display method was used for preparing geographical maps and topographical classification.

b. Major Specifications

DIGITIZING CAMERA

Optics : 55 mm f/3.5 Micro Nikkon Lens standard

Lens Mount : Ruggedized bayonet mount for Nikkon F standard lens

Photo Tube : Image dissector 1.5 inch diameter with 1 mil aperture standard

Spectral Response : S-20 Standard, S-1, S-11, and S-25 available.

Photocathode Sensitive Area : 0.8 x 0.8 inch max. Effective are limited to .5 x .5 inch.

Photocathode Uniformity : ± 5% over effective area of .5 x .5 inch.

Image Resolution : 1000 x 1000 point matrix for .5 x .5 inch effective cathode sensitive area with a .5 mil aperture

X-Y Axis Orthogonality : Less than 1/2°

CONTROL UNIT

Deflection Resolution : 12 bit digital to analog conversion (.25% ± 1/2 bit) standard (4096 x 4096 stepping increments)

Deflection Linearity : .5% over effective cathode area standard

Deflection Stability : .1% for 30 days, .05% for 8 hours

Gray Scale Resolution : 8 bit analog to digital (256 levels)

Raster Scanning Rate : 1 frame/sec

Digitizing Rate (computer or manually controlled) :

Sequential	100,000 points/sec
Random	50,000 points/sec

Intregating Rate - 4 rates standard

Operating Modes : Focus, manual, or computer mode

Video Amplifier : Linear or logrithmic

Video Threshold Selector :

Computer Mode - 8 bit digital to analog converte

Manual Mode -0 to -10 VDC

Video Selector - White or black

Image Dissector Protection : A protection circuit is provided to turn off the high voltage automatically when an excessive photocathode current is detected

SCAN CONVERTER

Storage Time : 25 minutes minimum

Gray Scales : 7 shades of gray

Dot Writing Speed : 500 nanoseconds

Zoom : X10 magnification of selected area

Read Video : Standard composite video per EIA Specifications RS-380 or RS-343

Video Output : Positive or negative

Display : TV monitor 9-inch diagonal. Multiple display with large screen TV monitors are possible (525 to 1029 lines)

Operating Modes : Focus, manual, computer, superimposed, and graphic modes

DIGITAL PROCESSOR

Mini Computer : Nova 800 fully-parallel, 16 bit, general purpose computer. 4 K memory standard

Interface Board : PDS special interface board

Operating Modes : Point by point, block transfer, and reference coordinate modes

Interrupts : Overflow, high voltage trip, or when the video threshold detector is triggered

POWER REQUIREMENTS

115v ± 10%,50/60 Hz at 750 watts

OPERATING TEMPERATURE

15°C to 35°C (59°F to 98°F)

PHYSICAL DIMENSIONS

		Console	Camera
Length	:	25-1/8	13-3/8
Width	:	19-5/8	5-3/8
Height	:	23-3/8	6-3/4
Weight	:	200 lbs.	16 lbs.

(2) Methods

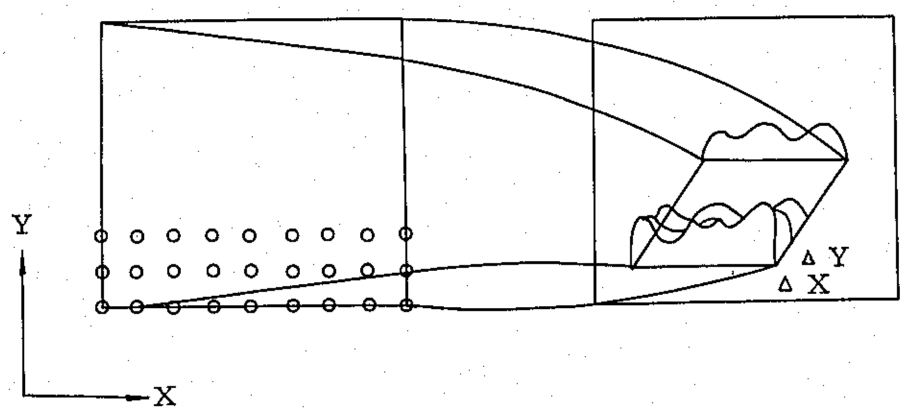
The following procedure was used for the three dimensional display.

The X and Y co-ordinates and the gray scale values of the images were transformed into three dimensional lengths on the monitor screen.

The co-ordinates of the display panel were calculated from the gray scale and X and Y co-ordinate values obtained from scanning the image on constant sampling intervals. The data sampling and display were repeated for every line scan in the X direction.

256 sampling points in the X direction, 128 points in the Y direction, and the display angle $\alpha = \tan^{-1}(3/2)$ were established.

Comparative register was made for one scanning line in the Y direction in order to avoid the piling up of the displayed images. Conditions were set so as not to write the co-ordinate values which were included in the already written points.



Scan direction

$$\alpha = \tan^{-1}\left(\frac{\Delta Y}{\Delta X}\right) = \tan^{-1}\left(\frac{3}{2}\right)$$

(3) Experimental procedure

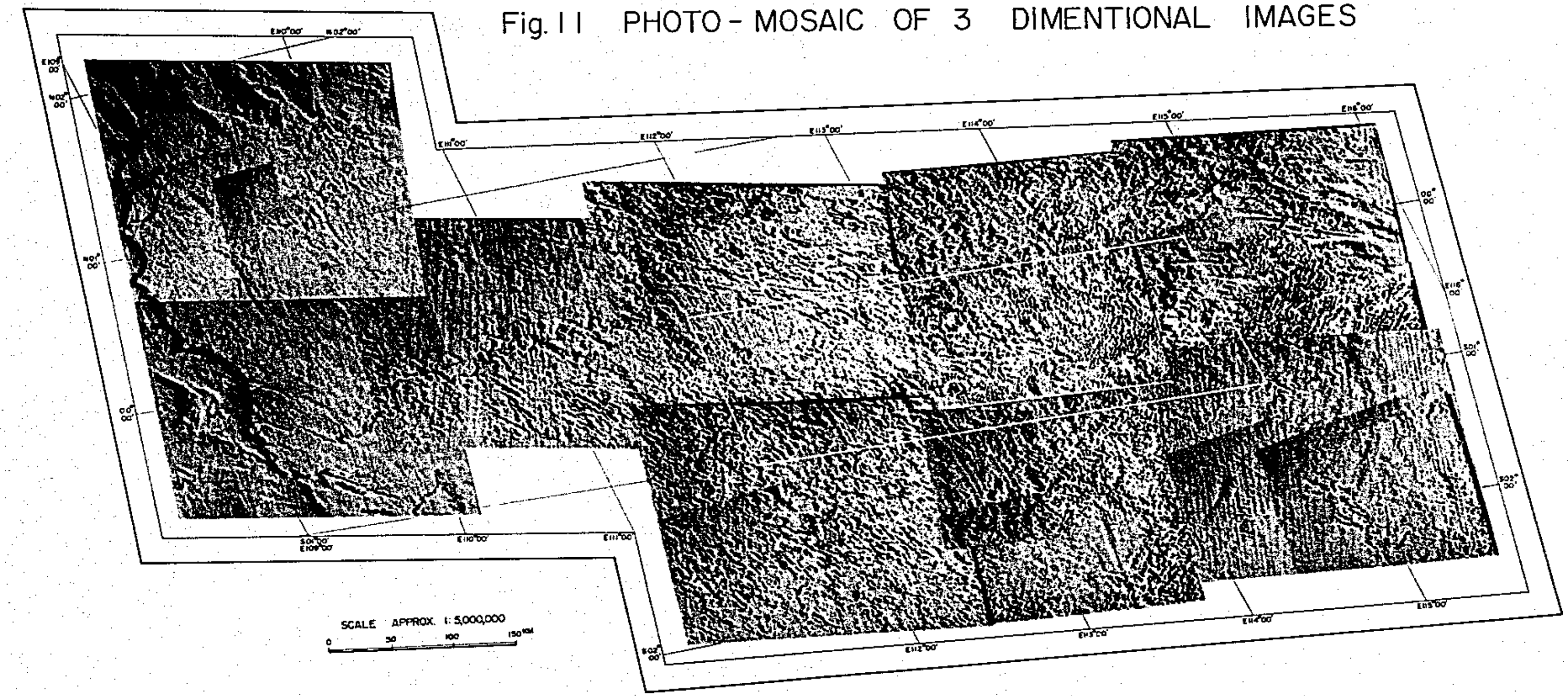
Positive films of band 7 of LANDSAT images covering the coastal zone in the west were also prepared. This was done with the purpose of clarifying the geographic location of the project area and the vicinity. The optimum conditions for the geographical and topographical classification were selected by observing the images of these films displayed on the Braun tube and the prints. Then these images were photographed.

