REPORT ON GEOLOGICAL SURVEY OF CENTRAL SULAWESI, INDONESIA

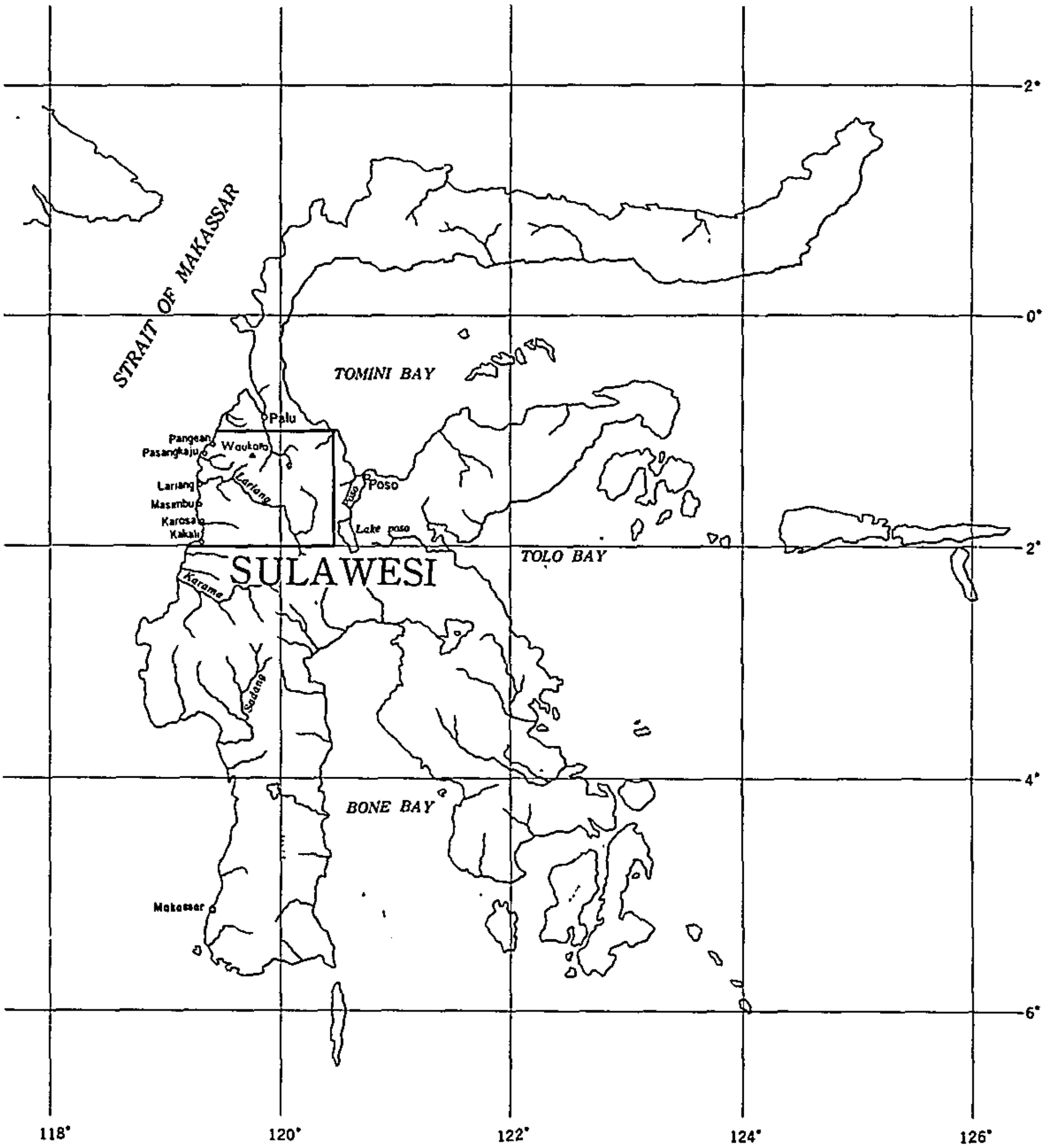
Vol. II

Part 1. AERIAL PHOTOGRAPHY
Part 2. PHOTOGEOLOGY
Part 3. GROUND CONTROL SURVEYS

March 1971

OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN



Location Map of

Sulawesi NO.4 Block

CONTENTS

Aerial photography for topographic mapping and geological survey was conducted in connection with survey on mineral resources in Central Sulawesi, the Republic of Indonesia. The aerial photography team, organized for this purpose, began to work on Sulawesi Island from September 26, 1970 and completed it on October 27, 1970.

1. PHOTOGRAPHED AEREA

The photographed area, covering the entire project area of about 14, 160 km^2, is bounded by the following grids;

Northern margin	latitude 1° south
Southern margin	latitude 2° south
Eastern margin	longitude 120° 28' 27.79"
Western margin	western coastal line of the Middle Sulawesi

2. FLIGHT PLAN

2-1 Airport

The airport as the base of photography was pre-determined to use Palu airport which is located in the northern part of the project area, according to the report prepared by the preliminary survey team.

2-2 Flight Direction

Topographically, the project area was divided into following divisions from west to east.

a. Western coastal plain division

b. Central mountainous division

c. *Fossa Sarasina division*

d. Eastern mountainous division

The central and eastern mountainous division and Fossa Salasina division include mountainous ranges with the elevation of over 2,000m extending the N-S direction.

In view of the above mentioned topographic features, the flight line was decided to set the N-S direction to permit the airplane to make the flight at the same height, and to keep the photographic scale constant. Furthermore, another factor determining this flight direction was that there was no effect of the West Wind because the project area is located near the equator.

In addition to the N-S direction of flight line, four other tie lines were planned to set; three lines of the E-W direction of near northern margin, central division and southern margin of the project area, and one line extending the NNW-SSE direction along the Palu River, in consideration of the convenience of aerial triangulation for compiling topographic map.

2-3 Selection of Aerial Camera

Reflecting upon the service ceiling of the Aero-Commander and the fact that the topography is characterized by mountains with the elevation of over 2,000m, the RC-9 Camera with a focal length of 88mm was selected to use for photography on the scale of 1/40,000.

2-4 Flight Altitude

In this project area where difference in elevation between the western coastal plain division and the central mountainous division is over 2,000m, flight altitude must be changed in each line in order to keep scale of the said photo constant. Then, it has been determined to make a flight between 4,000m and 5,300m high in each line.

3. EXECUTION OF PHOTOGRAPHY

3-1 Airport

The Palu airport was used for the base of photography as planned.

3-2 Equipments

a. Aerial Camera

Name: WILD RC-9 Camera

Lens; Super Aviogon

Focal length; 88mm

Filter; Minus Blue

b. Film

KODAK Double-X

c. Airplane

Aero-Commander CF-ULD

3-3 Photography

As scheduled, 23 lines of the S-N direction and 4·tie-lines were photographed.

a. Length of lines

N-S line: Approx. 2,310 km

Tie line: Approx. 650 km

Total length: Approx. 2,960 km

b. Scale

   1:40,000 on an average

c. Over-lap: 60-75%

d. Side-lap: 30-50%

e. Exposure: F 5.6 1/200

f. Navigation: Doppler Radar Method

4. WEATHER CONDITION

Weather condition was not so favourable for photography as it had already been at the outset of the West-Monsoon season. However, most photographies covering 2,390 km in length were taken on fine days, and rest of such kind was shot on cloudy days.

5. FILM PROCESS

The exposed film was immediately developed and printed on the spot and utilized as materials for geological and ground control surveys.

CONTENTS

Appendix

List of Figures

List of Table

List of Attached Maps

1. PROCEDURE OF WORK

1-1 General Procedure

Photogeological investigation is one of the geological survey methods and is effective for general and regional geological mapping as the preliminary process for the detailed study of geology. This method is performed through the process of study of existing geological data, interpretation of airphotographs and observations and checking in the field.

Photographic elements such as tone, tonal texture, color, linear pattern, drainage pattern, microtopography and surface shape and so on, are interpreted in order to obtain informations concerning the lithological character and the geological structure by using stereo-paired airphotographs.

Though a specialized photogeological working process has not been fixed, the results strongly depend on the quantity of the existing data and the obtainable photogeological informations which also depends on the purpose of investigation, the natural characteristics of the investigated area and on the experience of the interpreter. These factors also affect the ratio between the laboratory and field work.

The following operation flow is generally adopted in order to perform the photogeological investigation effectively as shown in Fig. 1.

A brief outline of photogeology is described in the appendix.

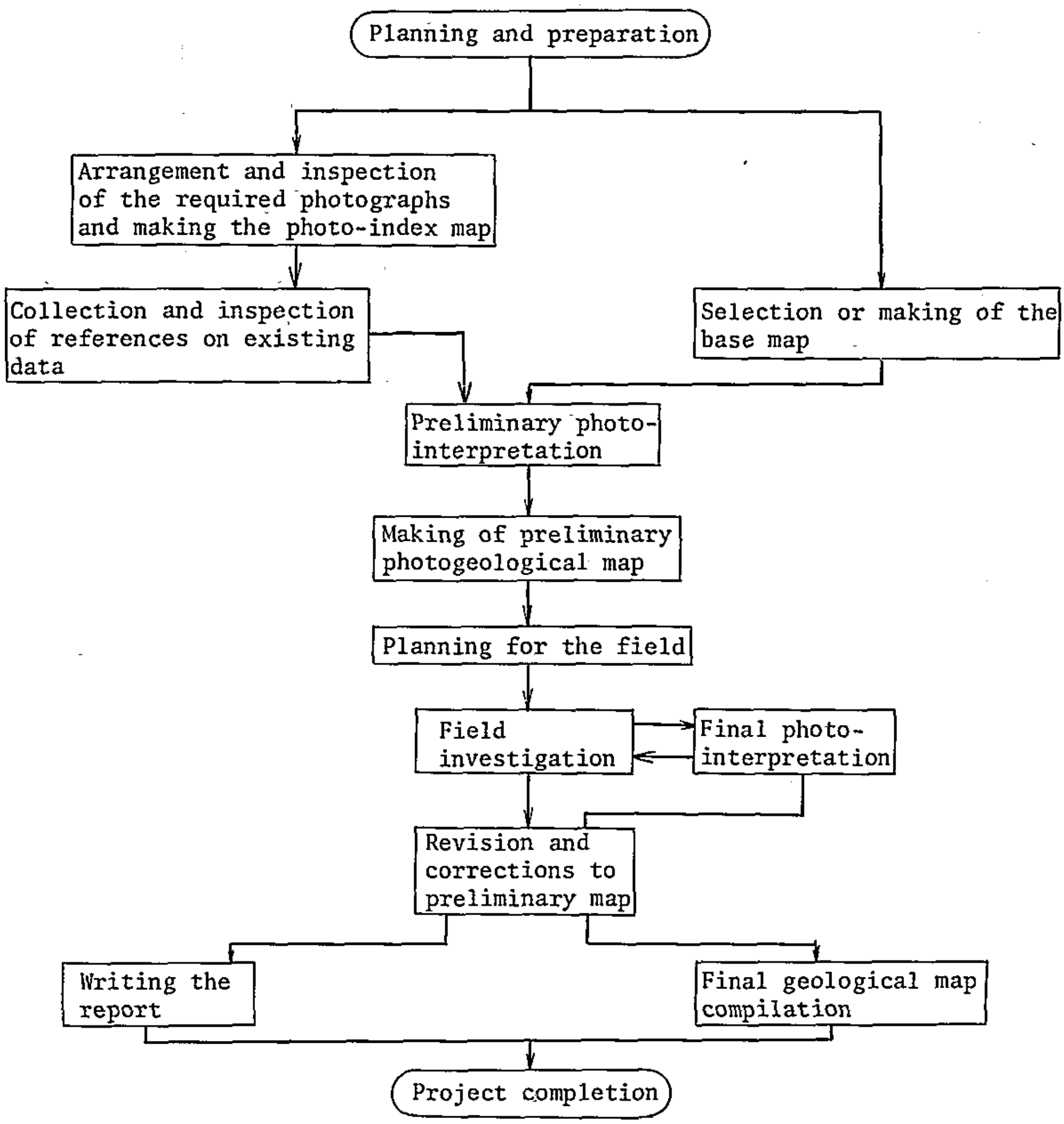


Fig. 1. General flow chart for photogeological investigations.

1-1 Procedure in this Project

The area covered by this photogeological investigation occupies the below mentioned area of approximately 14,160 Km^2.

the northern margin latitude 1° south

the southern margin latitude 2° south

the eastern margin longitude 120° 28' 27.79"

the western margin western coastal line of the Middle Sulawesi

The following airphotographs and topographic maps were available for this work.

Photographs(cf. Vol. II Part 1. Aerial Phtography)

Date of photography	; 1970
Scale of photography	; 1/40,000
Number of contact prints	; 1,000

Topographic Map

Date issued	; after 1957
Scale of map	; 1:250,000
Number of sheets	; 1
Issuing organization	; A.M.S.

This work was executed in Tokyo during the period from December 1970 to March 1971 by the geologists of the Kokusai Aerial Surveys Co., Ltd. Before and during this photogeological interpretation, the aerial phtographing, the field geological investigation and the aeromagnetic surveys were carried out by other investigation teams. The geological route-maps prepared by the field geological investigation team and the interim results of aeromagnetic surveys were used for this geological interpretation work.

A systematic regional geological investigation has not been carried out in this project area, since fragmentary descriptions and sparse geological maps of small scale were the only data available.

References on existing geological data concerning the work are listed in the appendix.

As shown in Fig. 2., this working process is slightly different from the general flow shown in Fig. 1. in some respects as follows.

1) The topographic map available was not suitable for this work due to the small scale of 1 : 250,000, therefore uncontrolled photomosaics of 1 : 100,000 scale were complied from new airphotographs and were used as a substitute for the base map.

2) The drainage pattern maps which were drawn from the mosaicked photomaps served as the base maps for the photolineation maps.

3) The photogeological interpretation and the field investigation were carried out independently of each other and the drainage pattern maps and the photolineation maps were performed only by photo interpretation. Obtainable data were used as described above.

In regard to this project area, the dense tropical vegetation the thick overburden, and similar-type lithological distribution made detailed interpretation difficult. Very difficult accessibility to such a vast area was very disadvantageous for field observations through which detailed information would be supplied for the photographic interpretation. Poor existing geological data also decreased work efficiency. The lack of the reliable topographic maps was disadvantageous for showing the interpreted information. The remarkable major geological structure and the characteristic topography, however, were suitable for macroscopic interpretation. The results of the work are considered appropriate to the extend technically feasible in photogeology under such situations.

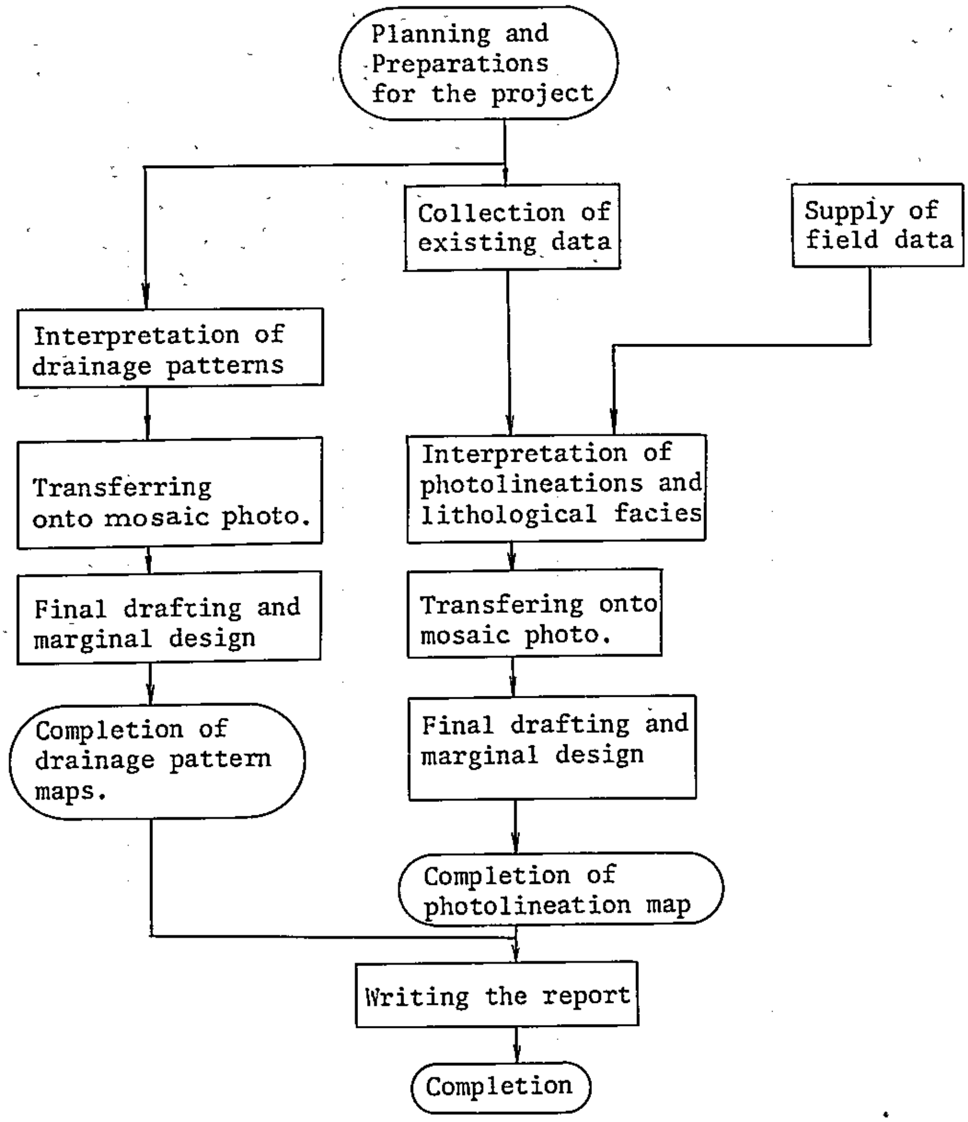


Fig. 2. Flow chart of photogeological interpretation in this project

2. GENERAL TOPOGRAPHY

The central part of Sulawesi Island can be divided roughly into three major tectonic zones by the geological structure trending in the N-S direction. These are called the "Kolonodale Zone", "Poso Zone" and "Palu Zone" from east to west(Fig. 3.).

Palu Zone and Poso Zone are separated by the N-S trending faults and graben(thought it is not photogeologically interpreted remarkably) called the "Tawaëlia Graben". The western Palu Zone is further divided into two blocks by the fault zone called "Fossa Sarasina – another name:Palu Fault", which elongates from Palu Bay to the Gulf of Bone.