The conditions were as follows.

(a) The objects with film intensities closer to white were more enhanced and,adversely,those with intensities closer to black were subdued.

(b) 1024 points were sampled in the X direction and 512 points were sampled in the Y direction in order to increase the accuracy of the images.

Fig. 11 PHOTO - MOSAIC OF 3 DIMENTIONAL IMAGES



(4) Results obtained

A mosaic of the images obtained by this method is shown in Fig. 11. The features which are shown in black in the films such as the sea, rivers, and swamps, and dark grey features such as parts of the mountains were weakened in the background while those which come out in lighter colors in the films such as timbered open zones, alluvium deposits, and white clouds were shown clearly in these images. The linear structures such as drainage systems come out in the films as fine alternating bands of black and white shades, and these were shown as very irregular patterns. And thus the difference of topography for each lithologic unit became clear in these images and also the outline of these bodies were identified clearly.

2-7 Print out method

In this method, LANDSAT data of any given area are directly printed on the record chart by pixels from the CCT (computer compatible tape). This is used with the objective of analysing data which could not be clarified by the films and images obtained by photographic processing.

Multi spectral scanner (MSS) is carried by LANDSAT -1, and the view of the detector of the scanner is 79m square on the ground. The energy intensity of each wavelength (band 4, 0.5 - 0.6 μm; band 5, 0.6 - 0.7 μm; band 6, 0.7 - 0.8 μm; band 7, 0.8 - 11 μm) reflected from the above 79 m square of the ground is recorded as video signals on the wide band tape. These signals are then transformed into digital signals and transmitted to ground stations. These signals were then recorded as digital signals in the HDDT (high density digital tape), and were transformed into films or CCT according to the usage.

In CCT, each scene contains 2,150 pixels in the orbiting direction and 3,240 pixels in the scanning direction. Therefore, each pixel corresponds to approximately 80 x 60 m on the ground. The reflected energy intensities are recorded in 0 - 255 steps.

Analyses were made with band 5 which reflects the conditions of vegetation and with band 7 which reflects the geology most effectively.

(1) Experimental procedure

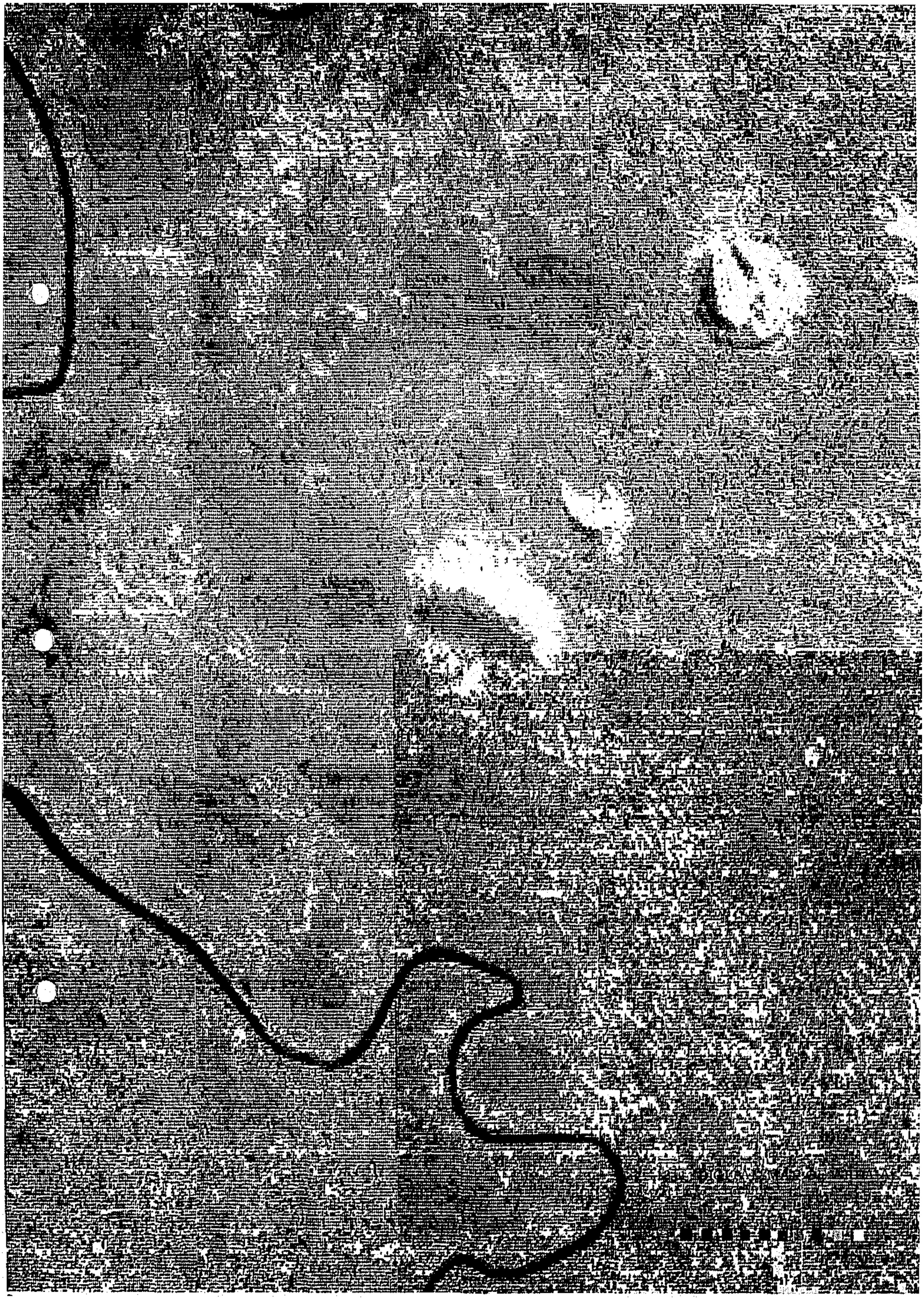
First the intensity distribution was studied by constructing a histograph from all the pixels which constituted the area. Then appropriate symbols were given to each intensity step (or to a range of intensity steps) and the data were printed out in these symbols.

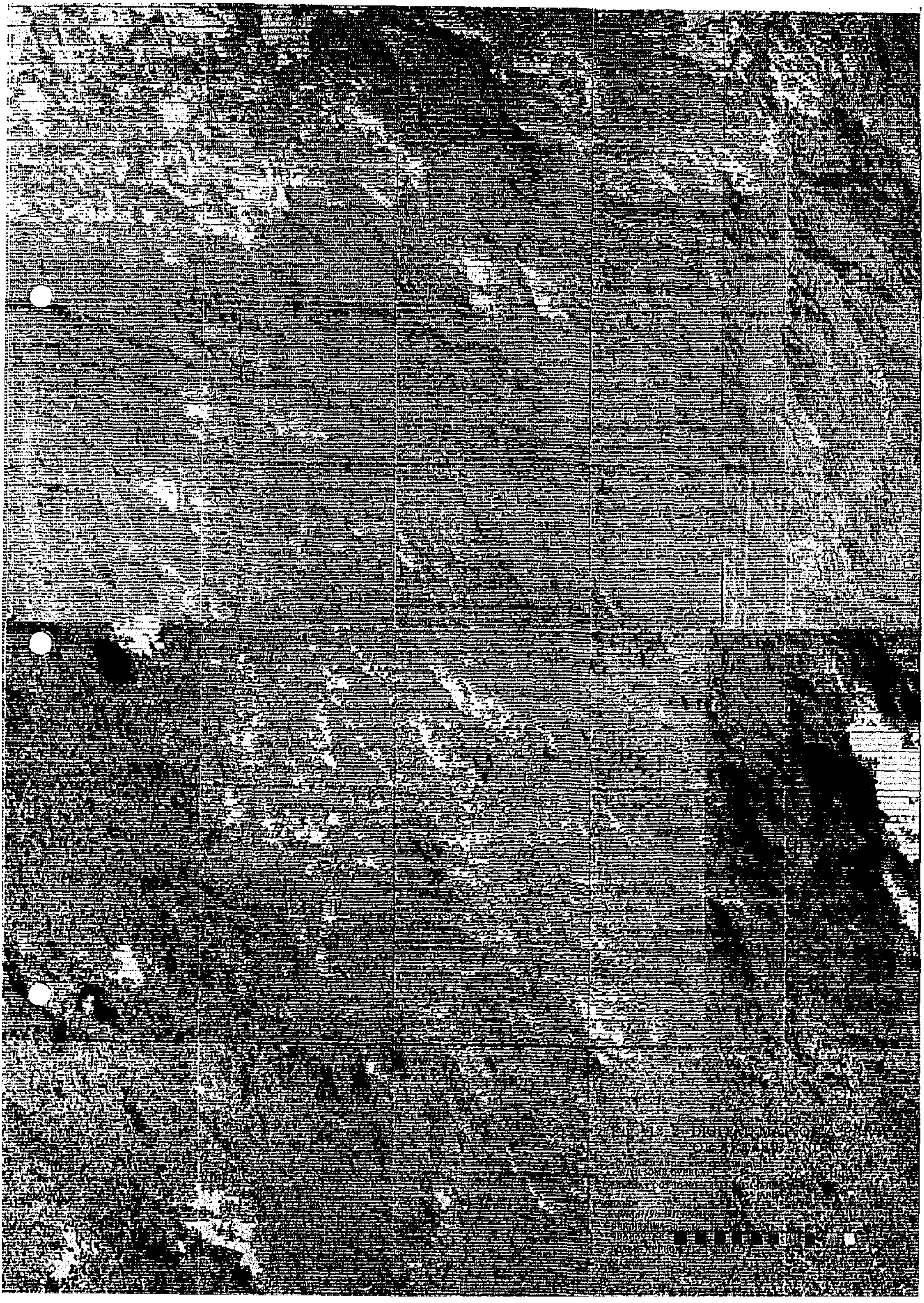
(2) Results obtained

Three areas were extracted from the pattern analysis, and they will be designated as areas A, B, and C. Area A and B are recorded in tape No. E-1355-02131 (ID No.) and C in E-1355-02133. Areas B and C are continuous with some overlap. There are differences in intensity distribution by the bands and more than 90 per cent of the pixels were concentrated in intensity steps 8 to 17 with band 5, and in steps 6 to 30 with band 7. Thus symbols were given for each step in band 5, while they were fixed for every two intensity steps in band 7. The compilation of histographs and print outs are shown in PL. IV 1 ~ 6, and also digital maps with coloring of Area A and a part of Areas B and C are shown in Fig. 12-1, -2.

It is seen that geological information cannot be obtained from that of band 5. But from the band 7 data, discrimination of geological units is possible because; metamorphic rocks are shown mostly in range of 16 - 18, granites in 18 - 22, tuff in 18 - 20, andesite dykes in steps higher than 26, and the timbered open areas in steps over 24, and the metamorphic bodies show a veriety of patterns such as abundant lineations or ring-like structure, and granites usually show homogeneous pattern.

Occurrence of metallic veins is not known in this project area and since comparative study of the images is impossible, two anomalies which were extremely different from the features of other geologic units were extracted. One is near the boundary between metamorphic rocks and granitic rocks where clear linear structure of intensity steps of 18 to 22 and of 14 to 18 are observed. The other is in the granitic area where parts with intensity steps of 24 to 26 and of 10 to 14 are arranged in belts.





Chapter 3 Interpretation

3-1 General geography

The rivers, villages, vegetation, and the road network were analysed by false color images, additive color compositions, and color enhanced compositions, and the ridge forms were analysed by the edge enhancement images and three dimensional display images. The results are as follows.

(1) The topography of the project area can be largely divided into low area (eastern and western parts of the project area) where alluvial deposits are developed along the meandering rivers; and the mountain region (southeastern, central, and northwestern parts) where ridges of 1,000 to 2,000 m (by published topographic maps) high continue. Protrusions of the intrusive bodies are often found in the low area.

(2) There are no large villages and only small villages are rarely found scattered along the rivers.

(3) The project area is covered completely by jungle except where timbering has been done along the rivers.

(4) Transportation is done generally by rivers, and some roads are found along rivers in the eastern and western parts.

3-2 Geology

Pattern analysis reported in Part I is the basis for the identification of the geologic units and the geologic structure. Spectral analysis was used as a complementary method and to obtain objective data. The results of these work have been mentioned in the preceding paragraphs and here the relationship between the results of spectral and pattern analysis will be mentioned.

3-2-1 Geologic units

Spectral analysis did not provide data in exceed of those by pattern analysis for Units M, D, and N. This is because the tone of these units were similar to that of other units and because the identification was made by texture, resistance, and the linear structure for M, texture, drainage pattern, and linear structure for D, and texture, drainage pattern, resistance, and linear structure for N.

Unit G was identified clearly by spectral analysis. The distribution of this unit was clearer by additive color composition with conditions of Nos. 10, 11, 15, 16, 17, 18, 20, and 21 of Table 4 than by pattern analysis. Of these conditions, the linear structure was clearly observed with Nos. 11, 17, and 18. Color enhancement method under Nos. 4, 9, 20, and 21 of Table 5 revealed the distribution of bodies with two different intensities. The intensity cross section of the unit showed many small fluctuations due to the effect of the linear patters (Line 1, 2, 3, 8, 9, and 10 of PL. III). This pattern appeared even when this unit occurs in the opened timbered areas regardless of the relative intensity difference.

Spectral analysis of T and E did not reveal data newer than those available by pattern analysis. This is due to the great variation of the tone of the two units.

Key beds which could be clearly traced from pattern information are developed in Units H and $\mathcal{L}$. These beds can be traced by additive color composites, color enhanced images or intensity cross sections.

Spectral analysis did not provide data in exceed of those from pattern analysis for Units F, C, S, and B. These units show similar tone and they cannot be distinguished by spectral data alone.

Unit A is distinguished much more clearly by any of the spectral methods than by pattern analysis. This is caused by the extremely light tone of this unit and by also the protruding topographic characteristics.

3-2-2 Geologic structure

Pattern analysis yields much more data than spectral methods for the study of folding structures, but in the northwest, the tracing of the key beds is done easily by edge enhancement and three dimensional display.

As for linear structures they will be clearly identified, the trend of the systems determined very easily, and the continuation of the systems traced without difficulty by edge enhancement and additive color composition with rotation process.

3-3 Economic geology

There are very limited literatures concerning the ore deposits and mineralization of the project area. And in the few reports available, the type of the deposits, size, and the accurate location are often missing. The known deposits are generally divided into those occurring in the granitic bodies in the southwest and the placer deposits in the alluvial and diluvial sediments. Gold has been mined from the former type mineralization together with wilver, copper, lead, molybdenum, and other metals. Gold and diamond are among the minerals known from the placer deposits. Pattern analysis was practically useless in obtaining information of these mineral showings, but as will be mentioned later, some information were obtained from spectral analysis.

The vein deposits could not be extracted by analogic processing such as additive color composition and color enhancement method. But clear linear structure was observed in areas shown to comprise vein deposits. The reason for the failure of the analogic method to extract vein areas was the small intensity difference. In other words the effect of the mineralization was limited to a very small area. Therefore the print out method which is much more sensitive than the analogue method was applied. Two types of anomalies were extracted by this process as shown in PL. IV-3, -5. One of these anomalies is the clearly developed linear structures and the other shows the banded arrangement of light and dark belts.

The placer deposits could not be extracted by either methods. Alluvial and diluvial sediments were observed in localities of placer deposits on the map. This is interpreted as the result of the placer deposits exerting almost no influence on the vegetation of the area.

The occurrence of porphyry copper type mineralization is expected in the project area from the geology and geologic structure although no mineral showing has been found. The area is located on the porphyry copper belt which extends from the Philippines. And the closest deposit is the Mamut mine in Sabah of Malaysia in the northern part of the Kalimantan Island. Thus LANDSAT data of the mine area were chosen as the standard sample for extracting the mineral showings of this type.

The Mamut mine is located on the eastern foot of Mt. Kinabalu (4, 101 m) which is the highest peak of the island. The geology of the vicinity consists mainly of Tertiary sedimentary formations such as sandstones and mudstones. Intrusions of acidic and ultramafic bodies are found only at Kinabalu and the vicinity. It is reported that the porphyry deposits of the Mamut mine is closely related to these Tertiary acidic plutonic rocks.