This project area distributes mainly in the Palu Zone and includes the western part of the Poso Zone, and can be divided topographically as follows (Fig. 4.):

(I) Western coastal Plain division

(II) Central mountainous division

(III) Fossa Sarasina division

(IV) Eastern mountainous division

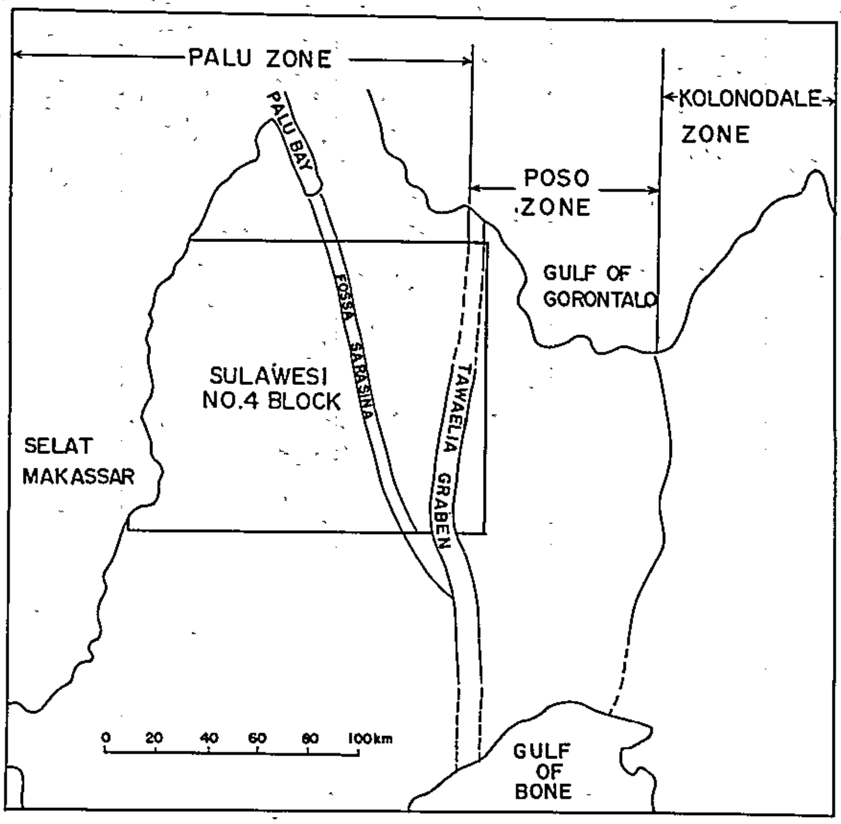


Fig.3. Structural Belt in Central Sulawesi.

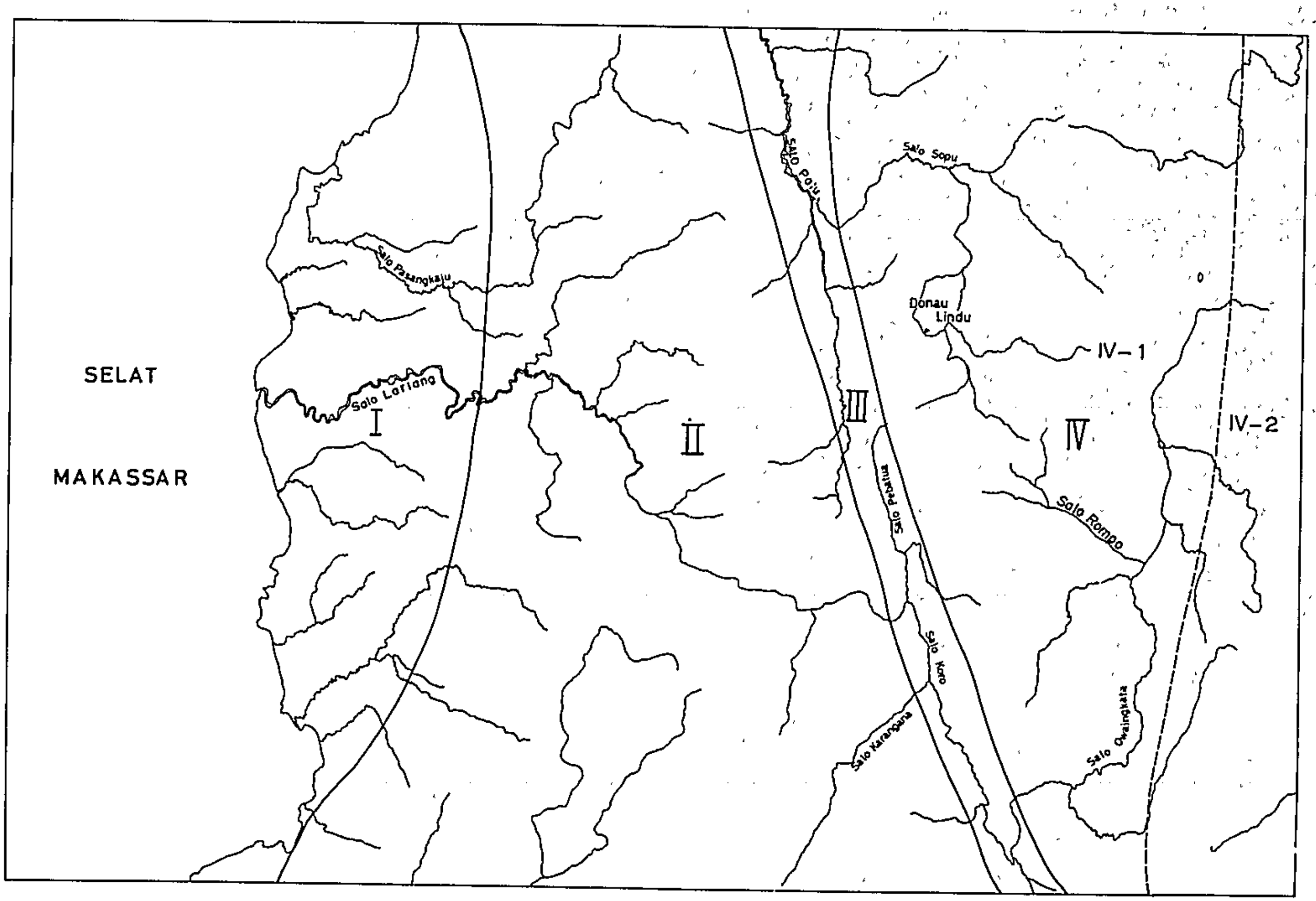


Fig. 4 Topographic Division of Sulawesi No.4 Block

I Westerncoastal Division.
II Central Mountainous Division
III Fossa Sarasina Division
IV Eastern Mountainous Division
IV-1 Western Sub-division of Median Line
IV-2 Eastern Sub-division of Median Line

2-1 Western Coastal Plain Division(I)

A wide alluvial Plain is located between the midstream area of Salo Pasankaju, Salo Tike and Salo Lariang in the western part of the project area and the western coastal line. This alluvial plain ranges from the northern edge to the southern edge of this project area with a 30 km width at the maximum and less than 5 km wide at the northrn and southern edges.

This division is the alluvial plain which consists of the gravels, sands and clay derived from the central mountainous division(II) and forms a very flat plain 50 m in elevation. For this reason, the rivers flow down this plain with considerable meandering and many oxbow lakes and stream scars are recognizable with a remarkable difference in vegetation covering along the present river course.

It is believed that swamps are distributed in some parts in this division such as the northwest part of the project area, the Salo Pasangkaju catchment area, the downstream area of a nameless river located south of Salo Pasangkaju, the downstream area of Salo Lariang and the downstream area of a nameless river flowing into the sea near Dapuran. In this low and flat plain, the hills with the monadnock like landform which consist mainly of Tertiary sedimentary rocks are distributed chiefly from Kaliee to Nunu, in the surrounding area of Bulu Pondju and the northern area of Salo Pasangkaju. The coral reefs are distributed along the coast line except the estuary of Salo Lariang though which the transported materials are supplied in quantity.

2-2 Central Mountainous Division (II)

The mountainous division between the western coastal plain division and Fossa Sarasina is consisted mainly of the older rocks such as granitic rocks, gneiss, slate etc., and forms the N-S trending core zone of the mountain range 300 m and 2700 m in elevation.

(II-1) : The western part of this division shows small topographic relief and remarkable fine and close drainage patterns. These patterns are arranged remarkably in the NE-SW direction and oblique to this direction. These facts and the existing data suggest that this western part may be consisted mainly of Tertiary sedimentary formations.

(II-2) : The southeastern part of this division up to the midstream area of Salo Karangana and the up to the midstream area of Salo Lariang are consisted mainly of the older rocks such as slate and gneiss, and shows large topographic relief and also has the relatively rough drainage pattern(Fig.12.). The mountain slope shows a generally smooth surface and has been distinctively utilized for orchards or vegetable gardens.

(II-3): The northeastern part of this division, such as the area along Fossa Sarasina and the southern part of this division which is located at the east side of the Tertiary zone, has large topographic relief and dense feather-shaped drainage patterns(Fig. 11.). These areas are believed to be consisted of granitic rocks or gneiss. Though there is little topographic difference between granitic rocks and gneiss, generally the area of granitic rocks shows fine and long feather-shaped drainage patterns, and the area of gneiss shows relatively rough drainage patterns.

In the central mountainous division, besides the topographic difference due to the lithological condition, the characteristic topography which is controlled by geological structures, especially by fault systems, can be interpreted easily. The remarkable photo-lineament interpretable along the Salo Lariang is estimated to indicate the sheared zone and a part of this was confirmed by the ground geological investigation.

Also the remarkable linear arrangements of the drainage patterns are recognizable in this division, especially in the sourthern part in the oblique direction to Fossa Sarasina.

Thus, in the central mountainous area, the present topography has been formed under the control of the geological structure and the lithological character. Photo interpretation of the geological structure is easier than that of the lithological units in this division.

2-3 Fossa Sarasina Division (III)

The V shaped linear valley which elongates from Palu Bay to the Gulf of Bone along the Salo Palu, Salo Pebatua and Salo Koro is considered to be formed by erosion and dissection along the fault zone — Fossa Sarasina (Fig. 3. and Fig. 5.).

The structural valley elongating along Fossa Sarasina is wide in the Palu Bay side and narrow in the Gulf of Bone side.

It can be observed that the steep cliffs consisting of granitic rocks or gneiss at both sides of the valley, and the small fans consisting of debris derived from the hinter mountain have been formed along the skirt of steep cliffs.

This division has been formed not only by a single long elongated fault but also by many faults ranging roughly parallel to each other. The fault topography oblique to Fossa Sarasina and the step fault topography are observed notably in both divisions of this valley.

2-4 Eastern Mountainous Division(IV)

The eastern area of Fossa Sarasina consits of Granitic rocks, gneiss, Tertiary sedimentary rocks, lake deposits etc., and form a mountainous area 2,500m in elevation. The Tawaëlia Graben and the Median Line are located in this division(Fig. 5, Fig. 7.). The remarkable geological and topographical differences are recognizable between the east side and the west side of the Median Line.

This division can be divided into the following two topographic sub-divisions.

- IV-1 Western Sub-division of the Median Line
- IV-2 Eastern Sub-division of the Median Line

2-4-1 Western Sub-division of the Median Line(IV-1)

The division between Fossa Sarasina and the Median Line is the mountainous area consisted mainly of granitic rocks and gneiss and 2,400 m in maximum elevation. In this sub-division, the drainage patterns are developed predominantly in the oblique direction to Fossa Sarasina,namely, the NE-SW direction and the NW-SE direction. The lake deposits are distributed at the eastern and southern area of Donau Lindu located at the tributary of Salo Sopu. This lake is estimated topographically as a depression, filled with surface water, which was formed by fault movement. There is a gentle sloped landform which indicates the intermediate topography between the lake deposits and the fan deposits on the right bank of the midstream part of Salo Sopu. In this division, the topographic difference between granitic rocks and gneiss is so small that the lithologic interpretation of these rocks is very difficult. Generally this division has large topographic relief all over the range. The slope is not as smooth as the slate area and has remarkably dense and long feathershaped drainage patterns.

2-4-2 Eastern Sub-division of the Median Line(IV-2)

In the eastern area of the Median Line, only the crystalline schists of the Poso Zone are distributed. Though it is supporsed that lithologically identical crystalline schists are distributed all over this sub-division, there is a little topographical difference between the northern part and the southern part of this sub-division.

a) The area between the northern part of this sub-division, up to latitude 1° 45' south, about 30 km long in the N-S direction, has generally high elevation. But the mountain slope shows a remarkably gentle and smooth surface and is poor in topographic relief, similar to the slope of a volcano.
The drainage patterns developed on the mountain slope are roughly parallel to each other and are similar to that of the volcano-slope (Fig. 9.). In the northeastern part of this sub-division, many parallel fault scarps formed by the fault movements in the later stage, elongate perpendicularly to the dipping direction of the mountain slopes.
Many small lakes, which seem to be relatively shallow, are distributed in the small hollows located on the mountain slopes though they are not as many as in the southern part of this division.

b) In the southern part of this division, the mountain slope is poor in topographic relief similar to the northern part but is rich in fine irregularity. These very fine drainage patterns, which are distributed among the parallel drainage pattern, are so fine and dense that they are difficult to express on the drainage pattern maps (Fig. 8.). Sometimes these small hollows are filled with surface water and makes numerous small lakes in this division(Fig.16.). The western rim of crystalline schist belonging to the Poso Zone makes the steep cliffs or steep mountain slopes.

3. GENERAL GEOLOGY

3-1 Geology in the Surrounding Area of Sulawesi No. 4 Block

As mentioned before, the Central Sulawesi can be divided roughly into three N-S trending structural zones(Fig. 3.).

(1) The eastern zone is called "Kolonodale Zone" and is characterized by basic and ultra-basic igneous rocks, mesozoic limestone and chert.

(2) The central zone is called "Poso Zone" and consist mainly of the muscovite-rich epi-to meso-metamorphic cristalline schists.

(3) The western zone is called "Palu Zone" and consists of the biotite-rich granodioritic rocks, crystalline schists, and the more near-shore sediments than those of the Kolonodale Zone.

However, Brouwer(1947) indicated that the Poso Zone and the Palu Zone are separated by "Tawaëlia Graben" and the so-called "Median Line" of Central Sulawesi elongates along the west side of this sub-zone. There are different opinions about Tawaëlia Graben and the Median Line, due to the reasons mentioned in Chapter 5.

The Palu Zone, located in the western part of Central Sulawesi is divided into the west and east blocks by the fault zone called Fossa Sarasina(sometimes it is called Palu Fault) extending from Palu Bay to the Gulf of Bone. It is, however, estimated that the displacement caused by Fossa Sarasina is not on such a large scale as the Median Line because no remarkable geological differences can be recognized between the east side and the west side of the fault zone.

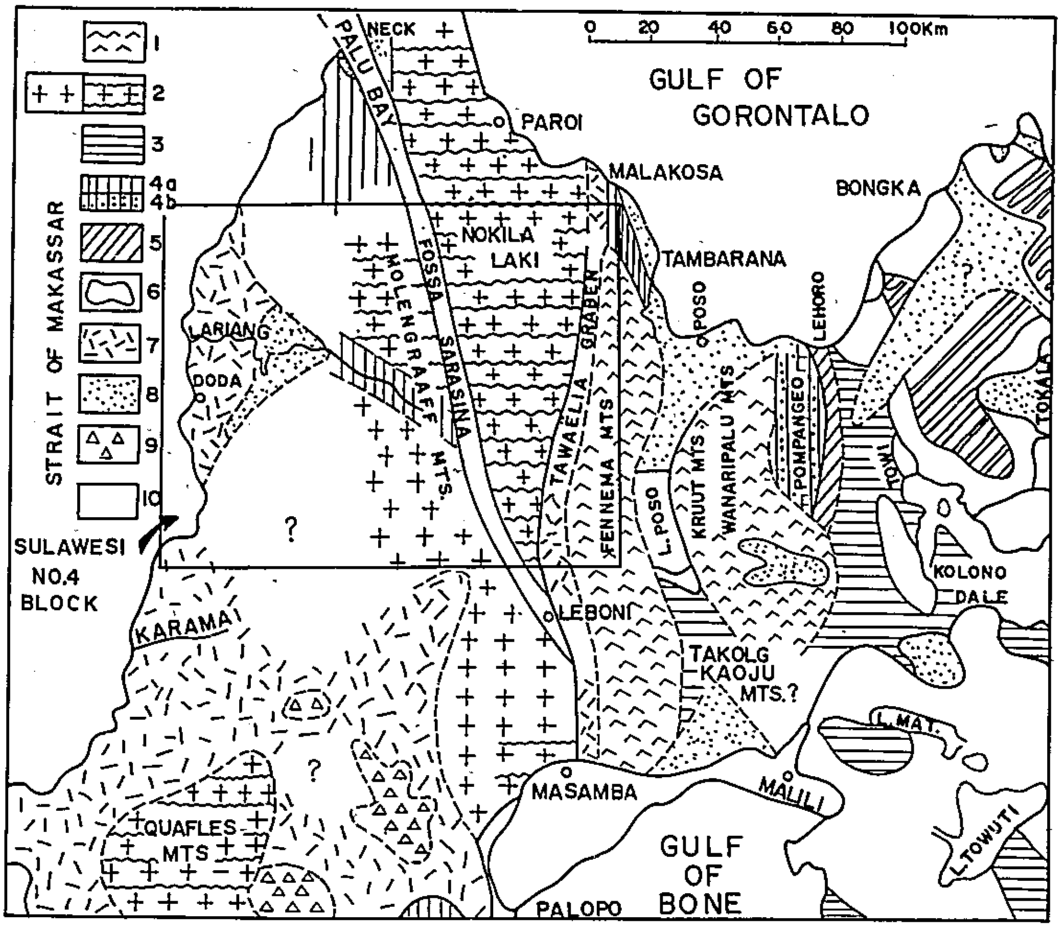
3-2 Geology in sulawesi No. 4 Block

3-2-1 Distribution

1) This project area is chiefly located in the Palu Zone, the western part of the structural belt, and partly includes the Poso Zone(Fig.5.). The schematic representation of the geological distribution and geological structures of this project area are shown in Fig. 6 and Fig. 7. The schematic stratigraphic table is shown in Table. 1.

Table 1. Schematic Stratigraphical Table in Sulawesi NO. 4 Block

Period	Petrography		Igneous Activities	Structural Movement
Quaternary	Clay, Silt, Sand, and Gravel (Al, Ta, F_1, F_2, L_2)		Andesite Dacite Rhyolite Granite Gabbro	Unconformity Fault
	Sand, Silt and Clay (L_2)			Unconformity Fault
Tertiary	Shale, Sandstone, Conglomerate, Tuff, and Tuffbreccia (T_1 - T_7)			Unconformity Fault
Mesozoic	Slate (S_1)			
Unknown	Crystalline schist (S_2) and Gneiss (Gn) (Palu Zone)	Crystalline schist (S_1) (Poso Zone)		Unconformity Metamorphism



LEGEND

(1) Crystalline schists.

(2) Plutonic ignoous rocks, gneissesand schists.

(3) Mesozoic rocks.

(4a) Tinombo-and Maroro Formation (Young Mes.-Eoc.).

(4b) Pompangeo Formation (Yong Mes.-Eoc.).

(5) Mixed belt of Peleru.

(6) Basic-ultrabasic rocks (ophiolites)

(7) Tertiary of the Palu Zone and the Tawaëlia Graben.