The acidic plutonic bodies can be extracted by additive color composition and color enhancement methods with relative ease. And the above methods were used for extracting these bodies and deposits in the project area. The intensity of the negative and positive films of the scenes which cover the Mamut mine and the project area was, however, different to a degree that the extraction was rendered impossible by the same combination. Thus these bodies of the project area were extracted by the combination of Nos. 3, 4, 9, 20, and 21 of Table 5. It was confirmed that there are more than two types of granites and that there are many large granitic bodies in the area.

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PHASE II

AERIAL PHOTOGRAPHY
AIRBORNE MAGNETIC SURVEY

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PL. VII	Airborne magnetic survey total intensity map	(scale 1 : 250, 000)

Abstract

1) The surveys conducted during this year are aerial photography and airborne magnetic survey. The survey flight was made for the period from June to October, which falls upon the dry season in Kalimantan.

2) Aerial photography covered about 71 per cent of the total survey area of 36, 300 km^2.

3) Airborne magnetic survey was carried out over the effective survey line of 3, 606 km, which corresponds to about 25 per cent of the total area.

Chapter 1 Introduction

1-1 Objective of survey

In 1974, integrated geological survey was started in Kalimantan as the technical cooperation project between the Republic of Indonesia and Japan. In the initial year, analysis was made on the Landsat data to clarify topography, forestry, geology and geological structure.

In this year, the second stage survey was conducted by aerial photography and airborne magnetic survey. The purpose of aerial photography was to prepare aerial photographs for airborne magnetic survey, photogeological interpretation and geological survey. The purpose of airborne magnetic survey was to clarify geological structure, igneous rock distribution and potentiality of ore deposit.

1-2 Outline of survey

1-2-1 Survey area

The survey area covered by aerial photography and airborne magnetic survey is located in the center of Kalimantan as shown in Fig. 1.

The area is approximately 36, 300 km^2 and bounded on the north and south by latitudes 0°00' and 1°00' respectively and west and east by longitudes 111°45' and 114°45' respectively.

1-2-2 Survey period

Main time schedule was set up as follows :

Aerial photography

April 20 to June 1, 1976 :	Mobilization and preparatory works
June 2 to September 17, 1976 :	Aerial photography and film development
September 18 to October 30, 1976 :	Making of contact prints
October 31 to November 5, 1976 :	Compilation and arrangement of data Demobilization
November 6, 1976 to January 31, 1977 :	Report

Airborne magnetic survey

April 30 to May 11, 1976 :	Mobilization and preparatory works
May 12, 1976 :	Aircraft accident (failure in landing during test flight due to trouble of landing gear)
May 13 to August 6, 1976 :	Arranging for substitute aircraft
August 7 to October 23, 1976 :	Airborne magnetic survey
October 24 to November 5, 1976 :	Arrangements and compilation of data Demobilization
November 6, 1976 to January 31, 1977 :	Report

1-2-3 Members of teams

The members engaged in the project works are listed herein.

List of members

Indonesian team

Coordinator (Team leader)

Adjat Sudradjat (G.S.I.)

Aerial photography

Turus Soejitno (G.S.I.)

Sae'un Hardjoprawiro (G.S.I.)

Ungkap L Batu (G.S.I.)

Aircraft crew (EXSA, INDOAVIA)

Airborne magnetic survey

Soetijoso Djojomihardjo (G.S.I.)

Marzuki Sani (G.S.I.)

Kastidjo Mardjo (G.S.I.)

Aircraft crew (PENAS)

Japanese team

Supervisor

Nobutaka Miyazoe (M.M.A.J.)

Masaharu Kaneko (M.M.A.J.)

Toshio Kawaguchi (M.M.A.J.)

Yutaka Hatano (J.I.C.A.)

Coordinator (Team leader)

Haruhiko Hirayama (N.E.D.)

Aerial photography

Junichi Umezawa (A.A.S.)

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Notes :

G.S.I.	Geological Survey of Indonesia
J.I.C.A.	Japan International Cooperation Agency
M.M.A.J.	Metal Mining Agency of Japan
N.E.D.	Nikko Exploration and Development Co., Ltd.
A.A.S.	Asia Air Survey Co., Ltd.
EXSA	P. T. EXSA International Co., Ltd.
INDOAVIA	P. T. Indonesian Aviation Corporation
PENAS	Perusahaan Umum Survai Udara

The surveys were carried out in cooperation with Indonesian aerial companies ; for aerial photography with both P. T. EXSA International Co., Ltd. and P. T. Indonesian Aviation Corporation and for airborne magnetic survey with Perusahaan Umum Survai Udara.

1-2-4 Geography

The greater part of the survey area is located in a comparatively lowland area comprising plains of 100 m to 500 m in altitude. The mountain ridges extend from southwest to north in the center of the area and the highest peak reaches 2, 278 m in altitude (Mt. Raja). The area is mostly a tropical jungle.

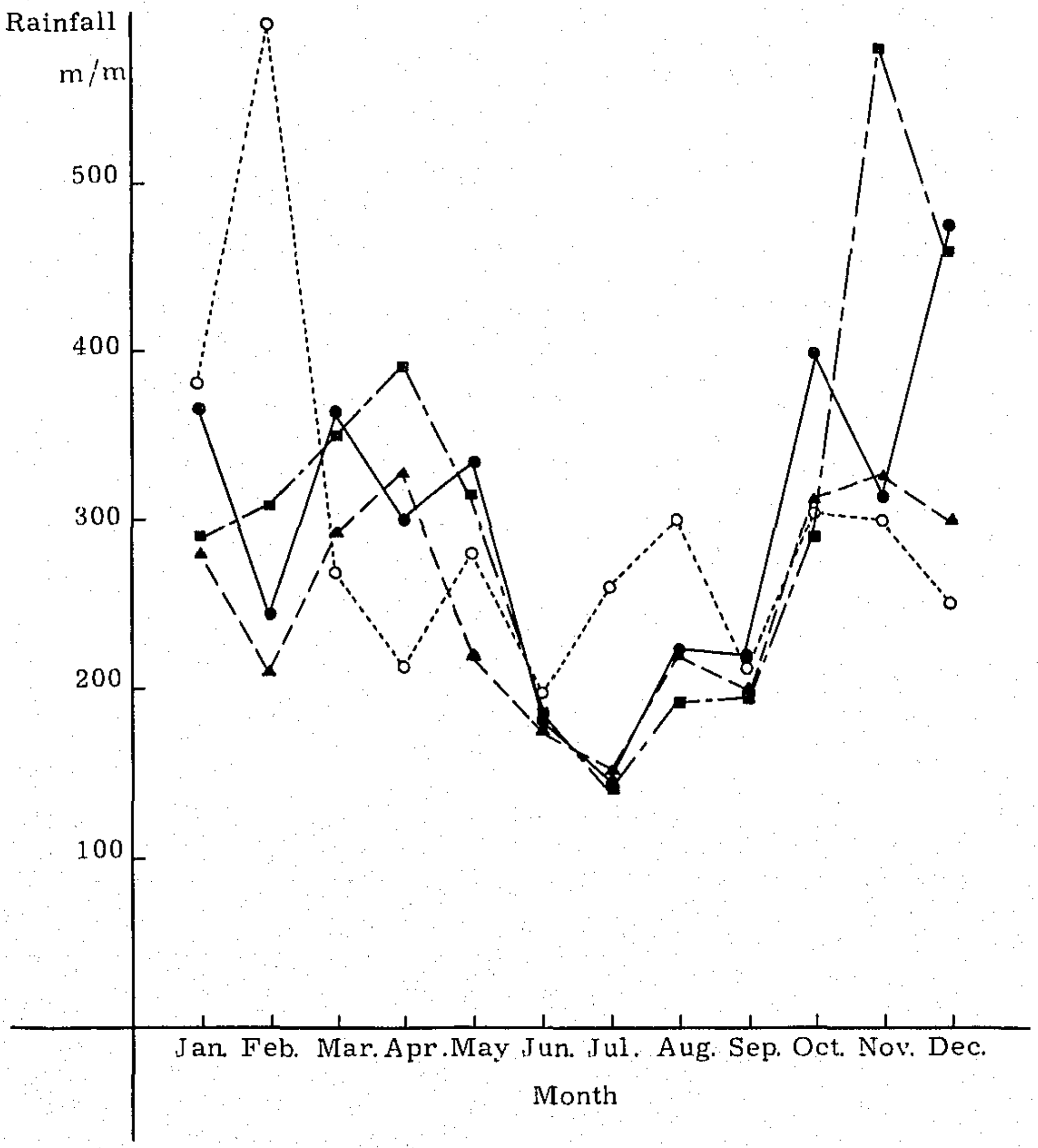
As for water system, in an area ranging from east to southwest, water flows predominantly in a north-south direction and consists of the main streams and the tributaries of the Barito River, the Kapuas River, the Kahajan River and the Mendawai River. In the northwest part of the area, the main water system is composed of the Melawi River flowing to the west and of its tributaries.