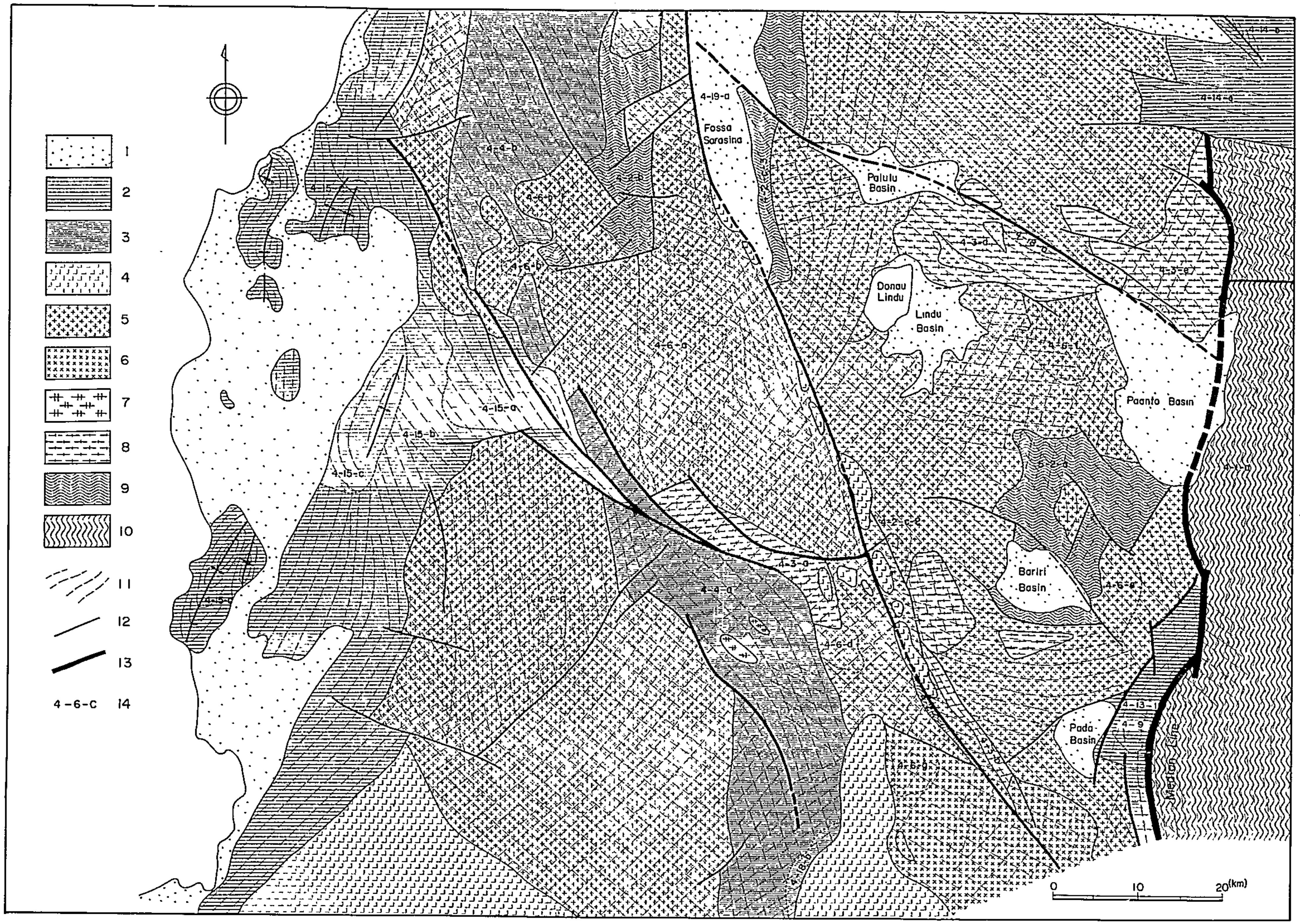
(8) Celebes Molasse and elevated coral reefs of the Poso Zone and the East arm.

(9) Plio-pleistocene Barupu tuffs.

(10) Quaternary alluvium, unknown, sea, and lakes.

Fig. 5 Geological sketch map of Central Sulawesi

(Data from the publication of ABENDANON 1915/1918, REYZER 1920, KOOLHOVEN 1932, VON LOCZY 1933/1934, BROUWER 1934, WITKAMP 1940)



1. Quaternary unconsolidated deposits
2. Tertiary sedimentary rocks
3. Mesozoic sedimentary rocks (Slate)
4. Volcanic rocks
5. Granitic rocks I, II
6. Granitic rocks III
7. Gabbro
8 Gneiss
9 Crystalline schists II (Palu zone)
10 Crystalline schists I (Poso zone)
11 Main direction of fracture traces
12 Main photolineaments
13. Photolineaments showing the Median Line
14 Location number shown in the report

Fig. 6 Simplified Geological Map of Sulawesi No. 4 Block

The basement rocks are consisted of the muscovite-rich crystalline schists of the Poso Zone, the granitic rocks, gneiss, the biotite rich crystalline schists and the mesozoic slate of the Palu Zone, and distributed mainly in the central and the eastern mountainous area of the investigated area. In this basement rock group, the gneiss, the biatite crystalline schists and the Mesozoic slates of the Palu Zone are distributed in the granitic rocks as the roof-pendant(Fig. 7.).

2) In the western investigated area, Tertiary sedimentary rocks are distributed over the basement rocks and sometimes in contact relation by faults.

The Quaternary sediments, chiefly alluvial deposits, cover these rocks unconformably.

3) In the southeastern investigated area along the west side of the Median Line mentioned in Chapter 5, the marine deposits which are consisted mainly of clayshale or volcanic agglomerates estimated as Tertiary are distributed by zones and the lake deposits cover the flat plains(e.g.Paanto Basin etc.) which are located between the Poso Zone and the Median Line.

3-2-2 Geological Structure

1) So-called Fossa Sarasina extending from Palu Bay to the Gulf of Bone has been formed by many fault systems arranged in the same direction and can be interpreted very clearly on the air-photographs.

The liparitic and andesitic rocks estimated to be derived by fissure eruption are distributed intermittently along these faults.

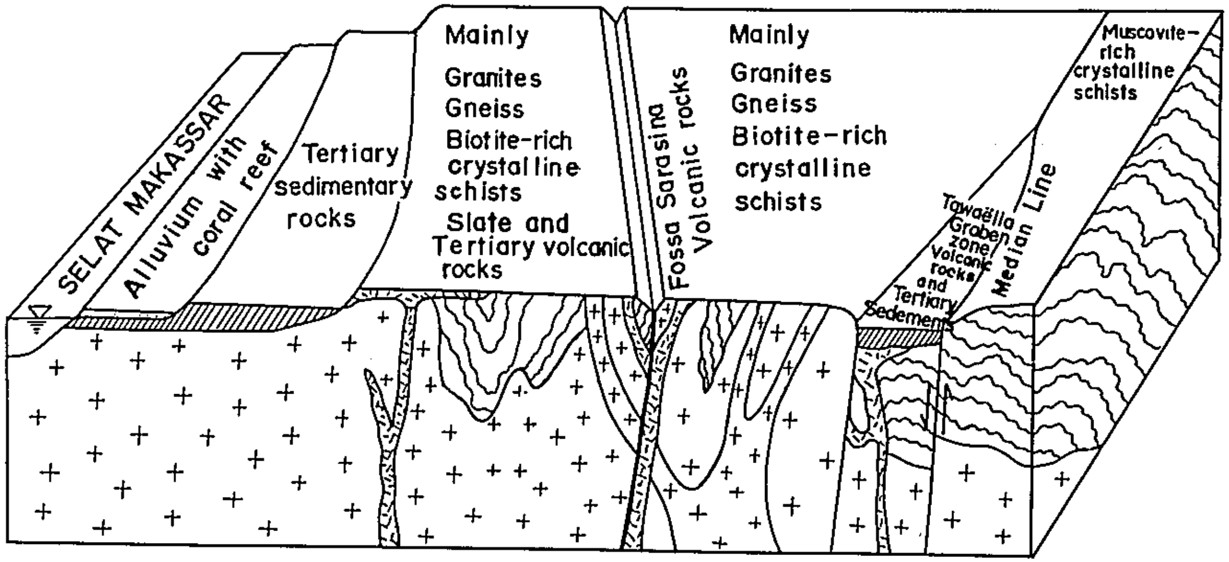


Fig. 7. Schematic representation of Sulawesi NO.4 Block
(Retouched to Fig.167 of Bemmelen: 1949)

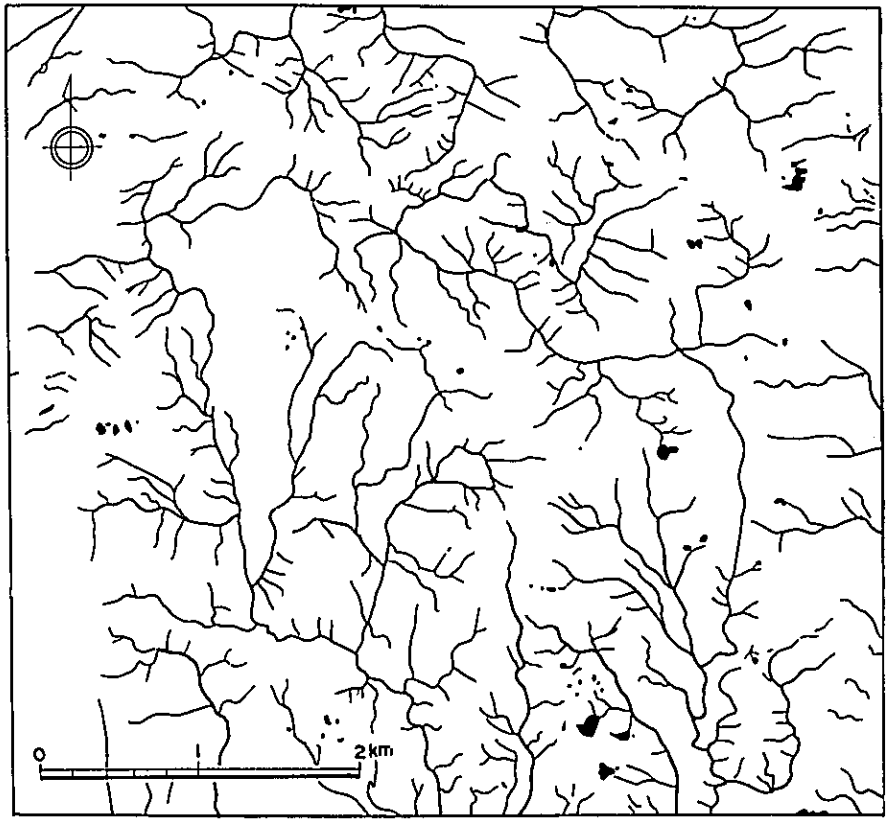


Fig. 8. Drainage pattern in crystalline schists of Poso Zone(Southern part)

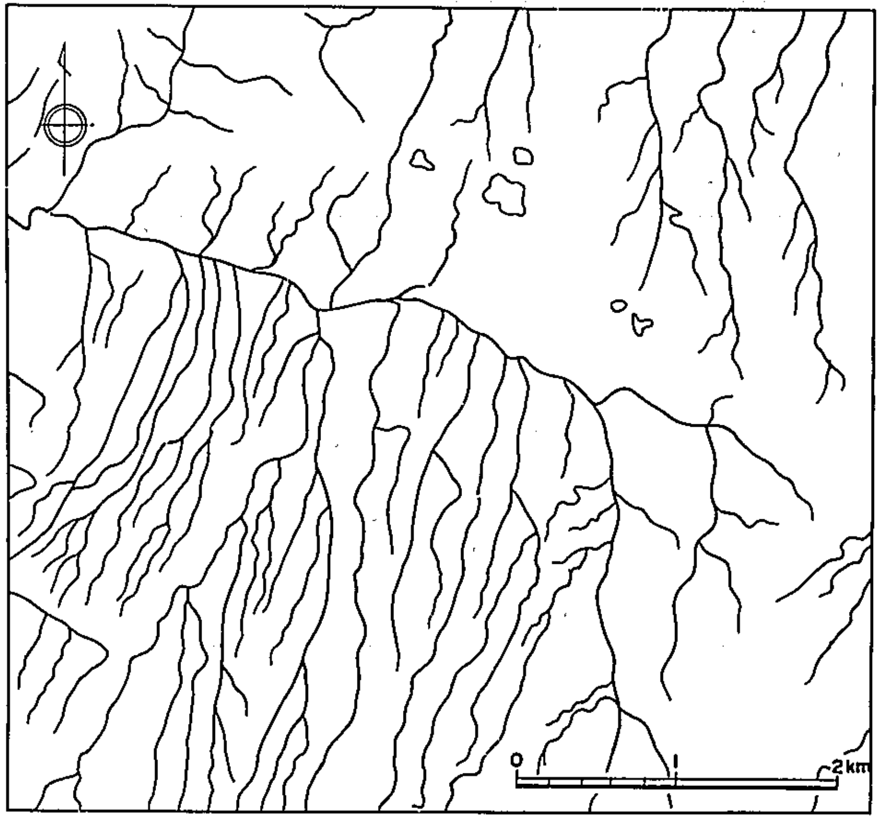


Fig. 9. Drainage pattern in crystalline schists of Poso Zone (Northern part)

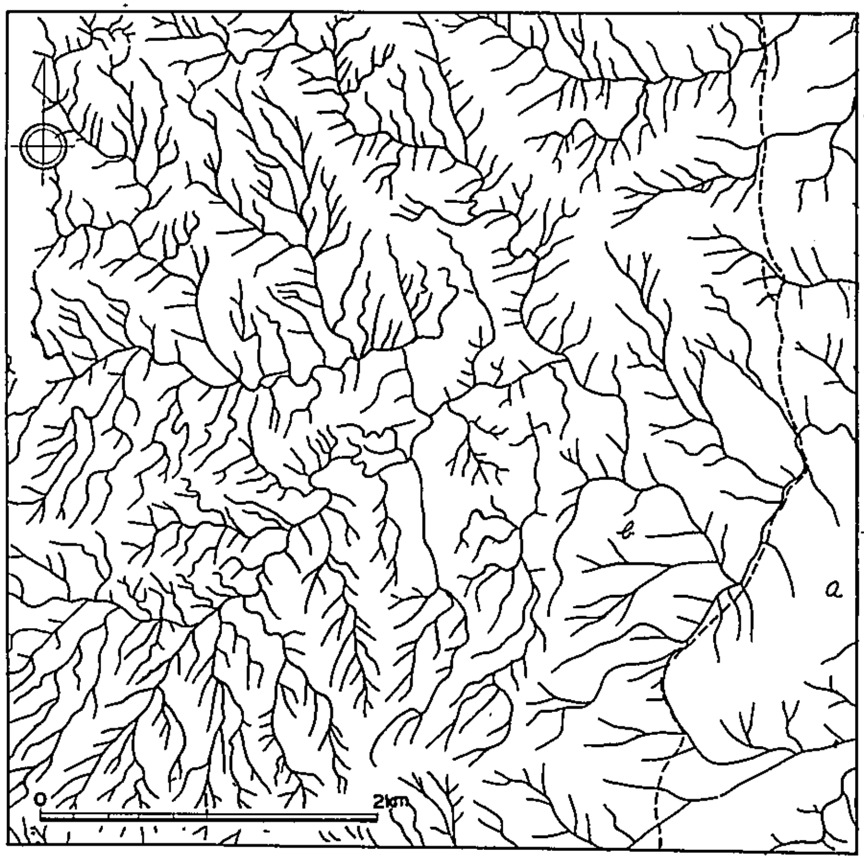


Fig. 10. Drainage pattern in granite II (G_2) area

(a) Granite (G_1) and gneiss

(b) Granite (G_2)

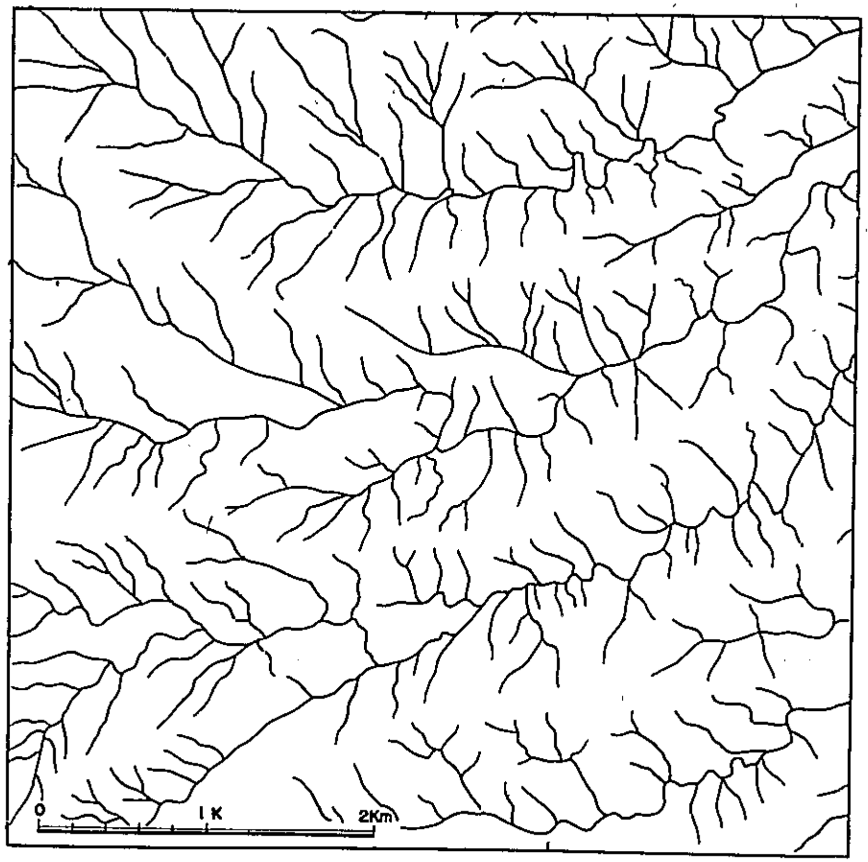


Fig. 11. Drainage pattern in granite (G_1) area.

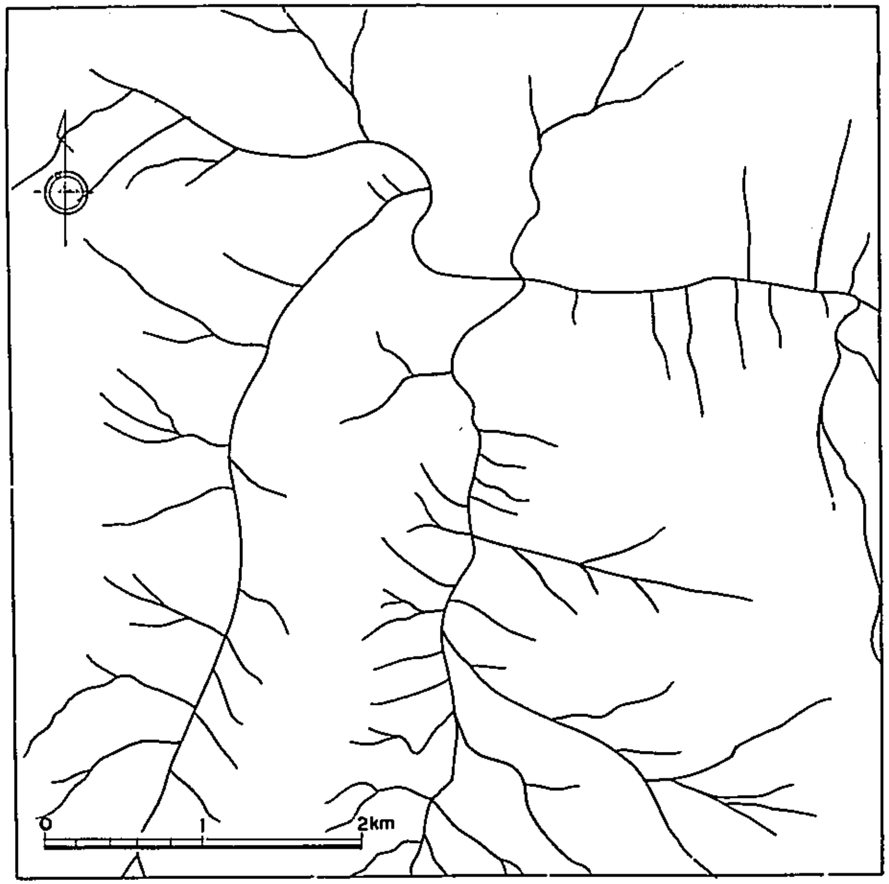


Fig. 12. Drainage pattern in slate area

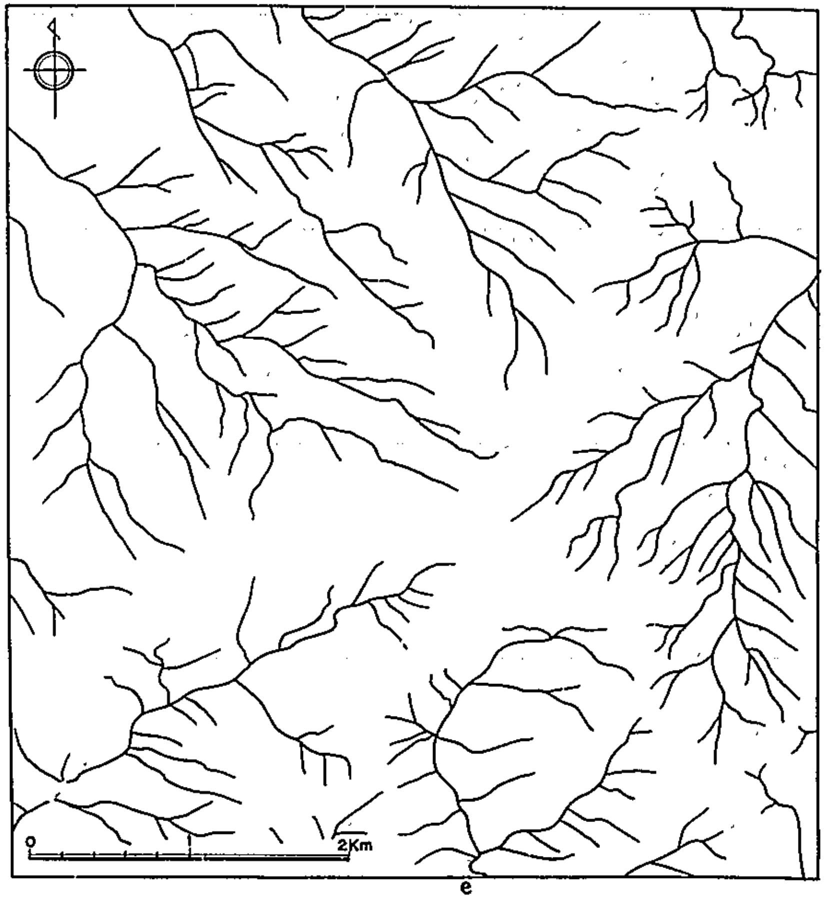


Fig. 13. Drainage pattern in gneiss area

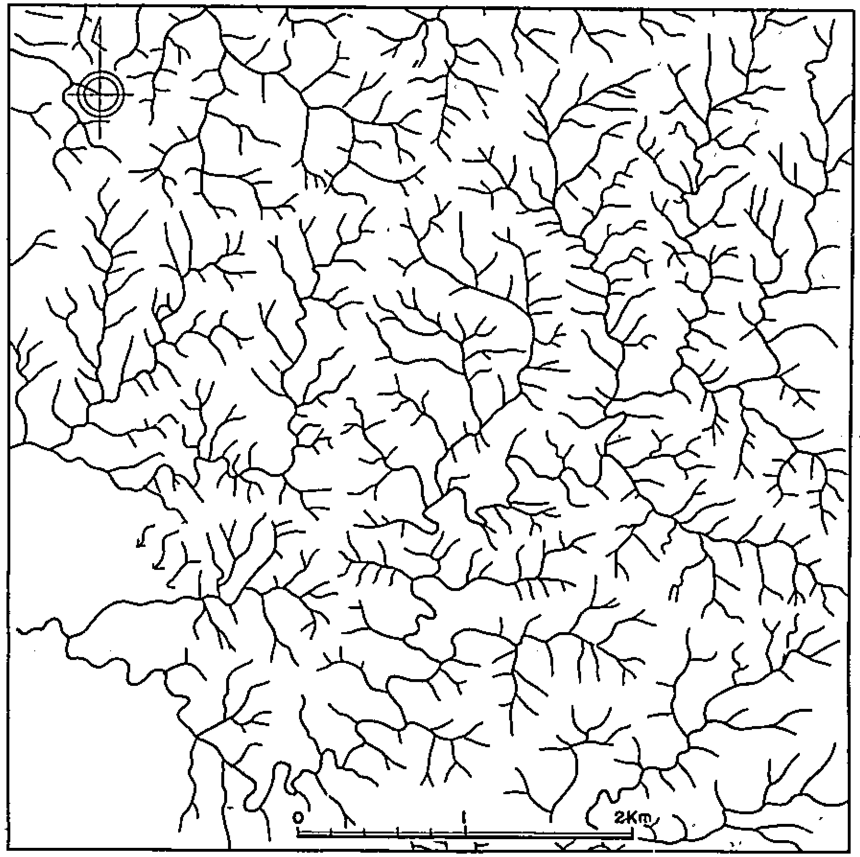


Fig.14. Drainage pattern in Tertiary area (T_5).

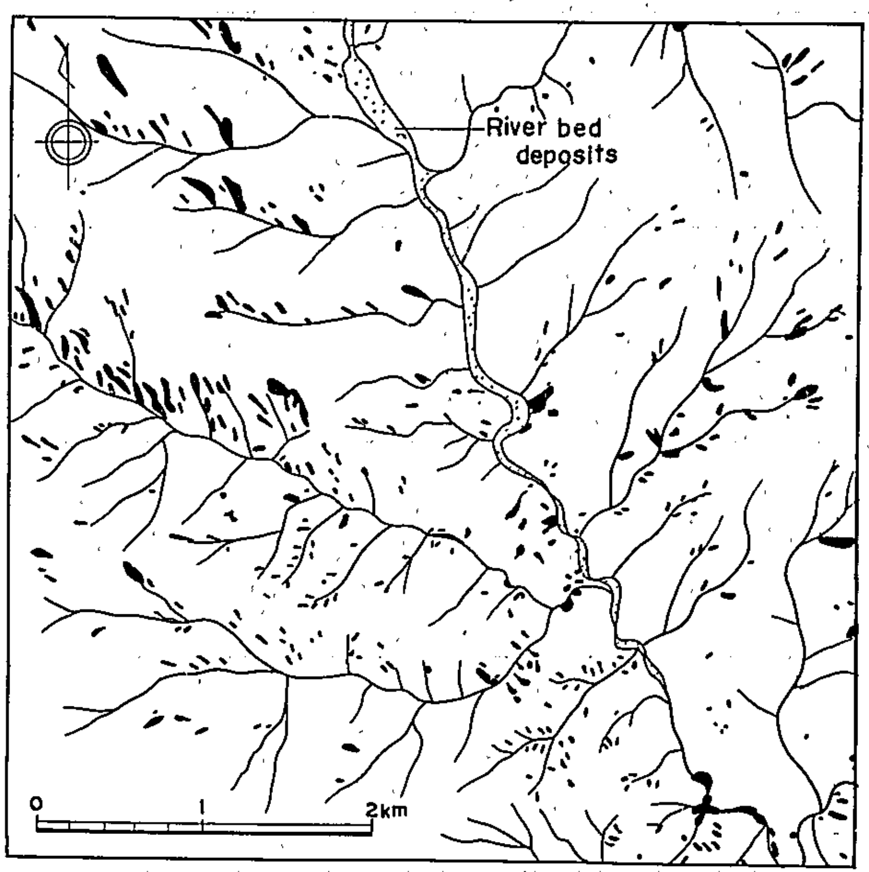


Fig.15. Drainage pattern and scars in granitic rock (G_3) area.

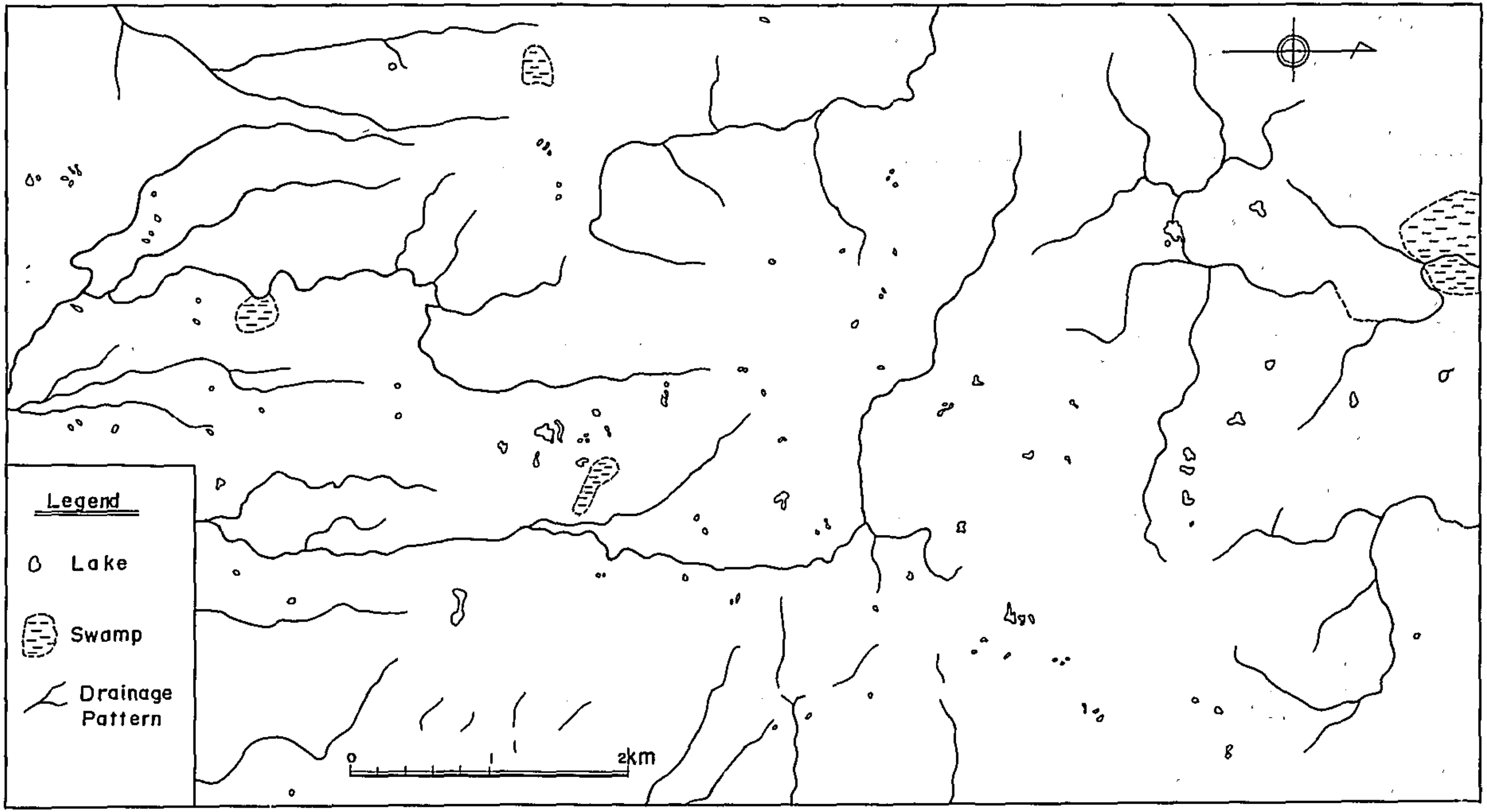


Fig.16. Numerous small lakes distributed on the schist in Poso Zone

2) In this project area, the existance of so-called Tawaëlia Graben cannot be easily recognized as indicated by Brouwer's description. As shown in Fig. 6., only the zonaly distributed marine sediments in the south eastern part of the investigated area which is consisted mainly of shale suggest the existence of the Graben. However, this Graben does not have as clear a zonal distribution and continuity as described by Brouwer(1947).

4. PHOTOGEOLOGICAL DISTRIBUTION

4-1 Muscovite Crystalline Schists in the Poso Zone(S_1)

4-1-1 Distribution

In the eastern part of this investigated area, the crystalline schists are distributed from north to south covering an area 80 km in length 17 km in width. Assuming that the marine shaly sedimentary rocks distributed on the western side of this schists zone are the sediments of the so-called Tawaëlia Graben, the muscovite-rich crystalline schists can be estimated as one of the Poso Zone described by Brouwer(1947). The existence and the lithological facies of these rocks were confirmed by the ground geological investigation along the path leading from Bomba to the east area.

4-1-2 Photogeological character

1) The northern part of the distributed area, from the northern range to around latitude 1^{o} 45", south for about 30 km has a generally high elevation. But the mountain slope has a remarkably gentle and smooth surface but is poor in topographic relief the same as the slopes of a volcano. The drainage patterns developed on the mountain slope are roughly parallel to each other and are similar in pattern as the skirting slopes of the volcano(Fig.9.). The vegetation cover is not as dense and shows a relatively light photographic tone (light grey - grey).

2) In the southern part of this area, it is clearly interpreted on the drainage pattern maps that many drainage courses, which flow down the mountain slope of this rock, are arranged in the same direction as the elongating direction of this rock body.

Though the mountain slope is poor in topographic relief, remarkably fine drainage patterns, which are so fine and dense that it is difficult to show on the drainage pattern maps, are distributed among the parallel drainage patterns(Fig. 8.).

3) The main characteristic of this area is the distribution of numerous small lakes in the area of these rocks (Fig. 16.).
It is interpreted that these lakes are topographically small hollows filled with surface water and have very shallow depth. These facts suggest that the crystalline schists have poor fractures originally and even though they may have many fractures, they may be filled with weathered or clay materials and changed into impermeable bedrock. It is estimated that the surface of these rocks is covered with weathered material of basement rocks.

4-1-3 Structure

1) As stated in 4-1-2, the parallel drainage patterns with the N-S direction are recognized predominantly in the southern half of this area.
Also the N-S trending fracture traces are predominant. These facts may suggest that this mass has erosionalbe properties along the N-S direction, and further, that the schistosity of the crystalline schists are in the N-S system macroscopically.

2) It is estimated that this rock and the granitic rocks and the undetermined marine shaly sediments which are distributed on the western side of this rock are contacted by faults because clear topographic differences are recognizable between these rocks. The fault is not only one but are at least five separated

faults (e. g. photolineaments 12, 27, 33, 37, etc.).
Many photolineaments can be interpreted also in the crystalline schists and these information suggests the existence of a fault with a N-S trend in this rock area.
The middle of the western part of this mass(eastern side of Paanto Basin) is covered unconformably by Quaternary lake deposits I.

3) In the northeastern part of this area many parallel fault scarps with a southwestern downthrown, which were formed by the fault movements in the later stage, elongating perpendicularly to the dipping direction of the gentle mountain slopes (Fig. 19.). These faults may be derived from structural movements of the fault 12. Details will be described in chapter 5.

4-1-4 Problems or Questionable Points

1) This rock body is estimated to be crystalline schists belonging to the Poso Zone based on the assumption that the marine sediments distributed in the western side of this rock body may be Tertiary sedimentary rocks of the so-called Tawaëlia Graben. As will be mentioned later, the Graben cannot be recognized clearly in this area.

2) Because the photographic tone and the erosional features of the mountain slopes in the middle part of this mass(about 5 km in width), eastern side of Paanto Basin(4-1-a), shows the intermediate character between crystalline schists and lake deposits I, it remains a questionable point in the lithological identification. However, it seems reasonable to identify this area as

crystalline schists because the elevation of this area is 200 m or more higher than the main distributing area of the lake deposits.

4-2 Biotite Crystalline Schists in the Palu Zone(S_2)

4-2-1 Distribution

The biotite crystalline schists or phyllites belonging to the Palu Zone of the west side of the so-called Median Line are distributed in the following narrow areas.

a) the upstream area of Salo Rompo in the eastern part of the project area.

b) the central middle part of the northern area

c) the surrounding area along the Fossa Sarasina.

c-1: near Sabulu located in the upper-midstream of Salo Koro.

c-2: near Labua located the downstream of Salo Pebatua

c-3: the area extending from the upstream area near Pakuli to the left bank downstream along Salo Palu

The distribution is partly confirmed by ground geological investigations in these areas. These are estimated to be distributed as the roof-pendants mass in the granitic rock body. Especially, the block along Fossa Sarasina seems to have been taken in between the complicated fault system.

4-2-2 Photogeological Character

1) The topographic characteristics of this area is recognized relatively well in the upstream area of Salo Rompo where these rocks are distributed most widely. Other areas have no such remarkable features because the distribution of these rocks is relatively small.

2) The area of the crystalline schists in the upstream part of Salo Rompo is remarkably dissected. Therefore this area is generally flat and low in elevation and shows small topographic relief and poorLy developed drainage patterns. The valleys are generally shallow and wide. The ridges are generally rounded, low and roughly flat, and show a gentle landform. In same places, bare hills are observed.

3) The block which is distributed along the southern part of Fossa Sarasina among the fault system(C-1) also has rounded and gentle mountain slopes in comparison with the sorounding rocks (these may be granitic rocks).
On the right bank of Salo Palu in the northern part of Fossa Sarasina(C-3), the schist block does not have fine drainage patterns in comparison with granitic rocks and has bare hills or poor vegetation covering.

4-2-3 Structure

1) In the upstream area of Salo Rompo(C-1), this rock mass may be bounded to the granitic rocks by many faults. In this area, the photolineaments are predominant in the NW-SE direction (e.g. photolineament 26 etc.) and that of the NE-SW direction

follows.

The fracture traces are also predominant in the NW-SE direction and the NE-SW system follows this. These facts may suggest that the direction of schistosity will be in the NW-SE direction.

2) In the upstream part of Salo Koro along Fossa Sarasina, near Sabulu, these rock masses are in the fault system of Fossa Sarasina, and are elongated in the NW-SE direction.

3) In the upper - midstream part of Salo Palu, the rock mass distributed on the right bank is separated by the NW-SE trending faults and has resulted in horizontal displacement macroscopically. The photolineaments in this mass are predominant in the NW-SE and NE-SW direction(both are obilque to Fossa Sarasina). The fracture traces also show a similar tendency to the photolineaments.

4-2-4 Problems or Questionable Points

1) Poor topographic features of this area, except for the upstream area of Salo Rompo, made lithological interpretation very difficult. Especially the interpretation concerning the area on both sides of the Salo Palu presented some uncertainties.

2) It is impossible to interprete the part where the schistose rocks intercalate with the granitic rocks alternately.

4-3 Gneiss or Gneissose Granites(Gn)

4-3-1 Distribution

Gneiss or supposed gneissose granites are chiefly distributed in the central mountainous division - eastern mountainous division.

(a) In the Salo Lariang basin, the gneiss are distributed in an area approximately 20 km in length and 4 km in width on the northern side of the slate area. Its existence is partly confirmed by ground geological investigations along the Salo Lariang and its tributaries. Since the geological structure of the southeastern extension along the Salo Karangana cannot be determined, it is estimated that the rocks may be pinched out between Salo Lariang and Salo Karangana.

(b) Along Fossa Sarasina, the rocks are distributed in an area approximately 5 km in width and 19 km in length between the photolineaments 30 and 31.

(c) The intermittent distribution of the rocks are recognizable in the eastern side of(b), namely the range 5 km east of Gimou to the southern part of the basin located upstream of Salo Rompo.

(d) These rocks are also distributed toward the ESE direction in the area ranging from the northern side of Donau Lindu to about 3 km northwest of Wuasa along photolineaments 8 and 11.

(e) These rocks are also distributed at the southern side of Wuasa Sauradopi between photolineaments 12 and 13.

These gneiss or gneissose granites are distributed in the granitic rocks(G_1 and G_2) as roof-pendants similar to the crystalline schists.

Because of the lithological and the topographical similarity between granitic rocks and the gneissose rocks, it is very difficult to distinguish these rocks photogeologically. This may suggest the possibility of the additional distribution of gneissose rocks.

4-3-2 Photogeological Character

Gneiss or gneissose granites have no remarkable photogeological peculiarity.