No large villages exist in the area and only small villages are scattered about along the rivers.

There are very few roads along the rivers in east and west parts of the area. The area still remains undeveloped as a whole and the rivers are major means of transportation.

The climatic condition is characterized by high temperature and high humidity because the area is situated close to the equator and in a zone of moderate altitude (except for a part of the area). In Balikpapan and Pontianak, the seaside cities, located at almost the same altitude as the survey area, the annual average temperature and humidity reaches 26° - 28°C and 75 - 80 per cent respectively.

Generally, a year is divided into the dry season (June to September) and the wet season (October to May). As shown in Fig. 13 precipitation varied according to places of observation. Generally, however, the monthly precipitation registered 200 to 300 mm during dry season and 300 to 400 mm during the wet season, totaling 3, 000 to 4, 000 mm in annual precipitation. The precipitation data shows that the area is abundant in rainfall throughout the year.



Index map

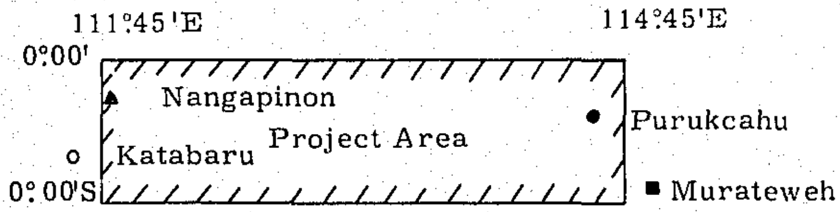


Fig. 13 Monthly rainfall in and around project area (mean value from 1963 to 1974)

Chapter 2 Aerial Photography

2-1 Survey area

The survey area planned to be covered by aerial photography this year is shown in Fig. 1. However, parts of the southwest and northeast areas and the area ranging from the center to the east of the whole area were covered with clouds throughout the survey period preventing aerial photographing to the last. In 1976, however, in spite of bad weather conditions, the aerial photography succeeded finally to cover about 71 per cent of the whole survey area.

2-2 Method of photography

2-2-1 Flight plan

Flight direction :

The north-south flight course was determined for aerial photography.

However, the weather conditions were bad in the survey area and the lesser coverage of cloud, extending and widening in east-west direction, was very often found in certain parts of the area. Under such cloud conditions, it was impossible to take more than 4 - 5 frames of photographs continuously if flown in north-sourth direction. In addition to the reason mentioned above, the topographic map was unavailable for proper orientation and we were forced to fly for aerial photography in east-west direction over such particular parts of the area.

Flight altitude :

Initially, the flight altitude was determined at 4, 200 m for the photography at a scale of 1/50, 000. However, difficulty was encountered in attempting to take photographs with a desired degree of continuity for orientation due to the spread of densely developed clouds beneath the planned flight altutude.

As clouds tend to gather at an altitude of 300 m at the lowest, and then at 1, 500 m and between 3, 600 m and 4, 000 m, the flight altitude for photography was lowered to about 3, 600 m, resulting in the photography at a scale of about 1/40, 000. The speed of aircraft was about 240 km per hour.

2-2-2 Air base

Within the survey area there existed no airport available for take-off and landing of the survey aircraft as shown in Fig. 14. In Balikpapan, which is in the eastern part of Kalimantan, and Banjarmasin which is in the southern part of Kalimantan, there exist airports provided with runways of sufficient length and sources of constant fuel supply. However, both of those airports are located about 350 km from the center of the survey area. This meant that the flight to and from the survey area would have consumed considerable time. This fact naturally posed a big problem considering that reconnaissance flights were required every day since no local weather reports were available for the survey area.

Name	Location	Size (m)	Surface
Balikpapan	1.15 S 116.50 E	1, 800	Asphalt
Ban jarmasin	3.22 S 114.33 E	1, 775	Asphalt
Batu Licin	3.00 S 116.00 E	900 x 12	Asphalt
Muratewe	0.57 S 114.54 E	600 x 20	Grass
Palangka Raya	2.16 S 113.56 E	1, 500 x 30	Asphalt
Pankalan Bun	2.45 S 111.40 E	1, 800 x 45	Grass
Pontianak	0.05 S 109.16 E	1, 600	Asphalt
Sampit	2.31 S 112.59 E	500 x 12	Grass
Sintang	0.04 N 111.29 E	557 x 30	Grass
Tanjung Warukin	2.13 S 115.26 E	1, 300 x 30	Asphalt

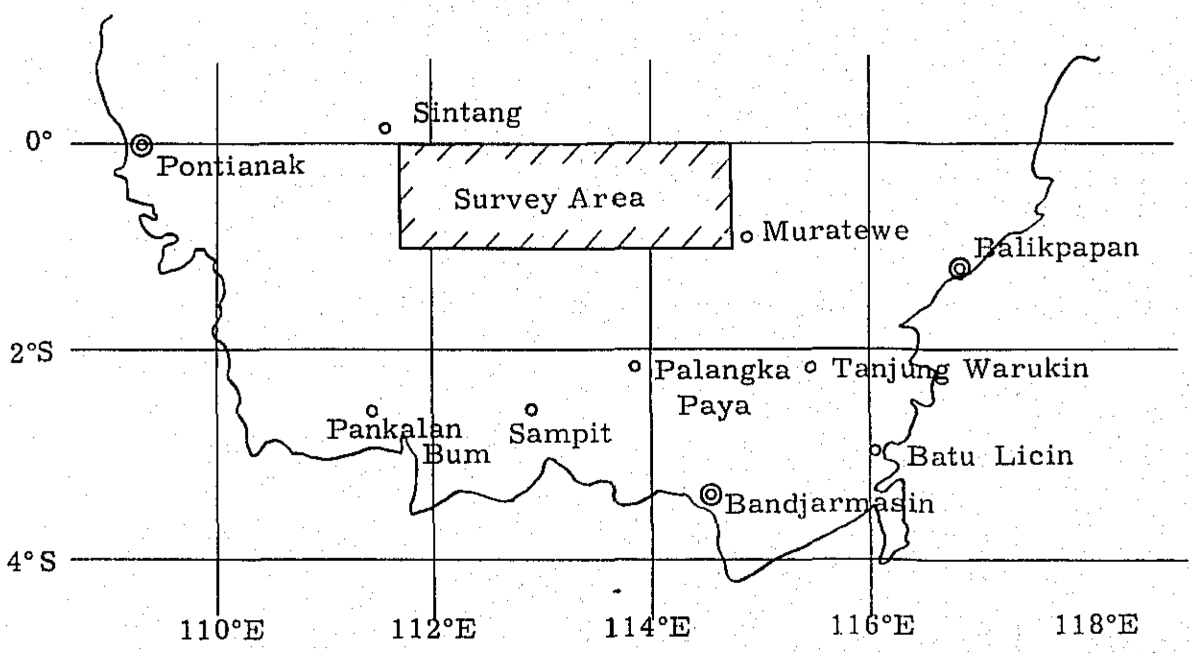


Fig. 14 Airport in Kalimantan

In Palangka Raya, which is about 150 km from the survey area, there is Panarung airport utilized by small aircraft (operated by private airlines). This airport was chosen as the air base because, even though there was no guarantee of constant fuel supply to the airport, it was located at a relatively short distance from the survey area and a river was readily available for fuel transportation to the airport.

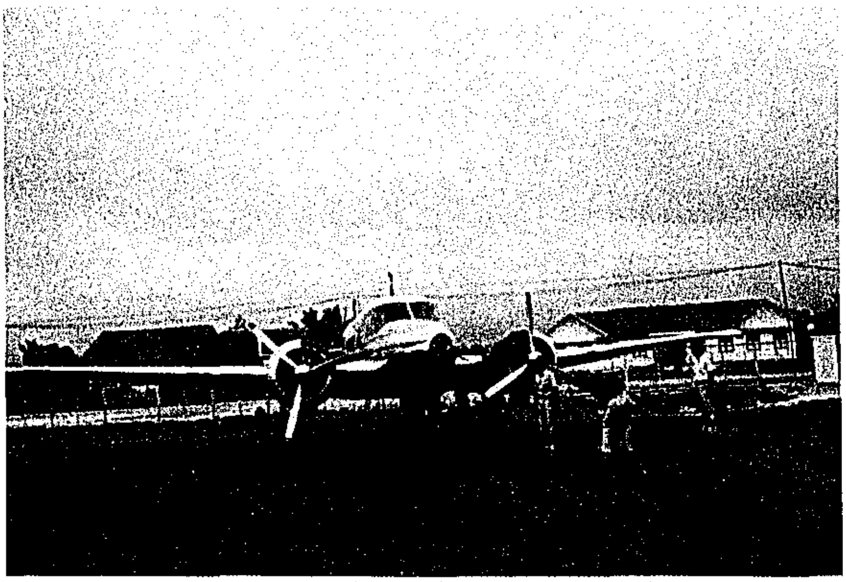
The airport had a 1, 500 m long and 30 m wide asphalt-paved runway and a radio beacon, permitting safe take-off and landing even when the weather was bad to some extent.

In order to secure fuel supply, aviation fuel in drums and lubrication oil were delivered from Jakarta to Banjarmasin and from Banjarmasin to Palangka Raya by cargo boat and barge respectively. At the beginning of survey work no fuel supply was available at Panarung airport because of the time required to obtain a fuel purchase permit and for fuel transportation. Therefore, fuel was temporarily supplied to the aircraft at Banjarmasin airport.

2-2-3 Aircraft and equipment

Aircraft and equipment used for the aerial photography were as follows :

a) Aerial camera : WILD RC-9 (See Fig. 15)
Super wide-angle lens "Super Aviogon"
Focal length : 88 mm



Beach H-18S

Camera RC-9

Fig. 15 Aircraft and camera for aerial photography

b) Film : Kodak TRI-X Aerofilm

c) Aircraft: Beach H-18S of Beach Aircraft Corporation (See Fig. 15)

Registered Nos. PK-BIB, -BIC, -BIE, and -BIF

The four aircraft used were of the same type. They were used in rotation to allow for periodic inspection and maintenance. The aircraft were selected on the basis of capability to operate continuously for 6 hours at a speed of 350 km per hour. The aircraft were partially remodelled to permit the mounting of camera for aerial photography purposes.

2-3 Film processing and printing

A temporary photo laboratory was established in Palangka Raya. Films were developed and printed immediately after photo flights in order to check the flight line, forward and side overlap, tip, tilt, crab and the cloud coverage.

By refering to the results of such checks the next flight schedule was planned. Developer and other chemicals used for processing were designated by Kodak.

Natural drying process was adopted to dry the film with special care to prevent any possible strain on the film surface. Copies were made in duplicate by use of "quick copy paper"; one copy for checking purposes and the other for mosaic for airborne magnetic survey.

Final contact print was prepared in Jakarta after the completion of all aerial photographic work.

2-4 Survey results

The specifications of aerial photographs are as follows :

a) Photographic scale : Approximately 1/40, 000

b) Overlap : Forward overlap : not less than 60 per cent
Side lap : 20 - 80 per cent

c) Tilt and tip of film angle : Within 5 degrees (and usually less than 3 degrees)

d) Cloud coverage : Less than 10 per cent (less than 20 per cent in some parts of mountainous area)

e) Type and size of film : Panchromatic black & white, 23 cm x 23 cm

f) Type of printing paper : Semi-glossy, double weight, Fuji AM2

As shown in Table 6, the number of aerial photographs taken this time is 1, 987 prints in total, consisting of 1, 413 prints taken in north-south direction and 574 prints in east-west direction. 1, 910 prints out of them satisfy the requirements of the specifications. The remaining 77 prints show cloud coverage of 20 or more per cent which exceeds the level permitted by the specifications. These prints are intentionally left in the series in order to avoid "blank spaces" which would disrupt and cause problems in the succeeding works.

As for the area not covered by photographs this year, a supplemental survey is planned to be carried out next year.

Chapter 3 Airborne Magnetic Survey

3-1 Survey area

The survey was conducted in the northwest and central parts of the area as shown in Fig. 1 and completed about 25 per cent of the whole area with effective survey line extension of 3, 606 km.

3-2 Method of survey

3-2-1 Flight plan

Main specifications for the airborne magnetic survey are as follows:

Flight altutude :	2, 000 m above sea level (except mountainous zone of 1, 800 m or higher in altitude)	
Flight direction :	Traverse line :	South-North
	Tie line :	East-West
Flight line spacing :	Traverse line :	3 km
	Tie line :	40 km

3-2-2 Air base

The airport used for the survey was Panarung airport in Palangka Raya, same as in the case of the aerial photography. For periodic overhauling inspection of the aircraft, the 50-hour cycling check was made in Palangka Raya, and the 100-hour cycling check in Banjarmasin airport which could afford complete facilities

Table 6 List of Photographs

N-S Direction

Run No.	Film count	Regist. No.	Sheet No.
R-1 A	4585-4591	1 - 7	7
R-1 B	0701-0709	9 - 1	9
R-1 C	0509-0514	6 - 1	6
R-2 A	4574-4582	10 - 1	10
R-2 B	0541-0547	1 - 7	7
R-3 A	4563-4569	1 - 7	7
R-3 B	0581-0604	24 - 1	24
R-4 A	3336-3342	7 - 1	7
R-4 B	0612-0626	1 - 15	15
R-5 A	3348-3355	1 - 8	8
R-5 B	0629-0638	10 - 1	10
R-6 A	3390-3399	10 - 1	10
R-6 B	3378-3384	1 - 7	7
R-6 C	3360-3366	7 - 1	7
R-6 D	4223-4229	1 - 7	7
R-7 A	4041-4054	14 - 1	14
R-7 B	4230-4235	6 - 1	6
R-8	3412-3419	8 - 1	8
R-9	3420-3422	1 - 3	3
R-10 A	3433-3437	5 - 1	5
B	4058-4062	1 - 5	5
C	4143-4151	1 - 9	9

Run No.	Film count	Regist. No.	Sheet No.
R-11	3722-3723	1 - 2	2
R-12	3702-3705	4 - 1	4
R-13	3698-3701	1 - 4	4
R-14 A	1821-1826	6 - 1	6
B	3669-3676	8 - 1	8
C	1809-1815	7 - 1	7
D	3677-3682	6 - 1	6
Gap	4180-4184	1 - 5	5
R-15 A	2303-2326	1 - 24	24
B	2217-2237	1 - 21	21
C	3630-3633	4 - 1	4
R-16 A	2272-2299	28 - 1	28
B	2238-2250	13 - 1	13
R-27 A	2125-2133	9 - 1	9
R-28 A	1982-1991	1 - 10	10
B	2105-2115	1 - 11	11
R-29 A	1964-1969	6 - 1	6
B	2092-2100	9 - 1	9
R-30 A	2070-2080	1 - 11	11
B	1534-1541	1 - 8	8
R-31 A	2059-2066	8 - 1	8
R-32 A	2045-2054	1 - 10	16
B	1526-1532	7 - 1	7
R-33 A	1955-1963	9 - 1	9
R-34 A	1937-1948	1 - 12	12

Run No.	Film count	Regist No.	Sheet No.
R-35 A	1909-1933	25 - 1	25
R-36 A	1882-1901	1 - 20	20
R-37 A	1410-1413	4 - 1	4
B	1849-1859	5 - 15	11
R-38 A	1415-1419	1 - 5	5
B	0655-0675	1 - 21	21
C	1653-1661	9 - 1	9
R-39 A	3581-3587	1 - 7	7
B	1437-1446	1 - 10	10
C	1662-1671	1 - 10	10
R-40 A	3568-3576	9 - 1	9
B	1448-1454	7 - 1	7
C	3741-3755	1 - 15	15
R-41 A	3551-3558	1 - 8	8
B	1459-1463	1 - 5	5
C	3562-3566	1 - 5	5
D	3773-3783	11 - 1	11
E	1606-1612	7 - 1	7
R-42 A	2401-2411	11 - 1	11
B	1490-1500	11 - 1	11
C	3784-3805	1 - 22	22
R-43 A	3523-3534	1 - 12	12
B	1478-1489	1 - 12	12
C	4471-4485	1 - 15	15
R-44 A	0117-0133	17 - 1	17
B	3809-3826	18 - 1	18
C	1632-1637	6 - 1	6
D	4402-4415	1 - 14	14