1) They have similar features as slate and crystalline schist.
2) The drainage patterns show the intermittent property between that of the slate with a coarse drainage pattern and the granites with dense and modified dendritic or feather-shaped drainage pattern(Fig. 13.).
3) In general, the area of these rocks have large topographic relief. The mountain composed of these rocks seem to be hard. This may be due to the unremarkable drainage distribution, the relatively smooth mountain slopes and rather rounded ridges.
4) The block(b) located between photolineaments 30 and 31 along Fossa Sarasina has rounded ridges compared to the surrounding granites.

4-3-3 Structure

1) In the block(a) located along Salo Lariang the fracture traces trending in the WNW-ESE and NE-SW direction are predominantly developed. According to ground geological investigations, the former is reflected chiefly by schistosity and the latter is perpendicular to schistosity. It is supposed that the photolineament 24 which bounds mass (a) and slate and the photolineament 23 which is developed in the mass (a), both extending NW-SE, are considered as the fault or fault-sheared zone extending oblique to Fossa Sarasina.
2) Photolineaments 30 and 31 between which the rock mass (b)

locates along Fossa Sarasina elongate in parallel with each other in the NW-SE direction and either one can be the fault system which forms Fossa Sarasina.

3) In either mass (c) and mass (d), the photolineaments and fracture traces are predominant in the parallel direction to the main trend of these masses. This fact suggests that the schistosity of these rocks are developed in the direction of predominant fracture traces according to the result in mass (a).

4) It is estimated that the photolineaments which bound mass (e) and the crystalline schists of Poso Zone, located in the eastern side of mass (e), are identified as the faults of the so-called "Median Line" which bound the Poso Zone and the Palu Zone.

4-3-4 Problems or Questionable Points

1) The fundamental problem of photo interpretation of the gneissose rocks is the difficulity of distinction between these rocks and other rocks, especially granitic rocks. Therefore, it is supposed that the gneissose rocks may occupy other areas than those shown on the Photolineation Maps. The opposite case may also be possible. That is to say, there is the possibility that the rock mass which is identified by photo interpretation and shown on the maps as gneiss may actually be granitic rocks. This depends chiefly on the poor data from the ground geological investigations.

2) At first, it was estimated that the liparitic rocks may be distributed on the gneiss in the southern half of mass (b) along Fossa Sarasina due to topographic factors, but the liparitic

rocks of this part have been omitted and changed to gneiss in accordance with the opinion of the ground geological investigation team.

4-4 Slate (Sl)

4-4-1 Distribution

(a) Slate is mainly distributed in the area extending from the upper midstream area of Salo Lariang to the upper-midstream area of Salo Karangana in the central part of the project area which is 12 km in width and 70 km in length.

(b) Slate is also distributed widely in the upstream area of Salo Pasangkaju in the northwestern part of the project area.

The existence of (a) mass was confirmed by ground geological investigations at the upper-midstream area of Salo Karangana and the upper-midstream area of Salo Lariang.

The existence of (b) mass was partly confirmed by the point ground geological investigations at the upstream area of Salo Pasangkaju. However, the (b) mass area, photo interpretation under natural conditions is impossible because the vegetation of the mountain slopes have been cut out artificially for a wide area. For this reason, the interpretation of lithological facies is very difficult. Accordingly the distinction between slate and granitic rocks or crystalline schists may be incorrect.

According to existing data(e.g. Bemmelen : 1949 etc.), slate is Mesozoic sedimentary rock and distributed in granitic rocks as the roof-pendant.

4-4-2 Phtogeological Character

Generally, since slate is distributed in the granitic rocks area, lithological distinction is relatively easy. In this project area, the interpretation is carried out easily except for a part of rock mass (b). The slate in this project area has the following photogeological character.

1) In general, the drainage pattern is poor(Fig. 12). Though the fine topographic irregularities which cannot be expressed as a drainage pattern are observable on the slate slopes, the gullies or valleys which can be expressed as a drainage pattern are few. In regard to this point, slate is similar to gneiss or crystalline schist.

2) The topographic relief is large and the ridges are rounded.

3) The weathered materials of slate is susceptible to change into soil, and moreover, since this soil is impermeable sometimes the slate areas are utilized for orchards, vegitable gardens or residential lands. For this reason, conversely the circumstances of land use can be an indication for photo interpretation of slate areas.

4) The mountain slopes is steep, and smooth but are rugged in the area and without vegitation cover.

5) Slate has a relatively light phtographic tone compared to the area of granitic rocks.

4-4-3 Structure

1) The rock mass (a) and the gneiss which are located at the northern part of (a) may be bounded by photolineaments 24 and 5. The mass (a) and the granitic rocks located at the west side are estimated as not being in contact but in intrusive relation.

2) In this rock, the fracture traces are predominant in the NW-SE direction and the NE-SW direction follows. The dip and strike of the bedding seem to be predominant in the NW-SE direction. According to the ground geological investigation the fracture traces with a NW-SE direction may reflect the strike direction of bedding or schistosity in slate. In general the bedding and schistosity of slate do not necessarily correspond to each other and also are rare to be perpendicular to each other. Therefore it is estimated that the main direction of schistosity will not be in the NE-SW direction which is perpendicular to the bedding but in the NW-SE direction. According to this idea it is estimated that the fracture traces with NE-SW direction reflects a joint system which may be perpendicular to the bedding or schistosity.

3) The photolineaments in the rock mass (a) are predominant in the NW-SE direction and one (4) is confirmed as the fault-sheared zone (solid paint on the photolineation map).

4) In the northwestern part of this mass (Salo Lariang basin) the rocks are bounded by the Tertiary formation. Though it is still obsucure whether these rocks are in fault contact y, or unconformity, it is estimated to be in unconformity in this report.

5) The rock mass (b) is chiefly bounded with granitic rocks at the western part of this mass and with crystalline schists at the eastern part. These may not be in fault relation. The fracture

traces in the rock mass (b) are predominant in the NW-SE direction as mass (a) area and the NE-SW direction is next. These facts suggest that the rock mass (b) may be roughly under the same geological condition, and furthermore, may be the northern extension of mass (a). The photolineaments in mass (b) are predominant in the NW-SE direction and NE-SW direction as fracture traces.

4-4-4 Problems or Questionable Points

1) In the upstream area of Salo Karangana, it is confirmed by ground geological investigation that the eastern part of this rock mass (a) has been changed into hornfels. It is estimated that the other parts of this mass which are under similar geological conditions to this area may also have been changed into hornfels but these are not expressed on the photolineation maps because of the lack of detailed data.

2) As was stated in 4-4-1, in the northwestern part of this project area the interpretation was difficult and somewhat uncertain because the vegetation cover of the mountain slope was cut artificially in recent ranging from the granitic rocks area, the slate area and the crystalline schists area. The next detailed ground geological investigation which will follow this work is expected to be carried out very carefully on this area.

3) The relation between slate and the Tertiary formation at the right bank of the midstream area of Salo Lariang is estimated to be in unconformity but is rather obscure.

4) The interpretation of the boundary between these rocks and the

granitic rocks is relatively obscure in the upstream area of Salo Pasangkaju.

4-5 Gabbro (Ga)

During the ground geological investigations boulders of gabbro (in detail should be called Kentàllenite) were collected at two places near Manja, shown on the 1:250,000 map, located in the tributary basin of Salo Lariang. But the original rock body of these boulders could not be identified photogeologically. Therefore, the distribution of gabbro shown in the photolineation maps are based on unreliable interpretation.

4-6 Granitic Rocks I and II (G_1 & G_2)

According to the results of the ground geological investigation, there is no difference between granitic rocks I and II which were discriminately on the photolineation maps. Therefore, these are described together based on the fact that the topographic differences distigushied on the airphotographs depend on the different erosional cycles and that these rocks are fundamentally the same. These are expressed in different patterns on the map in order to clarify the topographic characteristics.

4-6-1 Distribution

1) The granitic rocks I(G_1) and II(G_2) are distributed widely over the entire project area. It is very difficult to distinguish these rocks from gneiss or gneissose granites. On the contrary, it is relatively easy to distinguish granitic rocks II(G_2) from granitic rocks III(G_3) mentioned later, although these are also similar granitic rocks. As stated later, because of the remarkable topographic differences between granitic rocks I(G_1) and granitic rocks II(G_2) shown on the airphotographs, it was

initially considered that these rocks are different rock facies but the ground geological investigations indicated that there were no differences between them. The granitic rocks G_2 are distributed for a length of 30 km in the ridge area of the left bank of the Salo Palu with a N-S trending(a). It is distributed also at two places in the upstream part of the Salo Pasankaju (b), at two places in the left bank side of the Salo Lariang(c), at one place in the left bank side of the Salo Karangana(d), at three places in the Salo Owaingkata basin area(e) and at two places in the west side of Donau Lindu(f).

2) It is estimated that granitic rocks G_2 which is distributed at the right bank side of the Salo Karangana does not belong to granitic rocks I (G_1) but belong to granitic rocks III (G_3). In the southwest part of the project area granitic rocks I(G_1) are bounded with volcanic rocks III(V_3) by photolineament 19 which many be the fault, and it may be covered by volcanic rocks IV(V_4). But because of the linear boundary between these rocks and the volcanic rocks IV there may be some possibility of a fault contacting relation.

3) In the west part of the project area G_1 is chiefly covered by Tertiary formations(T_4 or T_5) unconformably. There are, however, some places where it is estimated to be in fault contacting relation(e.g. 17 etc.). In the right bank of the midstream area in the Salo Lariang though these rocks and the Tertiary formation (T_4) seem to be in unconformable relation, as was stated before there is the possibility of a fault contacting relation.

4-6-2 Photogeological Character

Granitic rocks I(G_1) have the following photogeological character.

1) The mountain slope of G_1 have many fine and elongated gullies along the maximum dipping direction. For this reason, not only are small ridge indented in the slopes but also the main ridges seem to be remarkably sharp.

2) The mountain slopes have large topographic relief and appears brittle because of the sharp ridges.

3) The fine gullies are intersected perpendicularly or are at right angles to the main feather-shaped drainage patterns (Fig.11).

4) In general, the vegetation covering is dense and homogeneous and artificial cutting is scarcely observed.

5) In the G_2 area the drainage patterns are developed remarkably and are very dense (Fig. 10). The topographic relief is small and the ridges rounded.

4-6-3 Structure

1) The photolineaments along Fossa Sarasina are remarkably clear and all of them indicate the fault system forming Fossa Sarasina.

2) The photolineaments shown in these rocks such as 3, 5, 12, 23, 25, 26, 27, 32 etc., indicate the faults clearly and are oblique to Fossa Sarasina and the Median Line.

3) Many other photolineaments of these rocks are estimated to be faults. They are predominant in the NW-SE direction and next to this in the NE-SW direction.

4) Though the fracture traces are controlled by the local geological structures these are predominant in the NW-SE direction and the

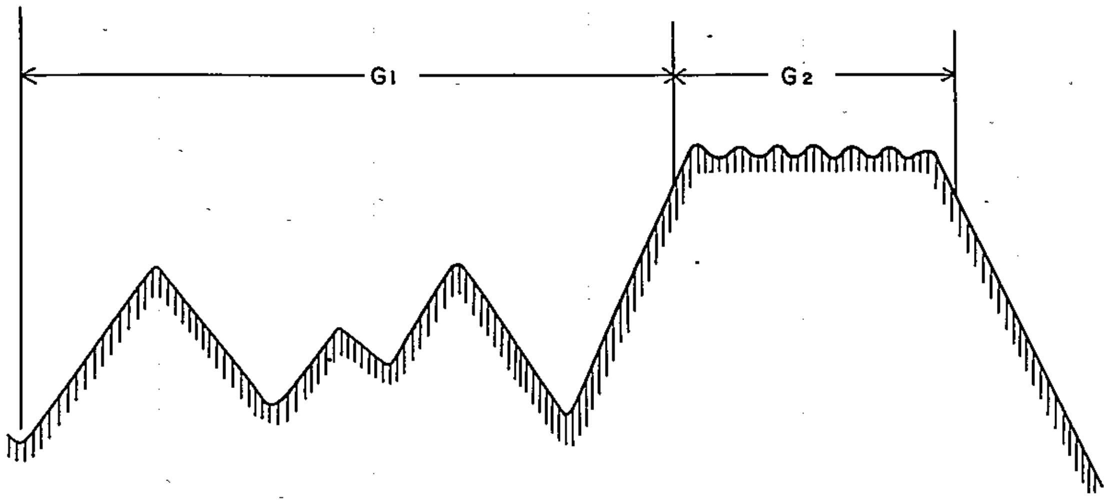
NE-SW direction.

4-6-4 Problems or Questionable Points

1) The differences between G_1 and G_2 are not caused by the fundamental lithologic differences but caused only by the differences of erosional cycles, Granitic rocks (G_2) are, in general, located at topographically higher parts, poor in topographic relief and the ridges are at similar elevations, but no lithologic differences were observed in the ground geological investigations (Fig. 17.).

2) In the northwestern part of this project area the lithological interpretation is very difficult due to the recent artificial cutting of vegetation cover. Also the geological complexity obscured the lithologic distribution in this area.

3) The distinction between granitic rocks and gneiss or gneissose granites is very difficult because of the poor topographic differences between them. Also it is impossible to distinguish the granites and granodiorites photogeologically even if distinguished in the ground geological investigations.



Drainage pattern	Coarse	Very Dense
Topographic relief	Large	Small
Shape of ridge	Sharp	Rounded

Fig. 17. Schematic representation of topographic differences between granitic rock I (G_1) and II (G_2) caused by difference of erosional cycle. Lithologically, G_1 and G_2 show same rock facies.

4-7 Granitic Rocks III (G_3)

4-7-1 Distribution

These rocks are distributed at the upstream part of the Salo Koro in the southern middle part of the project area. The western part of this rock mass is covered by volcanic rocks consisting mainly of andesite lavas and pyroclastic rocks.

The real rock facies of these rocks are entirely obscure because they have not been confirmed by ground geological investigations. But these rocks are shown as another type of granitic rock (G_3) on the photolineation maps in accordance with the photogeological difference.

The northern margin of this rock mass is bounded by photolineament 38. The G_2 located in the southern side of the photolineament 38 may reasonably belong to G_3 in accordance with the erosional circumstances of the mountain slope.

4-7-2 Photogeological Character

1) These rocks not only have the character of granitic rocks similar to granitic rocks G_1 but also have many remarkably developed gullies.

2) The most remarkable feature of these rocks is the numerous small scars at the top of the gullies. For this reason, the stream courses are widened by debris derived from these scars in this rock area (Fig. 15.).

4-7-3 Structure

Both the fracture traces and the photolineaments are predominant in the NW-SE direction and the NE-SW direction the same as other area.

4-7-4 Problems or Questionable Points

1) Since the real rock facies are entirely obscure because they have not been confirmed by ground geological investigations, it

is estimated to be granitic rocks in accordance with the collapsible tendency and the photogeological features.

2) According to the interim aeromagnetic survey report strong magnetic relief is observed surrounding the area where these rocks are distributed. This strong relief area extends over not only the volcanic rock area located in the west side of these rocks but also in this rock area. This fact suggests that rocks may be the ultrabasic-basic rocks which are rich in mafic minerals.

3) It is also estimated that these rocks may be formed from coarse grained materials because of the remarkably collapsible tendency.

4-8 Dyke Rocks (Dy)

One of the dyke rocks is confirmed as intruded into the slate with the strike and dip of N45° W, 85° SW by ground geological investigations. This is dacite at this point. Many dyke rocks can be interpreted in the volcanic rocks of the southeastern part of this project area.

The dyke rocks along photolineament 21 elongate in the NNE-SSW trend. The dykes which were distributed in the volcanic rocks III (V_3) are extended in the W-E directions. Their lithological facies are obscure because they are not confirmed by ground geological investigations.

4-9 Dolerite (D_0)

In the west side of Kamba, the southeastern part of this project area (a), the dolerite is confirmed by ground geological investigations to intrude into the Tertiary formation consisting mainly of shale. It is, however, impossible to identify dolerite photogeologically. Therefore, the distribution of these rocks is extremely obscure and it is believed to be sufficiently distributed in a small range besides the distribution shown on the photolineation maps.

4-10 Volcanic Rocks I and II (V_1 & V_2)

4-10-1 Distribution

The volcanic rocks are distributed along photolineaments (22, 29, 30, 31, etc.) which form Fossa Sarasina.

1) The volcanic rocks which are distributed at the Salo Koro basin are identified in several places as the liparitic tuffbreccia and tuff by ground geological investigations.
2) On the other hand, the volcanic rocks located in the Salo Palu basin are identified as andesitic rocks.
3) Though the distribution of the liparitic and andesitic rocks are confirmed in Salo Lariang basin, the interpretation of the distribution of the andesitic rocks is obscure due to dissected topography.

4-10-2 Photogeological Character

The most remarkable topographic features of the volcanic rocks along Fossa Sarasina are as follows:

1) The ridges of these rocks are very rounded and appear soft.
2) In general, the drainage patterns are poor.
3) The vegetation covering is not very dense and is heterogeneous.

4-10-3 Structure

These volcanic rocks are estimated to erupt along the fault system which form the Fossa Sarasina. This is suggested by the limited distribution of the volcanic rocks along the structural line and small ranging. The present rock masses are the remaining parts after erosion of the volcanic rock masses which have erupted along the faults. The volcanic rocks appear to have adhered to the granitic rock slopes.

4-10-4 Problems or Questionable Points

1) In the destroyed and dissected area of the primary volcanic topography it is difficult to interprete the volcanic rocks. There is a possibility of other volcanic rocks being in the area besides the volcanic rocks shown in the photolineation maps.

4-11 Volcanic Rock III and IV (V_3 & V_4)

4-11-1 Distribution

The rock mass estimated as volcanic rock is distributed in the south-western part of the project area. This rock mass can be divided into the western and the eastern parts bounding the cliff trending in the NE-SW direction at the western side of photolineaments 21. The former (western part) is called provisionally Volcanic rock III (V_3) and the latter (eastern part), is called Volcanic Rock IV (V_4). Generally V_4 is higher in elevation than V_3. The cliff bounding both volcanic rocks is estimated to be the tip of the lava of V_4. At the skirt zone of this cliff the talus is distributed in an area approximately several hundred meters to 1 km in width. The rock mass which is estimated as the extending part of the V_4 rock mass is distributed in the V_3 rock mass.

4-11-2 Photogeological Character

1) The drainage patterns of both volcanic rocks (V_3 and V_4) are as dense as the granitic rocks but they do not show a regular arrangement as found in the granitic rocks.

2) In the granitic rock area the main drainage courses are distributed regularly and the elevation of the ridges are of uniform height, but in the volcanic rock area the main drainage courses are very irregular and local swells can be observed.

3) In the V_4 area the mountain slopes are remarkably steep, are not smooth and are very rugged.

4) The small scars are distributed sparsely not as many as in the G_3 area.

5) In general the volcanic rocks have a dark grey photographic tone.

4-11-3 Structure

1) In the V_4 area though the fracture traces trending in the NW-SE direction and the NE-SW direction are developed, they are not as predominant as in the granitic rock area.

2) In the V_3 area the fracture traces are remarkably predominant in the NE-SW direction.

3) Photolineament 20 bounds the V_3 area and the Tertiary formation area (T_5), and photolineament 19 bounds the V_3 and G_3 area. Either of the photolineaments may indicate faults.

4) Photolineament 21 is a fault extending into the V_4 area. Many dykes are intruded between photolineament 21 and the cliff located at the western side of it along the extending direction.