Run No.	Film count	Regist No.	Sheet No.
R-45 A	0075-0091	17 - 1	17
B	3827-3832	1 - 6	6
Gap	2381-2399	1 - 19	19
R-46 A	0097-0113	1 - 17	17
R-47 A	0024-0044	21 - 1	21
R-48 A	3513-3520	8 - 1	8
B	1094-1106	1 - 13	13
R-49 A	2375-2378	1 - 4	4
B	1076-1091	16 - 1	16
C	1187-1200	1 - 14	14
R-50 A	1220-1230	11 - 1	11
B	1065-1073	1 - 9	9
C	1207-1215	9 - 1	9
Gap	2366-2371	6 - 1	6
R-51 A	1233-1240	1 - 8	8
B	1011-1019	9 - 1	9
R-52 A	0797-0814	1 - 18	18
B	0820-0826	7 - 1	7
R-53 A	0727-0746	1 - 20	20
R-54 A	0775-0796	22 - 1	22
R-55 A	0719-0726	8 - 1	8
B	0512-0524	13 - 1	13
R-56 A	0446-0449	1 - 4	4
B	0999-1006	1 - 8	8
C	0456-0467	1 - 12	12

Run No.	Film count	Regist No.	Sheet No.
R-57 A	0985-0994	10 - 1	10
B	0545-0555	1 - 11	11
C	4512-4521	10 - 1	10
R-58 A	0939-0957	19 - 1	19
R-59 A	0958-0976	1 - 19	19
R-60 A	0828-0838	11 - 1	11
B	2018-2022	5 - 1	5
C	0988-1008	11 - 1	11
Gap	1051-1052	1 - 2	2
R-61 A	1076-1092	17 - 1	17
R-62 A	0850-0857	8 - 1	8
B	1099-1108	1 - 10	10
Gap	0980-0984	1 - 5	5
R-63 A	0842-0849	1 - 8	8
B	1110-1119	10 - 1	10
R-64 A	0870-0879	10 - 1	10
B	0842-0850	9 - 1	9
C	1172-1183	1 - 7	7
R-65 A	0968-0977	10 - 1	10
B	0878-0883	6 - 1	6
R-66 A	0959-0967	1 - 9	9
B	0866-0873	1 - 8	8
C	1124-1134	1 - 11	11
R-67 A	0945-0955	11 - 1	11
B	0900-0906	1 - 7	7
C	1136-1144	9 - 1	9

Run No.	Film count	Regist No.	Sheet No.
R-68 A	0919-0931	13 - 1	13
R-69 A	0934-0943	1 - 10	10
B	0347-0354	8 - 1	8
R-70 A	0326-0341	1 - 16	16
R-71 A	0304-0322	19 - 1	19
R-72 A	0266-0283	1 - 18	18
R-73 A	0247-0263	17 - 1	17
Total			1,413

E-W Direction

Run No.	Film count	Regist No.	Sheet No.
EW 1	2534-2558	25 - 1	25
EW 2 A	2352-2365	1 - 14	14
B	2570-2586	1 - 17	17
EW 3	2587-2605	19 - 1	19
EW 4 A	2337-2351	15 - 1	15
B	2606-2626	1 - 21	21
EW 5 A	2627-2659	33 - 1	33
B	2329-2333	1 - 5	5
EW 6 A	2660-2691	32 - 1	32
B	2952-2965	14 - 1	14
EW 7 A	2692-2725	34 - 1	34
B	2973-2988	1 - 16	16
EW 8 A	2750-2781	32 - 1	32
B	2989-3003	15 - 1	15
EW 9	3259-3297	39 - 1	39
EW 10	3219-3258	1 - 40	40
Gap	4306-4317	1 - 12	12
EW 11	3180-3215	36 - 1	36
EW 12	3148-3179	1 - 32	32
EW 13	3135-3147	13 - 1	13
EW 14 A	3124-3134	1 - 11	11
B	1345-1360	1 - 16	16
EW 15	1361-1377	17 - 1	17

Run No.	Film count	Regist No.	Sheet No.
EW 16	4102-4121	20 - 1	20
EW 17	4070-4101	1 - 32	32
EW 18	4353-4366	14 - 1	14
Total			574

for check and inspection.

3-2-3 Aircraft and equipment

The aircraft and equipment used for the survey are listed hereunder :

a) Aircraft for airborne magnetic survey

b) Magnetometer for airborne magnetic survey

c) Magnetometer for observation of daily magnetic variations

d) High-accuracy digital clock

e) Radar altimeter

f) Barometric altimeter

g) 35 mm tracking camera

h) 2-channel analog recorder

i) Doppler radar navigation system

All the equipment is devised to be synchronized by the signal coming out of the high-accuracy quartz-clock to allow easy data check during the data processing.

The aforementioned aircraft and equipment are described hereunder:

a) Aircraft for airborne magnetic survey

The aircraft used for the survey is Cessna 402 B, registration No. PK-VCE, manufactured by Cessna Aircraft Company (See Fig. 16).

It is equipped with twin engines, normally capable of carrying

10 persons. The aircraft remodelled for a crew of 4 persons, durable for continuous 6-hour flight at a speed of 350 km per hour. Besides, it is equipped with a tail stinger of about 2 m length for airborne magnetic survey.

Originally, a Cessna 402B, equipped with Doppler radar and radar altimeter, registration number PK-VCD, was intended for use in the survey. However, there happened a landing accident during the test flight at Jakarta owing to the disorder of the landing gear causing damage to the body of the aircraft. As a substitute, therefore, the same type of aircraft, registered number PK-VCE, was used as stated above although it was not equipped with Doppler radar and radar altimeter.

b) Magnetometer for airborne magnetic survey

The magnetometer used for the survey is Gulf Mark III magnetometer. The Gulf magnetometer is a fluxgate instrument for measuring variations in earth's magnetic field with a resolution of 1 gamma. The fluxgate magnetometer makes use of a ferromagnetic element of such high permeability that the earth's field can induce a magnetization that is substantially proportionate to its saturation value. If the earth's field is superimposed upon a cyclic field induced by an alternating current in a coil around the core, the resultant field will saturate the core at each half cycle of the current flow. The phase in each energizing cycle at which saturation is reached depends upon the sum of difference between the ambient field and the strength of the imposed alternating field.

In practice, two parallel cores are aligned with their axes in the direction of the earth's field. Identical primary windings in series magnetize the two cores with the same flux density, but in opposite directions since their coil windings are opposite around the respective cores. Thus, at any given point in this energizing cycle the earth's field reinforces the field set up by one coil and opposes that of the other. In the Gulf Mark III airborne magnetometer, a compensating coil, operated by any unbalance in the two coils, cancels the unbalancing effect of the ambient field. The current flowing through this coil is recorded on a self balancing moving type potentiometer recorder, and being proportionate to the ambient field, supplies a precise measure of the amount of the field.

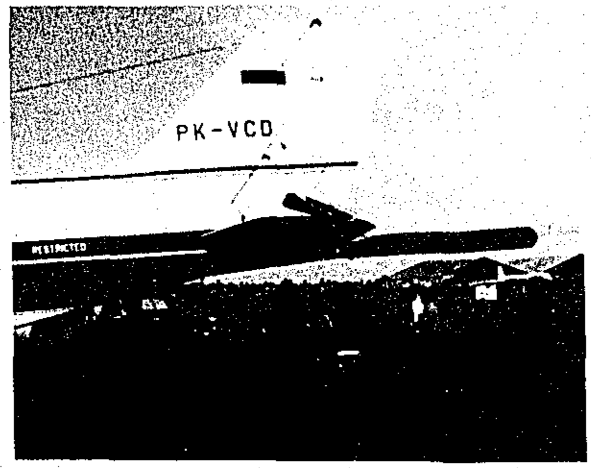
The orienting system automatically keeps the measuring element described above parallel with the earth's total magnetic field, by employing the output of two fluxgates on the support platform to actuate orienting servo systems.

The head which includes the detecting element is installed in a tail stinger on the rear of the aircraft (See Fig. 16).