4-11-4 Problems or Questionable Points

1) In the northwestern part of V_3, however, the fracture traces extending in the NE-SW direction are remarkably observed and a portion appears to be sedimentary rock. This is summarized as

volcanic rock III because it extends into the southwestern part which has a volcanic character. There is a possibility that the rich part in fracture traces may be a volcanic conglomerate or a tuffbreccia area.

2) The cliff which divides V_3 and V_4 is estimated as the tip of the lava flow of V_4 but the linear extension of it may suggest a possibility of a fault.

3) V_4 and G_3 were consisted to be in the intrusion relation but the linear boundary between them suggests that they may be in fault relation bounded by the southeastern extension of the fault 19.

4) According to the interim aeromagnetic survey report, in the V_3 and V_4 area strong magnetic relief is observed and V_3 and V_4 are indicated to have a magnetically active character.

4-12 Volcanic Rock V(V_5)

4-12-1 Distribution

These rocks are distributed on the right bank of the upper-mid-stream of the Salo Karangana basin overlaying the slate and the granitic rocks.

A part of these rocks is confirmed as andesite lava by the ground geological investigation conducted at the right bank of the upstream area of this river. In this area the talus derived from the andesite area is distributed between this volcanic rock mass and the slate covering an area 2km ± in width and 10km + in length.

The extended part of this rock mass is distributed in the shape of a volcanic neck on the slate of the left bank of the Salo Karangana (shown as the shaded portion with? mark on the photolineation maps).

4-12-2 Photogeological Character

1) The drainage patterns are as dense as in the granitic rock area but they are not regular as in the granitic rock area.

2) The mountain slopes are very steep and have large topographic relief.

3) The elevation of the ridges are roughly uniform in the granitic rock area. However, in the volcanic rock area they are very irregular and local swells and hallows can be observed.

4) In general the mountain slopes are rugged.

4-12-3 Structure

1) The topograplic features and photolineations which are characteristic in the primary lava flow cannot be observed due to the developed dissection.

2) There is remarkable tendency in the fracture traces or the photolineaments. The only distribution of these rocks indicates the southern extention.

4-12-4 Problems or Questionable Points

1) The western boundary of this volcanic mass can be interpreted relatively clearly but the eastern boundary is rather obscure.

2) Though the masses estimated as the volcanic necks are interpreted in two places, these have not been verified by ground geological investigations.

3) Strong magnetic relief is recognized sorrounding the area of these rocks by the result of aeromagnetic surveys and it ranges further east of volcanic rock V(V_5) area. It is not clear

whether (a) this fact indicates the further distribution of andesite to the east of the volcanic rock V area or (b) indicates the existence of another magnetically active rock mass at the further eastern part of this rock mass. In this report the possibility of case (b) is believed to be stronger than (a).

4-13 Tertiary formation (?) I (T_1)

4-13-1 Distribution

The Tertiary (?) formation I is distributed on the right bank (a) of Salo Matei located in the southeastern part of this project area, ranging 4km± in width and 30km + in length. The eastern part is in contact with the muscovite crystalline schists of the Poso Zone by photolineaments 33 and 37, and the western part is in contact with the granitic rocks I and II by photolineaments 28, 34 and 35.

It is estimated that the sediments of the graben zone described by Brouwer are identified with the Tertiary formation I(T_1) shown in the photolineation maps. In this report the geological age of this formation is stated as "Tertiary" in accordance with Brouwer's descriptions.

4-13-2 Photogeological Character

1) T_1 does not have any remarkable features. Though this formation is confirmed to be consisted mainly of shale found along the ground investigated route, T_1 does not have the photogeological features which were generally recognized in the shale area but rather indicate that of volcanic rocks such as volcanic conglomerate-like materials.

2) The fracture traces shown in the T_1 area are predominant in the NW-SE direction which suggest that the strike of this formation

may be in the NW-SE direction.

3) Also many fracture traces extending in the NNE-SSW direction parallel to photolineaments 28, 33, 34 etc. are interpreted.

4-13-3 Structure

1) The structure of T_1 will be disscussed in Chapter 5 "Geological Structure" in connection with the Tawaëlia Graben.

2) T_1 seems to have the strike in the NW-SE direction and the dip in the SW direction considering the character and distribution of the fracture traces.

3) The existence of the fracture traces in the NNE-SSW direction parallel to photolineaments 28, 33 and 34 (all indicate faults), however, suggest the structural influences in connection with the fault construction.

4-13-4 Problems or Questionable Points

1) Brouwer described that the Tawaëlia Graben extends straight in the NNE-SSW direction with a fixed width. However, the distinct existence of the graben is hard to believe through photo interpretation. It is the most important question whether Brouwer assumed the existence of Tawaëlia graben based on distinct foundations.

2) It is also a question whether he called the fault located near Pada Basin*, near photolineament 34 in the maps, as "Median Line". Photogeologically a set of photolineaments 33, 37, 27 and 12 seem to be more appropriate to be called the "Median Line". Brouwer's description, :"...... At its eastern margin lies a

* The place name "Pada", which was confirmed by ground geological investigation team, may correspond to the name "Bada" used by Brouwer.

series of conglomerates, sandstones and clayshales, unconformably overlying the crystalline schists of the Poso Zone ....", also does not agree with the opinion in this report.

4-14 Tertiary formation II and III (T_2 & T_3)

4-14-1 Distribution

Tertiary formation II (T_2) and III (T_3) are distributed only in the marginal part of this project area.

T_2 is in contact with the crystalline schists and the granitic rocks by photolineaments 9 and 10 (Both seems to indicate faults).

4-14-2 Photogeological Character

1) In the T_2 area (a) the drainage pattern is passably dense. The topographic relief is small, the ridges are sharp and the mountain slopes are rugged. The photographic tone is generally dark grey. Considering these circumstances this rock formation is estimated to be consisted of normal sedimentary rocks such as shale and sandstone.

2) The anticlinal axis is observed clearly in the T_3 formation (b) and elliptical photolineations are developed surrounding this axis. This suggest that this formation is consisted of the alternation of sandstone and shale.

4-14-3 Structure

1) The fracture traces of the T_2 area are predominantly in the WNW-ESE direction indicating that the formation has the northern dip in the northern area and the Southern dip in the southern area. Considering these interpretations the anticlinal axis of the WNW-ESE trend may be estimated as the central part of the T_2 area.

approximately 12 km X 14km.

Lake deposit II is distributed on the upstream areas of the Salo Rompo and the Salo Koro and the northwestern part of this project area besides the five basins previously mentioned.

4-16-2 Photogeological Character

1) The L_1 plain is several meters higher than the L_2 plain in elevation. The L_1 area is advanced in land use and has a white to light grey photographic tone. The surface of the plain is very flat and smooth. In the Paanto Basin the flat bedding plain of these deposits can be interpreted.

2) The L_2 area has a flat and smooth surface as is seen in the alluvial deposits and is the lowest plain in all of the formations of the project area except alluvium even though its absolute elevation reaches several hundred meters in some places.

3) It is obvious that the L_1 and L_2 area are in unconformable relation because the L_2 buries the eroded vallys of L_1.

4) The rivers which flow down the L_1 and L_2 area meander remarkably.

4-16-3 Structure

Around the basin in which the lake deposits are distributed large scale photolineaments, which seem to be faults, are always interpreted. For example, the Pada Basin is chiefly between photolineaments 32 and 34, the Bariri Basin is between photolineaments 26 and 39, also the Paanto Basin is between the extension of photolineament 27 and 40 or 13, and also the Lindu Basin is between many photolineaments in the same manner as the

2) T_2 is in contact with T_3 bounded by a fault.

3) The existence of the NW-SE trending anticlinal axis in the T_3 area is obvious and the after folding movement the folded bed is cut by the faults which are oblique to the anticlinal axis.

4-14-4 Problems or Questionable Points

Though it is rather obscure whether the marginal part of T_2 is in contact with G_1 bounding the fault, unconformity or is intruded by G_1, we concluded to be in unconformable relation.

4-15 Tertiary formations IV - VII (T_4-T_7)

4-15-1 Distribution

1) The Tertiary formations (T_4, T_5, T_6 and T_7) are distributed in the area ranging from the midstream area of Salo Lariang to the western coastal plain area overlying the granitic rocks unconformably. They show a wide arc-shaped distribution.

2) T_4 is distributed on both banks (a) of the midstream area of the Salo Lariang. It covers the slate or granitic rocks (G_1) unconformably in the western part and is in contact with G_1 being bounded by photolineaments 3 (which may be a fault). T_4 and T_5 seem to be in conformable relation.

3) T_5 is distributed in the area (b) ranging from the northern margin to the southern margin of this project area in the western side of T_4. It is in contact with volcanic rock III (V_3) being bounded by photolineament 20 (estimated as a fault), and is in contact with G_1 by photolineament 17 in the southern part. T_5 covers G_1 and T_4 unconformably in the middle part. In the northern part it covers G_1 unconformably (partly being bounded

area but the ridges are rounded. The vegitation covering is generally poor and land use is advanced. This formation has generally a light photographic tone. Considering this information the T_6 area is estimated as having relatively tough beds consisting of sandstone, siltstone and shale.

3) In the T_7 area the topographic dissection is also advanced and the drainage pattern is not well developed. The topographic relief of ridges is small as is seen in the T_6 area. T_6 does not show distinct bedding, but in the T_7 area the photolineations indicate that the clear bedding is developed. The vegetation cover is good and T_7 shows generally a dark photographic tone. This information suggests that this formation is consisted of the alternation of sandstone and shale.

4-15-3 Structure

1) These Tertiary formations show arc-shaped distribution macroscopically.

2) The fracture traces of the NW-SE trend are predominant in the T_4 area and this suggests that T_4 has the strike in the NW-SE trend. Especially the photolineations indicating the dip and strike of this formation can be observed in the right bank area of the uppermost-stream area of the Salo Pasangkaju.

All of the photolineaments observed in this formation are in the NW-SE direction and photolineaments 2, 3 and 4 indicate the fault clearly. The distribution of T_4 itself seems to be between the NW-SE trending faults such as 3 and 4.

3) In the southern part of the T_5 area the fracture traces are pre-

dominant in the NE-SW direction, which suggest that T_5 shows NE-SW trending strikes. The photolineaments also run parallel to these fracture traces. In the middle area the NW-SE trending fracture traces are predominant and in the northern part of the T_5 area those of the N-S trend are predominant. The relation between T_5 and G_1 obscure in the northern part of the T_5 area whether in fault contact or in unconformity.

4) The bedding foliations are remarkably developed both in the T_6 and T_7 areas. They are folded along the synclinal and anticlinal axis of the NE-SW direction. Many photolineaments which intersect this axis are observed and estimated as faults.

4-15-4 Problems or Questionable Points

1) In the Tertiary area of the western coastal plain division, the most important problem is that the identification of the stratigraphical relations of these Tertiary formations is almost impossible by photo interpretation only. In the photo-lineation maps T_4 is shown as the oldest formation and T_7 as the youngest considering the distribution of these formations and their elevation.

   But the interpretable fact that T_6 and T_7 seems to be disturbed much more than T_4 and T_5 geologically may contradict the stated order.

2) T_4 and T_5 have photogeologecally very similar features. Especially, this tendency is evident in the Salo Lariang basin. Therefore, their geological classification is considered as being not very important.

3) The relation between T_4 and slate or granitic rocks located in the northeastern side of T_4 is uncertain whether they are in unconformable or fault contacting relation. The relation is shown as conformity on the maps.

4) The relation between T_5 and G_1 located in the eastern side of T_5 is also uncertain as in 3) above.

4-16 Lake deposits I and II (L_1 & L_2)

4-16-1 Distribution

Most of the lake deposits I and II are distributed in the basin of the eastern mountainous division. The main basin in which the lake deposits I and II are distributed are as follows:

1) Pada Basin
2) Bariri Basin
3) Paanto Basin
4) Lindu Basin
5) Palulu Basin

(These names were temporarily used in this report)

In this report the lake deposits which form the higher plain are called lake deposit I and the lower are called lake deposit II. Naturally, lake deposit I is older than II considering the elevation of the plains. Lake deposit I is considered to be later Tertiary or early Quaternary sediments and II Alluvial sediments as of the other alluvial deposits. There is a little difference only in their depositional environments between the lake deposit II and the alluvial deposits.

Lake deposit I is mainly distributed in Pada Basin, Bariri Basin and Paanto Basin. In the Paanto Basin it is distributed in a wide range of by a fault). The western part of this formation is covered conformably by T_6.

4) T_6 is distributed on the western side of T_5 overlying T_5 unconformably. In the northwestern area this formation is covered by T_7 conformably.

4-15-2 Photogeological Character

1) T_4 and T_5 have very similar topographic features especially in the Salo Lariang basin. Namely, the mountainous regions of T_4 and T_5 are small in topographic relief and the ridges have rough uniform elevation. The drainage patterns are very dense (Fig. 14) and dendritic. The mountain slopes are steep and the ridges are sharp but not as sharp and brittle as found in the granitic area (G_1). Also the developement of gullies is not as remarkable as in the G_1 area and all are recognized as clear valleys. The vegitation cover is generally uniform. Leaving both banks of the Salo Lariang the topographic relief of the ridges are apt to decrease. This formation seems to be lithologically homogeneous sedimentary rocks such as shale, T_4 and T_5 because of the dark photographic tone and the dense and uniform drainage patterns. Because of these photogeological features we can recognize the clear differences between this formation and slate or granitic rocks, thus making interpretation easy.

2) In the T_6 area the developement of drainage patterns is not very good because of the remarkably advanced topographic dissection. The topographic relief is as small as is seen in the T_4 and T_5

other basins.

These facts suggest that the old lakes in which lake deposits I and II are deposited are formed in the hollows formed by the fault movements. Donau Lindu may be a vestige of these fault movements.

4-16-4 Problems or Questionable Points

1) In the Paanto Basin where L_1 and L_2 are distributed most widely, L_1 which is distributed on the western side of photolineaments 27 and 12 has a possibility of being eroded crystalline schist with poor vegetation cover. This is because it is distributed at a relatively high elevation and on the outside of the hollow.

2) For the same reason as mentioned 1) there is some possibility that the L_1 area between Bariri Basin and Paanto Basin may be covered by other rock types.

3) L_1 distributed on the right bank of Salo Sopu in the Palulu Basin may have a fan depostional character considering its fan-shaped distribution and gentle dipping of the surface toward the river.

4-17 Fan and Terrace deposits I and II (F_1 & F_2)

4-17-1 Distribution

1) Among the fan deposits and the terrace deposits, the younger deposit which maintains a clear fan-shaped topography and the terrace topography is shown as F_2. On the other hand, the older deposit in which the gullies are incised and the primary fan topography or the terrace topography is broken is shown as F_1.

2) F_1 is distributed in two places at the left bank of Salo Palu, at the right bank of Salo Pebatua and in the area along photo-

lineament 32 located in the northern part of the Pada Basin.

3) F_2 is distributed with a typical fan shape at both banks of the middle - downstream part of Salo Palu. Also it is distributed in the northern part of the Pada Basin and catchment areas of Salo Karangana, Salo Lariang and Salo Koro.

4-17-2 Photogeological Character

1) F_2 has a typical fan shape and slopes gently from the top of the fan to the margines.

2) The terrace deposits are distributed on with flat surfaces on both banks of the river which flow down on the basement rocks.

3) Though the vegetation covering of the fan deposit is generally poor, there is a tendency for the vegetation cover to be poor in top part and to become denser in the marginal part.

4) Many small gullies can be observed on the surface of F_1 but the primary surface still partly remains.

5) Both F_1 and F_2 are consisted mainly of gravels derived from the hinter mountains. The surface of F_1 seems to change into clay by weathering.

4-17-3 Structure

F_1 and F_2 are distributed along Salo Palu and occupy the skirting area of the cliff formed by the fault movement of Fossa Sarasina. These sediments, especially F_2, cover the alluvial deposits.

4-17-4 Problems or Questionable Points

1) Though the geological age of sedimentation in F_1 and F_2 is not clear, according to the erosional grade, F_1 seems to be delluvium and F_2 seems to be alluvium.

2) The fan deposits and terrace deposits are not divided in this report. If necessary, for in this project area F_1 and F_2 which are adjacent to the alluvial deposits can be called fan deposits and those distributed along the streams in the mountainous areas can be called terrace deposits.

4-18 Talus Deposits (Ta)

4-18-1 Distribution

Only the widely distributed talus deposits are shown on these maps. They are distributed on (a) the area between Palulu Basin and Paanto Basin which locates along photolineaments 8 and 11, (b) the right bank of the upstream area of Salo Karangana and (c) the area along the cliff located in the western side of photolineament 21 in the southwestern part of the project area.

The talus deposits of area (a) is derived from the surrounding mountainside to the low land enclosed by faults and has a ship bottom-shaped topography, (b) is consisted of the debris derived from volcanic rock V (V_5) located in the upstream area of Salo Karangana and (c) is consisted of the debris of V_4 derived from the linear cliff located at the western side of photolineament 21.

4-18-2 Photogeological Character

1) The area where the talus is distributed shows a gentle dipping slope.

2) The mountain slopes have poor drainage patterns because of the underflow of surface water. Therefore, there are few gullies and the surface of the mountainside is very smooth.

3) The vegetation cover is generally good. The talus deposits

have a dark photographic tone.

4-18-3 Structure

4-18-4 Problems or Questionable Points

There are no special structure and problems concerning talus deposits.

4-19 Alluvial Deposits (A_1)

4-19-1 Distribution

In the middle part of the northern project area the alluvial deposits are distributed along the Salo Palu 5km in width. In the western coastal division the alluvial deposits are distributed in a wide region. Bisides the above it is distributed in the midstream area of the Salo Lariang and the upper-midstream area of Salo Pebatua in a very small area.

4-19-2 Photogeological Character

1) The area where alluvial deposits are distributed is low and flat and advanced in land use.
2) These deposits are distributed extensively and bury the lowest area of all the formations of the project area.
3) In the alluvial plain the lower plain can be recognized along the present rivers.

4-19-3 Structure

The alluvial deposits distributed along Salo Palu have buried the V-shaped valley constracted by Fossa Sarasina.

4-19-4 Problems or Questionable Points

There are no special problems concerning alluvial deposits.

5. PHOTOGEOLOGICAL STRUCTURE

5-1 General Photogeological Structure

In this report the results of photo interpretation for linear patterns observed on the airphotographs are classified and represented in accordance with Lattman's definition (1958). Namely, (a) the continuous photolineations which seem to be a fault or fault-sheared zone are shown as "Photolineaments" and (b) one which reflect the bedding, schistosity or joint and poor in continuity are expressed as "Fracture Traces". The term "Fault" is not used in this report directly for the photolineaments because they have not been checked by ground geological investigations and cannot be definitely ascertained as a "Fault". Also the term "Fracture Traces" is used under similar circumstances.

The most clear geological structure in this project area is the fault zone of Fossa Sarasina elongating along Salo Palu and the Median Line located in the eastern part of this project area. The Median Line extends with a N-S trend and contrarily the Fossa Sarasina extends with a NW-SE trend so as to intersect the Median Line in the southern side of this project area. Detailed conditions are mentioned in the following paragraph.

Most all other photolineaments extend in the direction oblique to these major structural lines. Namely, in these photolineaments the NW-SE and NE-SW directions are predominant. All photolineaments shown in the photolineation maps do not necessarily indicate the faults or fault-sheared zones but most of them, at least numbered one, may indicate faults.

Though the fracture traces are also generally predominant in the NW-SE and NE-SW directions they show some local variation in each formation and rock body. Their simplified directions are shown in Fig. 6.

5-2 Median Line and Tawaëlia Graben Sub-Zone

5-2-1 Former opinion

1) The sub-zone which is called "Tawaëlia Graben" by Brouwer is a belt located between the Poso Zone and the Palu Zone and a detailed location is described in "The Geology of Indonesia (RW. Van Bemmelen: 1949)" as follow:

"The main faults lie near the Bada Basin on the western side of this divided sub-zone. The so-called "Median Line" of Central Sulawesi runs along the westside of the Tawaëlia Graben."