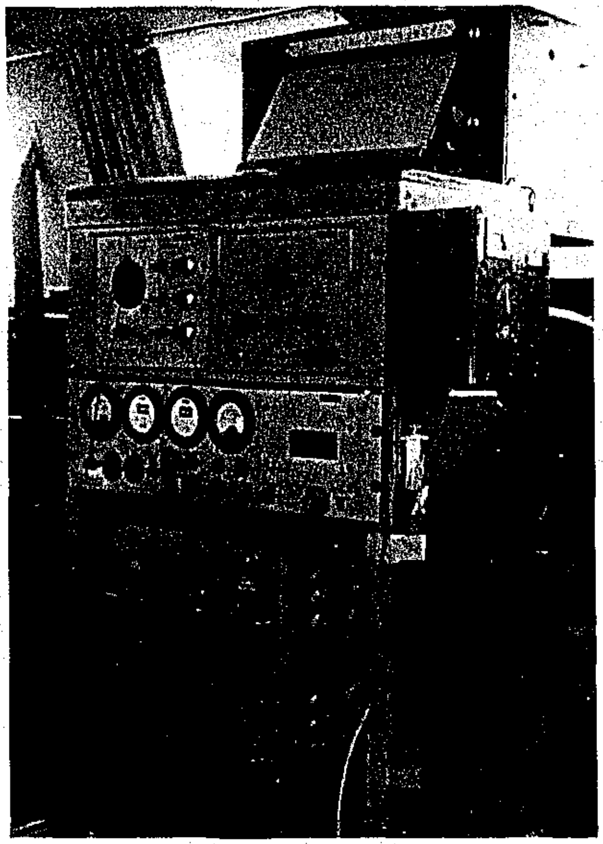
c) Magnetometer for observation of daily magnetic variation

The magnetometer used for the survey is Gulf fluxgate type magnetometer with accuracy of 2 gammas. It is used for dual purposes; the one purpose is to correct the magnetic values obtained from the

Cessna 402-B



Stinger (immediately after accident)



Fluxgate Magnetmeter Gulf Mark III

Fig. 16 Aircraft and equipment for airborne magnetic survey airborne survey through ground observation of the daily variations of magnetic field, and the other is to watch any possible magnetic storm which may arise during flight.

d) High-accuracy digital clock

A Seiko quartz-clock to be used not only for time indication but also for pulse output at intervals of 5 seconds. By signal to be issued every 5 seconds, time mark is put in the analog recorder and tracking camera. In data processing, analog record, tracking film and daily magnetic variation record can be checked at the synchronized time by use of the time mark.

e) Radar altimeter

Originally, the use of the Honeywell radar altimeter was planned for the survey. The available range of altitude by this altimeter ranges from zero to 5, 000 feet. The radar altimeter serves for constant check of the altitude during flight and the checked result is recorded by the Hewlett Packard anglog recorder.

f) Barometric altimeter

The barometric altimeter is used to keep a constant barometric altitude for the navigation of the aircraft. The aircraft navigated at such unchanged altitude of 2, 000 m for the survey.

The barometric altitude was recorded on the 8 mm film every 5 seconds by use of the 8 mm camera.

g) 35 mm tracking camera

The NAC 35 mm strip camera of ST-1000 type is loaded on the aircraft to determine the flight path.

The camera is of light weight and parashock construction, being characterized by the following features:

1) Changeable film speed

2) Remote-controllable

3) Counter to check consumed number of film

4) Two independently operated fiducial marks

5) Automatic power disconnecting system in case of film breakage

6) 400-ft. film length

The camera is mounted under the rear seat of the aircraft.

h) 2-channel analog recorder

The analog recorder of Hewlett Packard 7100 B was used. The magnetic value is recorded by setting the full scale of 500 gammas. The recorder is devised to record fiducial marks at an interval of 5 seconds for the synchronization with the other data available.

i) Doppler radar

The Doppler radar system of Bendix DRA-12C was initially proposed for use as the navigation system.

In order to lead the aircraft to the proposed survey line, such factors as survey line length, and flight direction are preset into the computer. Then, the deviation between the calculated value and the signal from the Doppler radar comes to the panel at the pilot seat.

From the Doppler radar and computer, the along-track, corresponding to integrated distance in the flight direction, and the cross-track, equivalent to deviation from the established survey line are obtained. The along-track signal is marked as a pulse signal, every mile of flight, on magnetometer analog record, tracking camera film and radar altimeter and barometric altimeter records. The cross-track output is recorded by the analog recorder to serve as the supporting data to determine the flight path.

3-3 Survey flight and data processing

The Cessna 402 B aircraft for airborne magnetic survey, installed with equipment at Kemayoran airport, Jakarta, was treated by compensating work of aircraft magnetization at Panarung airport, Palangka Raya.

After adjustment of compensating magnetization by use of tri-axial coil, the relationship between aircraft facing direction and magnetic value became as follows :

South-facing	42, 763 gammas
North-facing	42, 766 gammas
East-facing	42, 750 gammas
West-facing	42, 746 gammas

Survey flight began from the north-west part of the survey area, which is included within the range contoured with comparatively high accuracy in the topographic map of 1/250, 000 scale.

Data processing work was carried out at the field shop and the darkroom was provided near the air base.

The tracking film was charged at a speed of 2 mm per second, with due consideration enabling to set the reduced scale of film rolling direction at about 1/40, 000, since the aircraft speed is rated at about 110 knots. The flight path map was prepared in accordance with the following procedures.

Namely, after finish of daily flight, prompt action was taken to develop and dry up film on the same day. Then, the fiducial marks were transcribed into the aerial photographic mosaic(at a scale of about 1/40, 000) and finally into the topographic map of 1/250, 000 to be used as the flight path map. By reference to this map the following flight schedule and the need for additional survey line were reviewed.

Observation of daily magnetic variations was made at Panarung airport. In the daily magnetic variation record, no magnetic storm causing conspicuous magnetic change was not observed during the survey flight.

The standard magnetic value observed at the setting point of the ground magnetometer was determined at 42, 260 gammas. Any time change to this standard value was read from the analog record to prepare the correction table of daily magnetic variations. The magnetic value observed by flight was corrected by use of the correction table prepared as above, and regarded as the local variation of magnetic value not including time effect of magnetic field.

The data by flight, after daily magnetic variation correction, were transcribed into the flight path map every 25 gammas, in accordance with the fiducial marks, and the preliminary total magnetic map was thus prepared.

Analog magnetic data and flight path data from the field survey were changed into digital by use of the digitizer in Japan, and recorded into magnetic tape and data card finally to prepare the flight path map and the total magnetic intensity map through electronic computer.

3-4 Survey results

The airborne magnetic survey presently reported, as shown on PL. VI, comprises 49 effective survey lines covering 3, 606 km of effective survey line extension flown over the northwest and central parts of the survey area, the details of which are shown in Table 7. A total magnetic intensity map has been compiled to represent the results of the survey on PL. VII, which indicates the following tendencies in the magnetic anomalies observed in this survey area.

Table 7 List of effective flight lines

Line	Length (km)	Line	Length (km)	Line	Length (km)
T- 1	80.8	T- 18	67.7	T- 35	69.3
2	61.2	1019	66.5	36	60.0
3	42.7	20	70.1	2037	59.0
4	88.9	21	59.3	38	58.5
5	77.0	22	71.3	39	58.7
6	50.6	23	76.1	40	57.3
7	70.0	24	75.5	41	59.8
8	68.8	25	75.8	42	110.0
9	73.4	26	73.7	43	110.0
10	80.6	27	71.5	44	35.7
11	84.9	1028	69.6	45	76.7
12	79.7	29	72.4	78	110.0
13	82.3	1030	73.3	80	110.0
14	75.4	31	73.5	81	110.0
15	76.7	1032	65.5	84	85.0
16	78.2	1033	60.8		
1017	71.3	34	70.9	Total	3,606.0 km

a) Northwest area

The magnetic contour of this area trends in east-west direction predominantly and the magnetic value tends to increase from north to south, ranging from about 41, 700 gammas in the north to about 42, 100 gammas in the south. In the north, magnetic gradient is about 50 gammas/10 km and magnetic anomalies show most frequently gradual changes in long wave length while in the south magnetic gradient is about 100 - 200 gammas/10 km and magnetic anomalies of short wave length are typically distributed in east-west direction.

b) Central area

The magnetic contour of this area predominantly trends in northeast-southwest direction and the magnetic value is 41, 700 - 42, 000 gammas.

The data obtained in this year will be processed together with the results from the following survey.