2) And continuing"...... At its eastern margin lies a series of conglomerates, sandstones and clayshales, unconformably overlying the crystalline schists of the Poso Zone. Further west these layers contain much volcanic materials.

Also dacitic and andesitic lava flows are interbeded, which become westward (together with volcanic agglomerates) the main rocks. In the western part of the Tawaëlia Graben microdiorites and micro-quartz diorites are exposed.

At the boundary between these rocks and the granodiorites of the Palu Zone, a mylonititic zone is found, which also occurs father north of the Pada Plain. The mylonite zone generally has an almost vertical position, but also westward dips of 45° are present.

The sediments in the Tawaëlia Sub-Zone are young Miocene or younger according to Van Der Vlerk & Dozy (1934).

They are folded and lava flows are strongly crushed. The dip is chiefly 30 - 75° west."

3) In addition "Thus it appears that during the Young Neogene a sea strait separated the western and eastern zones of Central Sulawesi. Thereafter, sedimentary deposits in this strait were folded and highly elevated above sea level."

4) As is evident from these descriptions the former investgators, mainly Brouwer, estimated that the Tawaëlia Graben Zone bounded by the Median Line crossed through Central Sulawesi from north to south as a strait during the young Neogene period.

5-2-2 New Photogeological Opinion

1) According to the photo interpretation, it has become clear that the formation (T_1) which may be identified as the sediments in Tawaëlia Graben reported by Brouwer is distributed on the right bank area of Salo Marei ranging from 4km ± in width to 30 km + in length.

The eastern side of this formation is in contact with the muscovite crystalline schists being bounded by photolineaments 33 and 37, and the western side is in contact with granitic rocks I and II by photolineament 28, 34 and 35 (see photolineation maps of Fig. 18).

2) According to the photo interpretation, the Median Line described by Brouwer (which is described as follow: "The main faults lie near the Bada Basin on the western side of this dividing subzone." or "--- the Median Line runs along the western side of the Tawaëlia Graben.---") may correspond to the set of photo-

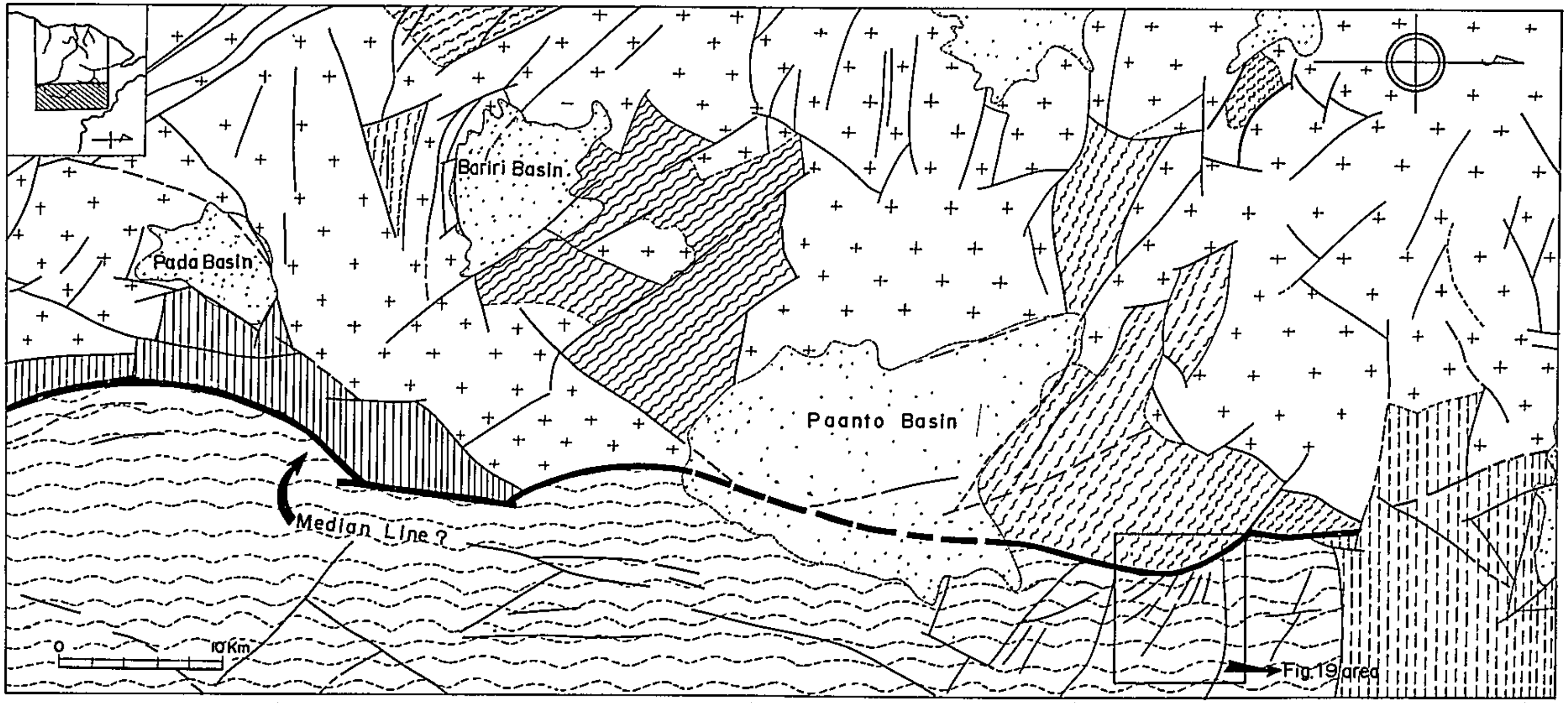


Fig.18. Map showing geological structure of adjacent area of Median Line

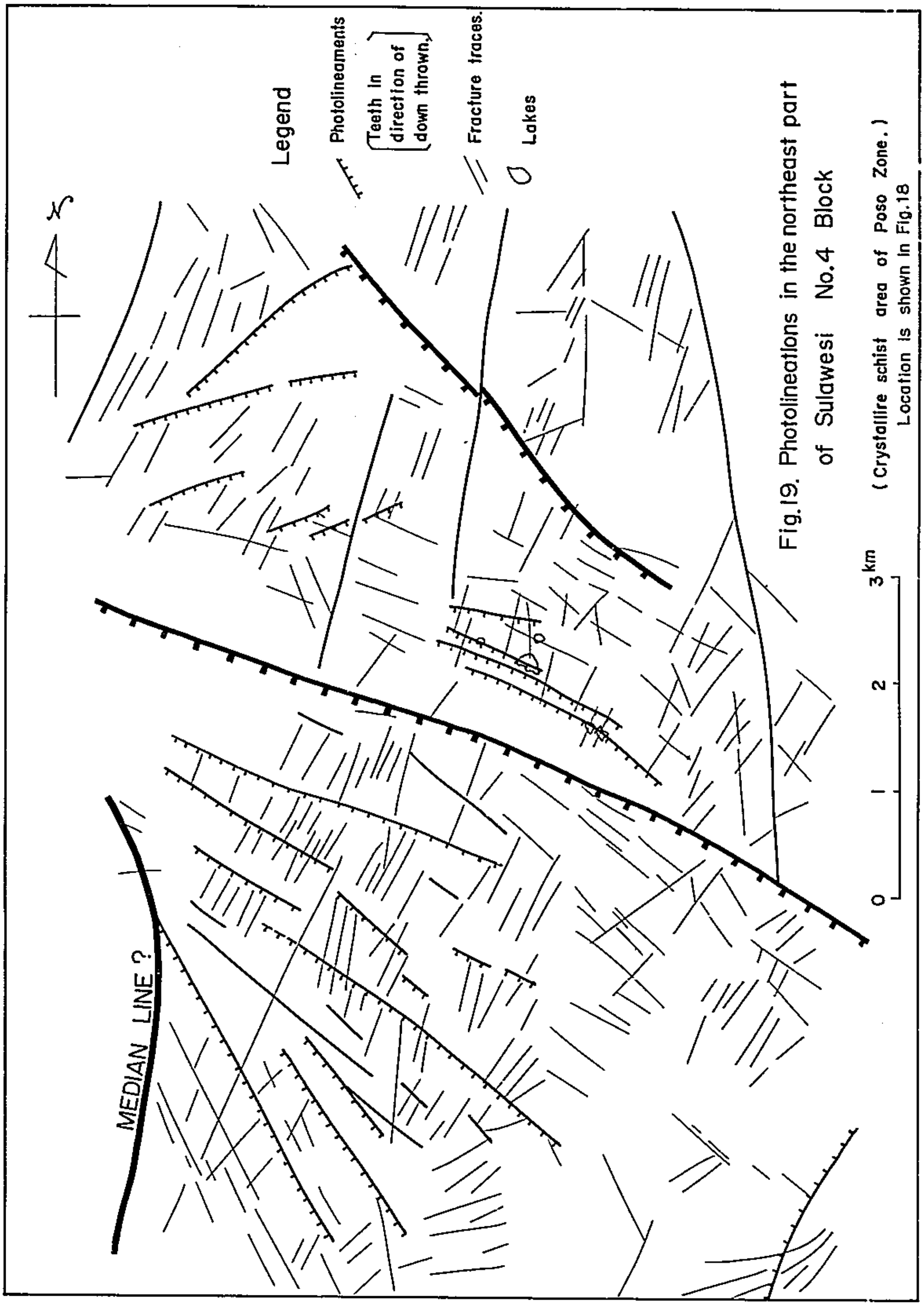


Fig.19. Photolineations in the northeast part of Sulawesi No.4 Block

(Crystalline schist area of Poso Zone.)
Location is shown in Fig.18

lineaments such as 34, 35 and 28.

3) According to the photo interpretation, however, these photolineaments are rather poor in continuity and photolineaments 33, 37, 27 and 12 which can be interpreted in the eastern side of T_1 are rather rich in continuity and clearer.

4) In addition the distribution of T_1 which is considered to be the sediments in Tawaëlia Graben is restricted to the southern part of the project area. In other words, T_1 does not show the zonal distribution extending from north to south as Brouwer's description.

5) In the northeastern part of the project area, as shown in Fig. 19, many parallel step faults which may have the SW downthrown side are observed. These faults have clear fault scarps on the smooth mountainside consisted of crystalline schists, which are not distributed in the gneiss area beyond photolineament 12 (Fig. 19). The geological explanation of these fault systems is one of the important problems. In this report these fault systems are explained as being derived by connecting with the removement of fault 12 (in detail it should be called photolineament 12). That is to say, with the downthrown of the western mass (consisted mainly of granitic rocks and gneiss) or the up-lifting of the eastern mass, "Dragging-in" is caused by the resistance between G_1 and S_1 and step faults are formed.

6) According to the foundations mentioned in 2), 3), 4), 5), it is concluded that a set of photolineaments such as 33, 37, 27 and 12 is suitable to be called the Median Line.

5-2-3 Problems or Questionable Points:

1) The weak point of this opinion is that most of foundations are based on the results of photo interpretation only.

2) The existence of mylonite in the western side of the Graben is reported by Brouwer (1947) but has not been confirmed yet along the "Median Line" based on the new opinion.

3) Furthermore, Brouwer described that the sediments of the Graben are unconformably overlain on the crystalline schists of the Poso Zone. This fact contradicts the results of this photo interpretation. Though the results of ground geological investigations should be respected, further detailed investigations on this problem is very desirable.

5-3 Fossa Sarasina (Palu Faults)

5-3-1 Distribution

So-called Fossa Sarasina extending in the NNW-SSE direction in the Middle part of the Palu Zone is composed of many faults and intersects the Median Line obliquely at the southern side of this project block. These faults extend along Salo Koro, Salo Pebatua and Salo Palu, and have formed the V-shaped valley along these main rivers.

5-3-2 Structure

The Fossa Sarasina is composed of not only one fault but also many faults such as photolineaments 6, 22, 29, 30, 31, 36 etc. The biotite crystalline schists and gneiss are distributed along and between these faults. Along the faults, volcanic rocks also erupted and these products i.e. the liparitic rocks are mainly distributed along Salo Koro and the andestic rocks are distributed mainly along Salo Pebatua. The volcanic rocks erupted along

Fossa Sarasina may show the present distribution after denudation by erosion. It seems, however, that large scale volcanic activities have not taken place originally in this area.

5-3-3 Problems or Questionbale Points

In this region it is difficult to determine the downthrown side of these faults and the vertical and lateral movements between the eastern mass and the western mass of Fossa Sarasina only by photo interpretation. The following information, however, may suggest these problems.

(a) In the eastern side of the Fossa Sarasina unbalanced distribution of the volcanic rocks is estimated due to fissure eruption.

(b) The distribution of photolineaments (38, 25, 32 etc.) is estimated to be derived from the activity of Fossa Sarasina.

(c) The existence of the small parallel faults with downthrow in the west side in the area of granitic rocks or crystalline schists and the sorrounding area of Salo Palu.

6. CONCLUSION

1) This investigations are carried out to obtain basic data for developing of mineral resources in the Republic of Indonesia. The main purpose of this work is to complete the drainage pattern maps which will be used for base topographic maps and to complete the photolineation maps.

2) The Central Sulawesi can be divided roughly into three major tectonic zones by the geological structure with the trend in the N-S direction. These zones are called Kolonodale Zone, Poso Zone and Palu Zone from east to west.

3) The basement rocks in this project area are consisted of muscovite crystalline schists of the Poso Zone, biotite crystalline schists, gneiss, granitic rocks and Mesozoic formations of the Palu Zone, the Tertiary formations covering unconformably and additional Quarternary sediments covering them.

4) The muscovite crystalline schists of the Poso Zone are distributed in the eastern part of this project area. The granitic rocks are distributed over the entire project area. Tertiary formations are partly distributed as sediments of the so-called Tawaëlia Graben and are mainly distributed in the western part of the project area in an arc-shape. Quarternary sediments are classified as lake deposits and alluvial deposits and the former is mainly distributed in the eastern mountanous division of the eastern side of the Fossa Sarasina and the latter is distributed in the western coastal plain division.

5) The geologecal structure is chiefly controlled by the so-called

Median Line dividing the Poso Zone and the Palu Zone and the Fossa Sarasina dividing the Palu Zone into two parts.

6) Generally speaking, in the whole project area both photolineaments and fracture traces are predominant in the NW-SE and the NE-SW direction and they seem to be under the control of the Median Line, Fossa Sarasina and the major faults which are derived by the main geological structures.

7) Many indistinct points occured through the photogeological investigations. Therefore, such questionable points or problems are indicated in each Chapter or Section.

8) The lithological interpretation is very difficult for the distribution between the granitic rocks and the gneiss or gneissose granites and that between the slate and the granitic rocks in the northwestern part of this project area. Also it is almost imposible to interpret the distribution of dolerite gabbro and some andesite which may occupy a small area even though their existence has been confirmed by ground geological investigations.

9) Considering the results of photo interpretation the graben reported by Brouwer is recognized in the southern part only and it does not seems to extend from the north to south of central Sulawesi. It may be reasonabl to consider that the so-called Median Line does not run the west side of the graben but the east side of it.

10) No remarkable alteration zone was recognized by photo interpretation in this project.

Appendix 1

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Appendix 2. Photographic Criteria of the Lithologic Units in Sulawesi No.4 Block

Type of Rocks	Photographic Tone	Drainage Characters		Topography (Shape of ground-surface)	Vegetation cover	Others
		Pattern	Density			
Alluvial deposits (Al)	Dull grey to medium grey (partly light grey)	Anastomotic drainage pattern with meandering stream	Very coarse	Very flat and smooth	Grass land or low - high tree rain forest	
Talus deposits (Ta)	Dark grey	Subparallel pattern	Very coarse or lacking the drainage	Relatively smooth. This deposits are formed at the skirt of cliff or steep slope.	Medium - high uniform shaded rain forest	
Fan & terrace deposits II (F_2)	Medium grey	Dichotomic pattern	Medium (sometimes dense in fine drainage pattern)	It has gentle fan-shaped topography.	Medium to high tree rain forest (dense in marginal parts and coarse in top of fan)	
Fan & terrace deposits I (F_1)	Dull grey to medium grey (lighter than F_2)	Dichotomic pattern	Dense	It has gentle fan-shaped topography and many gullies can be observed on it	Grass land or gallery type rain forest	
Lake deposits II (L_2)	Dull grey to medium grey	Anastomotic drainage pattern	Very dense	Very flat and smooth as alluvial plain	Grass land or low - high tree rain forest	
Lake deposits I (L_1)	White to light grey	Dendritic-pinnate pattern	Very coarse	Surface is very flat and smooth. Bedding foliations can be observed on the slope.	Grass land or gallery type rain forest	
Tertiary sedimentary rock VII (T_7)	Dark grey	Modified dendritic pattern	Coarse	The topographic relief is small. The ridges are arranged sorrounding a anticline axis.	High very dense rain forest	
Tertiary sedimentary rock VI (T_6)	Light grey to medium grey (partly white)	Dendritic angular pattern	Very dense	The ridges are rounded and surface is relalively smooth.	Low - medium tree rain forest. Heterogeneous distribution	
Tertiary sedimentary rock IV, V (T_4, T_5)	Dark grey	Dendritic-trellis pattern	Very dense	The topographic relief is very small but the slope is relatively steep and rugged.	High, uniform shaded rain forest	
Tertiary sedimentary rock III (T_3)	Medium grey to dark grey	Modified dendritic pattern	Medium	The topographic relief is small. The ridges are arranged surrounding the anticline axis.	Low - medium tree rain forest	
Tertiary sedimentary rock II (T_2)	Dark grey	Dendritic angular pattern	Dense	The topographic relief is small and the ridges are sharp. The mountain slope is ragged.	High, uniform shaded rain forest. Homogeneous distribution	The gullies follow in the lamination
Tertiary sedimentary rock I (T_1)	Dark grey to medium grey	Modified dendritic pattern	Medium	This rock area looks relatively massive. Absolute elevation is generally high but topographic relief is not so large.	High tree forest (more heterogeneous than G_1 - G_3)	

Type of Rocks	Photographic Tone	Drainage Characters		Topography (Shape of ground-surface)	Vegetation cover	Others
		Pattern	Density			
Volcanic rock IV, V (V_4, V_5)	Dark grey	Very irregular modified dendritic pattern	Medium	The mountain slope is very steep and has large topographic relief. The elevation of ridges are very irregular and local swells and hollows can be observed.	High - medium tree rain forest. Heterogeneous distribution	
Volcanic rock III (V_3)	Dark grey	Irregular modified dendritic pattern	Medium to dense	The mountain slope is remarkably steep, not smooth and is ragged. Local swells can be observed.	High - medium tree rain forest. Heterogeneous distribution	Several small scars can be observed.
Volcanic rock I, II (V_1, V_2)	Medium grey to dark grey (partly light grey)	Modified dendritic pattern	Coarse	The ridges are very rounded and show the soft appearance.	Low - high rain forest. (partly grass land.)	
Dolerite (Do)	Medium grey to dark grey	Modified dendritic pattern	Coarse	This rock does not show remarkable topographic features because of narrow distribution.	Medium tree rain forest	
Dyke rocks (Dy)	Dark grey	Lack in the drainage pattern		This rocks show the protrusive features	High tree rain forest	
Granitic rock II (G_3)	Dark grey	Subparallel - modified dendritic pattern	Very dense	This rock has not only characters of granitic rocks but also has many remarkably developed gullies.	High tree rain forest	Many small scars can be observed.
Granitic rock II (G_2)	Dark grey	Dendritic - modified dendritic pattern	Very dense	The topographic relief is small and the ridges are rounded.	High, uniform shaded forest. Homogeneous distribution	
Granitic rock I (G_1)	Dark grey	Parallel in steep slope, modified dendritic or feather shaped pattern	Dense	The mountain slope has many fine and elongated gullies along the maximum dipping direction. The topographic relief is large and ridges are sharp.	High uniform shaded forest. Homogeneous distribution	
Gabbro (Ga)	Medium grey	Modified dendritic pattern	Coarse	Similar to slate	Grass land or lower trees. Heterogeneous	
Slate (Sl)	Light grey to medium grey	Modified dendritic pattern	Very coarse	The topographic relief is large and the ridges are rounded. The mountain slope is steep and smooth.	Grass land and lower - high tree rain forest (Heterogeneous distribution)	Land using is advanced.
Gneiss (Gn)	Light grey to medium grey	Modified dendritic pattern	Very coarse	Similar to slate. The topographic relief is large. The ridges are relatively rounded.	Low - high tree rain forest. (partly grass land)	
Crystalline schist II (S_2)	Medium grey to dark grey (partly light grey)	Subparallel - modified dendritic pattern	Medium	The topographic relief is small. The ridges are generally rounded and the valleys are sharrow and wide (in the up-stream area of Salo Rompoj.	High - medium tree rain forest	
Crystalline schist I (S_1)	Dull grey to medium grey (partly light grey)	Parallel - subparallel pattern	Very dense in southern part Very coarse in northern part	The mountain slope has remarkably gentle and smooth surface and is small in topographic relief.	Low - high tree rain forest	

* In this table, the discription about photogeological structures such as photolineaments or fracture traces is abbreviated.

Appendix 3

Brief Outline of Photogeology

1. The technical term "photogeology" may possibly become to be recognized that geological survey is possible by using aerial photographs only. Photogeology is not the study of geology itself but is the study of a systematic method to obtain geological informations and data and the study of a method to express these data as geologic plans and profiles through photogrammetric principles.

"Photogeological investigation" is one of the methods of geological investigation applied by the above-mentioned study and is most effective for the work of geological mapping as the preliminary step for the study of geology.

The photogeological method and the obtainable information and data are essentially different from those of field geology. A geologic map is an accumulation of observed geologic information and data, and the reliability and accuracy depend mainly on the quantity of data portrayed. Photogeological observation's are much more effective than field geological observations to recongnize the relation between each geologic unit uniformly as plane- and stereo-figures. But in order to recognize true rocks, the physical and chemical features of rocks, the actual and detailed condition of fissures and the geohistorical age, etc, direct observations and measurement of out-crops, laboratory work of sampled rocks and fossils are indispensable.

As mentioned above, photogeological investigation is one of the effective methods of geological investigation, the same as seismic prospecting and the drilling method. It has tremendous merit which will be improved by using this method along with other methods.

The photogeological method is most effective in the following cases.

a) General and regional investigation for geologically virgin areas.

b) Preliminary investigation for detailed field investigation.

2. "Geologic interpretation" in photogeology may have two processes of observation and interpretation.

The "Observation process" includes observation of serial photographs to obtain geological information and recording them.

The "Interpretation process" includes interpretation of obtained geological information by observation and field confirmation.

Geological interpretation is the results of the combination of inductive and reductive inference from the obtained information and also requires theoretical and experimental treatment. One should note that the results of geological interpretation may not be conclusive without field observation and confirmation.

3. Photogeological interpretation depends upon information concerning the following photographic elements.

a. photographic tone

b. color

c. photographic texture

d. photographic pattern

linear pattern

- natural lineation
  - geological lineation
    - macro-lineation ⟶ photolineament
    - micro-lineation ⟶ fracture trace
  - non-geological lineation
- artificial lineation

drainage pattern

vegetation pattern

artificial pattern

e. topography (shape of surface)

- constructive shape
- destructive shape
  - erosion
  - relief

f. size

g. combination of each element

Vertical exaggeration of stereo-figures and the scale of the photographs also have direct effect upon interpretation.

4. Geological information interpreted from aerial photographs may be classified as follows.

a. lithological character

1) chemical composition

2) physical character

a-1) is almost impossible to be interpreted.

a-2) is also very hard to be interpreted.

b. geological structure

1) minor scaled structure (bedding, foliation, schistosity etc.)

2) major scaled structure (faulting, folding, etc.)

b-1) depends mainly upon the scale of photograph.

c. geological age

1) absolute geological age

2) relative geological age of geological unit and structural movement

c-1) is impossible to be interpreted.

5. The quantity of geological information interpreted from aerial photographs mainly depend on the lithological exposure conditions. These conditions may be under control of the following:

a. climatic situation

1) arid area

2) tropical area

a-1) is suitable for interpretation

a-2) offers relatively little information due to the thick overburden and the heavy vegetation cover.

b. lithological situation

1) sedimentary rock area { consolidated rock / unconsolidated rock }

2) igneous rock area { extrusive rock / intrusive rock }

3) metamorphosed rock area

Interpretable information increases from 1) to 3).

c. cycle of erosion

1) stage of youth

2) stage of maturity

3) stage of old age

4) ultimate form

The most important element for photogeological interpretation among those mentioned above are topographic features and linear patterns.

Topographic features reflect the lithological conditions and the geological structure.

Linear patterns reflect the bedding, fracture, fissure, sheared zone, fault line, folding axis and so on, but do not always present themselves directly.

6. From the point of view mentioned above, it seems quite reasonable to consider that there is a limit to photogeological investigations and that there may be some misunderstanding to expect detailed information and data which are directly practical and useful for such purposes as dam construction or research of mineral resourses. Namely, regional photogeological surveys are very useful in obtaining general geological information and data, but they are not necessarily of value to clarify the detailed conditions of specified areas.

CONTENTS

In compiling topographic maps required for surveys on the mineral resources in Central Sulawesi, Republic of Indonesia, the survey team composed of the following four engineers executed the ground control survey.

Chief Survey engineer :	Fumito Johno, Kokusai Aerial Surveys Co., Ltd.		
Members :	Tetsuo Shimizu	"	"
	Shiro Horibe	"	"
	Katsuyuki Kasai	"	"

The survey team collected various data for ground control surveys and conducted field works during the period from September 21 to November 25, 1970.

1. SURVEY AREA

The survey area is bounded by the following grids covering approximately 14, 160 km^2.

Northern margin	latitude 1° south
Southern margin	latitude 2° south
Eastern margin	longitude 120° 28' 27.79"
Western margin	western coastal line of the Middle Sulawesi

2. SURVEY PLAN

It is necessary to establish some new ground control points in the project area for carrying out succeeding aerial triangulation works.

The team was informed by the preliminary survey team that considerable number of national control point existed on the eastern side of the central part in the project area.

Though the number and distribution of these control points in Sulawesi Island were insufficient for carrying out succeeding aerial triangulation work, four tie lines and four ground control points were necessary for calculation of Block Adjustment, one of the effective ways of the Analytical Method in aerial triangulation.

For this purpose, three new control points were decided to be established on the western coastal side where no national control point existed on the tie line and one new control point was to be made on the north-eastern coastal side by astronomical survey and barometric altimeter.

3. DATA COLLECTION

The team obtained a coordinates list of national control point from Geological Survey of Indonesia (G.S.I.). The following features have been clarified upon confirmation at G.S.I. and the Indonesian Army.

(1) Initial point of the Republic of Indonesia is on the meridian of 106° 28' 27.79"E in the latitude of Greenwich base, which passes through Djakarta.

(2) Initial point of Sulawesi Island are longitude of 0° and latitude of 121 28' 27.79"E which is 15° easter from Djakarta meridian.

(3) The coordianates of national control point on Sulawesi Island are shown in the Mercator Projection.

4. FIELD OPERATION

4-1 Establishment of new ground control points.

As planned before departure for Djakarta, three points were established at Larian, Kasoloang and Kambunong of the western coastal area and another point was made at Tindaki of the north-eastern coastal area, which were given on the photos of tie line.

4-2 Equipments

A. Astronomical Survey

a. NI-2 (semi-first order leveling instrument)

b. Crystal Watch

c. Alarming Receiver

B. Distance Measurement

a. Tellurometer

4-3 Method

The coordinate of newly established control points are measured by astronomical survey by which latitude and longitude of observation point can be obtained by counting the reaching time of a star to a fixed height. For this survey 12 stars were observed to calculate the coordinate of four control points. And the distance between an observation point and planimetric features which clearly confirmed on the aerial photo were measured by Tellurometer.

4-4 Circumstances

a. Transportations

In the western coastal area, the survey team moved from Palu to Dongala by land and advanced south, from Dongala to Makassar Strait by sea, and in the eastern coastal area they moved from Palu to Pargi by land and from Parigi to Tindaki by sea.

b. Weather Condition

For this observation of points by the astronomical survey, the clear whather is most favourable. During this period when the West-Monsoon Season was approaching, 12 stars were barely possible to be observe and measurement of altitude by barometric altimeter had to be abandoned.

5. DOMESTIC WORK

5-1 Conversion of Coordinate

The coordinates of national ground control points in Sulawesi Island which were previously informed by the preliminary survey team are based on Indonesian intial point. Accordingly, the longitude of national control point on Sulawesi Island were converted into the Greenwich base, that is, UTM (Universal Transverse Mercatol) coordinate, by an electronic computer. The flattening adopted for conversion of coodinates is $(a - b) / a = 1/299.1528128$ where the Republic of Indonesia uses "Bessel Spheroid"

a : the longer radius of the earth

b : the shorter radius of the earth

5-2 Calculation of newly established control points

The latitude and longitude of each new control point was calculated by the Method of Least Square with data obtained through observation of 12 stars. The maximum error of the four new control point is 15" in angle, that is, approx. 40m in length, which is sufficient in accuracy for compiling a topographic map of 1/50,000.

5-3 Marking on the Aerial Photographs

The position of new control points were marked on the aerial photograph for aerial triangulation and mapping works.

DEPARTMEN ANGKATAN DARAT
DIREKTORAT TOPOGRAFI
DINAS GEODESI

TABLE (1) REPUBLIC OF INDONESIAN CONTROL DATA LIST

KOORDINAT TITIK^2 TRIANGULASI DI SULAWESI.

Titik		Bagian deradjat	Koordinat Polyeder :		Koordinat Mercator :		Koordinat Geografi :		Tinggi (meter)
No.	Nama		x	y	x	y			
P. 18	B. DALI	77/XXIV	-18.047,11	+13.092,48	-185.014,97	-189.635,61	-1°39' 43",958	-1°42' 53",682	2262,7
19	LAMPOPANA	76/XXIII	-13.427,55	+ 8.045,35	-217.493,74	-157.816,39	-1 57 14,422	-1 25 38,029	2479,6
20	NGKILALAKI	77/XXII	-15.973,78	- 9.975,02	-182.937,45	-138.976,82	-1 38 36,765	-1 15 24,776	2354,6
21	G.FEKAWA	75/XXII	+17.482,67	+ 8.684,38	-223.678,46	-120.313,45	-2 00 34,455	-1 05 17,218	2314,0
57	TILOE	77/XXIV	+17.716,11	+13.731,37	-149.235,98	-188.996,46	-1 20 26,754	-1 42 32,880	2244,1
T. 1425	B.KOKU	77/XXIII	- 9.486,09	-15.635,52	-176.449,80	-181.505,88	-1 35 06,934	-1 38 29,089	1293,6
1391	B.WITIMPONDO	77/XXIII	+11.057,14	+15.498,75	-155.899,61	-150.360,94	-1 24 02,277	-1 21 35,350	2295,4
1392	B.MOENGKOE	77/XXIII	- 4.607,06	- 3.310,40	-171.568,56	-169.176,23	-1 32 29,059	-1 31 47,786	1784,3
1396	B.PORAMBOEA	77/XXIII	+15.803,07	-11.962,48	-151.150,64	-177.831,05	-1 21 28,680	-1 36 29,483	1946,4
1397	B.MAPIPI	77/XXIII	-16.366,26	+16.146,99	-183.331,70	-165.817,16	-1 38 49,516	-1 29 58,452	1972,0
1400	B.TALABOBANGKE	77/XXIV	+10.298,53	+16.706,77	-156.656,97	-186.020,30	-1 24 26,772	-1 40 56,018	2198,8
1401	B.TOEO	77/XXIV	- 1.600,58	+10.880,78	-168.561,17	-154.978,69	-1 30 51,791	-1 24 05,661	1923,6
1405	B.PU E PUDI	77/XXIV	+ 3.394,50	-13.450,13	-163.563,41	-216.192,52	-1 28 10,148	-1 57 17,936	1836,3
1407	B.TAPU	76/XXIV	+12.587,91	- 4.455,19	-191.467,47	-207.192,23	-1 43 12,651	-1 52 25,048	1847,0
1408	B.MAREMO	77/XXIV	-16.362,60	+ 7.396,64	-183.330,18	-195.334,20	-1 38 49,467	-1 45 59,143	2232,0
1409	B.ULU BANASU	77/XXIV	+ 5.277,63	- 1.789,20	-198.781,70	-204.525,18	-1 47 09,217	-1 50 58,254	1775,2
1410	B.ULU MEA	76/XXIV	+ 2.167,33	-13.880,04	-201.893,48	-216.622,70	-1 48 49,861	-1 57 31,934	2529,8

Tjatatan : 1. Koordinat Mercator dan Geografi menurut sistim SULAWESI + 15° 0' 0" Timur Djakarta.
2. Meredian Djakarta = 106° 48' 27", 79 Timur Grenwich.

DEPARTMEN ANGKATAN DARAT
DIREKTORAT TOPOGRAFI
DINAS GEODESI

KOORDINAT TITIK2 TRIANGULASI DI SULAWESI.

Titik		Bagian deradjat	Koordinat Polyeder :		Koordinat Mercator :		Koordinat Geografi :		Tinggi (meter)
No.	Nama		x	y	x	y			
T. 1413	B. PAI PPNOPOA	76/XXIV	- 9.474,00	- 3.349,81	-213.541,04	-206.086,44	-1° 55' 06,580"	-1° 51' 49,062"	2348,0
1415	B. LAMATI	76/XXIV	- 419,47	+ 7.392,96	-204.481,72	-195.338,55	-1 50 13,573	-1 45 59,285	1815,1
1418	B. IEHIO	76/XXIII	-11.520,86	- 8.881,68	-215,587,26	-174.449,31	-1 56 12,761	-1 34 39,416	1779,2
1420	B. MENEIUTIH	76/XXIII	+ 3.033,56	-12.558,75	-201.027,31	-178.428,04	-1 48 21,846	-1 36 48,914	1204,7
1422	B.	76/XXIII	+11.983,11	- 2.376,37	-192.074,75	-168.241,62	-1 43 32,294	-1 31 17,365	1435,8
1424	B. WONGU	76/XXIII	+ 6.150,61	+ 8.385,43	-197.909,57	-157.476,50	-1 46 41,009	-1 25 26,966	1819,3
1389	B. ROREHANTIMBU	77/XXII	- 70,50	-12.250,97	-167.030,38	-141,253,72	-1 30 02,281	-1 16 38,894	2508,4
1390	B. TOW	77/XXIII	-14.603,52	- 5.846,14	-144.466,51	-171.712,48	-1 17 52,495	-1 33 10,337	2228,6
1399	B. INDURO	78/XXIII	-17.957,52	+15.115,53	-147.820,19	-150.743,86	-1 19 40,963	-1 21 47,814	2087,2
1472	B. ELL	77/XXIV	+10.310,19	- 1.571,53	-156.644,36	-204.307,20	-1 24 26,365	-1 50 51,160	2025,3

Tjatatan : 1. Koordinat Mercator dan Geografi menurut sistim SULAWESI + 15° 0' 0" Timur Djakarta.
2. Meredian Djakarta = 106° 48' 27", 79 Timur Grenwich.

Bandung, 16 - September - 1970
LEMBAGA

TABLE (2) REPUBLIC OF INDONESIAN CONTROL DATA LIST (UTM)

NO.	ZONE	LATITUDE LONGITUDE	N E	ELEV.
P-18	NI-51	– 1 42 53.682 120 8 43.832	9,810,231.436 182,412.701	2262.7
P-19	NI-51	– 1 25 38.029 119 51 13.368	9,842,023.339 149,868.581	2479.6
P-20	NI-51	– 1 15 24.776 120 9 51.025	9,860,918.434 184,425.923	2354.6
P-21	NI-51	– 1 5 17.218 119 47 53.335	9,879,552.618 143,632.601	2314.0
P-57	NI-51	– 1 42 32.880 120 28 1.036	9,810,921.080 218,200.426	2244.1
T1425	NI-51	– 1 38 29.089 120 13 20.856	9,818,376.686 190,969.474	1293.6
T1391	NI-51	– 1 21 35.350 120 24 25.513	9,849,558.215 211,488.822	2295.4
T1392	NI-51	– 1 31 47.786 120 15 58.731	9,830,717.562 195,836.168	1784.3
T1396	NI-51	– 1 36 29.483 120 26 59.110	9,822,085.987 216,271.088	1946.4
T1397	NI-51	– 1 29 58.452 120 9 38.274	9,834,062.977 184,063.483	1972.0
T1400	NI-51	– 1 40 56.018 120 24 1.018	9,813,887.911 210,774.196	2198.8
T1401	NI-51	– 1 24 5.661 120 17 35.999	9,844,924.570 198,827.512	1923.6
T1405	NI-51	– 1 57 17.936 120 20 17.642	9,783,700.844 203,910,672	1836.3
T1407	NI-51	– 1 52 25.048 120 5 15.139	9,792,657.890 175,985.444	1847.0

NO.	ZONE	LATITUDE LONGITUDE	N E	ELEV.
T1408	NI-51	−1 45 59.143 120 9 38.323	9,804,533.235 184,106.736	2232.0
T1409	NI-51	−1 50 58.254 120 1 18.573	9,795.313.792 168,663.768	1775.2
T1410	NI-51	−1 57 31.934 119 59 37.929	9,783,205.761 165,571.717	2529.8
T1413	NI-51	−1 51 49.062 119 53 21.210	9,793,726.317 153,899.770	2348.0
T1415	NI-51	−1 45 59.285 119 58 14.217	9,804,495.433 162,945.768	1815.1
T1418	NI-51	−1 34 39.416 119 52 15.029	9,825,380.381 151,800.432	1779.2
T1420	NI-51	−1 36 48.914 120 0 5.944	9,821,420.773 166.375.853	1204.7
T1422	NI-51	−1 31 17.365 120 4 55.496	9,831,625.670 175,319.045	1435.8
T1424	NI-51	−1 25 26.966 120 1 46.781	9,842.389.515 169,466.525	1819.3
T1389	NI-51	−1 16 38.894 120 18 25.509	9,858,657.338 200,343.831	2508.4
T1390	NI-51	−1 33 10.337 120 30 35.295	9,828,213.853 222,949.074	2228.6
T1399	NI-51	−1 21 47.814 120 18 46.827	9,849,163.684 201,013.524	2087.2
T1472	NI-51	−1 50 51.160 120 24 1.425	9,795,598.073 210,812.358	2025.3

TABLE (3) CONTROL DATA LIST (UTM) OF NEW GROUND CONTROL POINT

NO.	ZONE	LATITUDE LONGITUDE	N E	ELEV.
No. 1	NI-51	−0 59 59.800 119 28 9.200	9,889,275.035 106,967.478	0.7
No. 2	NI-51	−1 29 36.800 119 17 31.000	9,834,584.222 87,283.599	2.5
No. 3	NI-51	−1 56 59.600 119 17 1.100	9,784,041.688	0.7
No. 4	NI-51	−0 55 59.900 120 16 55.500	9,896.734.567 197,524.693	0.3