REPORT
ON
MINERAL EXPLORATION
IN
THE BICOL NORTH AREA
THE REPUBLIC OF THE PHILIPPINES

(PHASE I)

MARCH 2000

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

In response to the request of the Government of the Republic of the Philippines, the Government of Japan decided to conduct Mineral Exploration project consisting of Airborne survey, Geological survey, Geochemical survey, Drilling and the relevant work in the Bicol North area, the Republic of the Philippines, and entrusted the survey work to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

The survey conducted during this fiscal year is the first-phase (Phase-I) of a three-phase project to be completed 2002. MMAJ sent a survey team to the Philippines from February 2 to March 6, 2000. The field survey was completed on schedule with the cooperation of the Philippine government authorities.

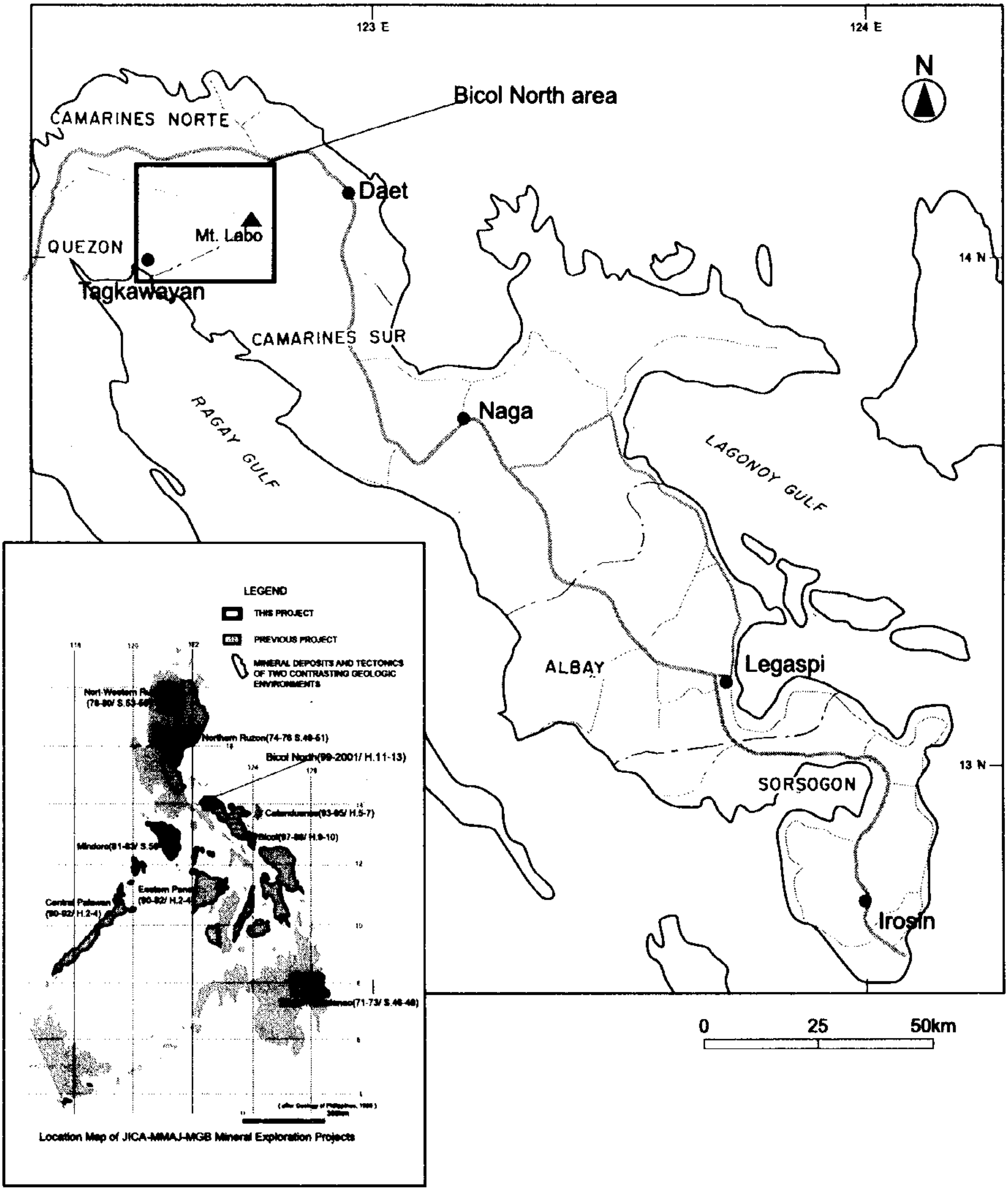
Results of the first-phase survey are summarized in this report which constitutes a part of the final report.

We wish to express our deep appreciation to the officials concerned of the Government of the Republic of the Philippines for their close cooperation extended to the survey team.

March, 2000

Kimio Fujita
President
Japan International Cooperation Agency

Naohiro Tashiro
President
Metal Mining Agency of Japan



Location map of the survey area

CONTENTS

FIGURES

Chapter 1 Introduction

1-1 The Objective of the Survey

The objective of the survey is to delineate mineralization from the Bicol North area in the Republic of the Philippines, through airborne geophysical survey, geological and geochemical survey. In this Phase I survey, the objective is to obtain aeromagnetic and aeroradiometric data of the Bicol North area to delineate geology and geological structure. Once prospective units and structures have been located, the airborne geophysical data can be used to give some indication of the potential for mineralization.

1-2 Description of Implementation of the Survey

The Republic of the Philippines is a country with considerable mineral resources, producing gold, silver, copper, nickel, etc., and has a high potential as regards mineral resource endowment in terms of porphyry copper ore deposits accompanying island-arc igneous activity, epithermal vein deposits, etc.

That being the case, the government of the Philippines lowered taxes on mining production in 1994, revised the Mining Industry Law (including FTAA allowing 100% foreign capital) in 1995 and started to make changes in registration of mining right in 1997. With stabilization of the political situation in the country and inauguration of an system open to foreign capital, many foreign companies will be participating in prospecting, and that can be expected to vitalize prospecting and development in the coming years.

Basic surveys by the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ) for cooperation in development of mineral resources in the Republic of the Philippines got started in 1971 and up to 1998 were carried out in the 8 areas indicated below (the figures for the years of implementation indicate the Japanese fiscal years [running from April 1 through March 31]) (see Fig.1):

- East Mindanao (mineral exploration survey) 1971-1973
- Northeast Luzon (mineral exploration survey) 1974-1976
- Northwest Luzon (mineral exploration survey) 1978-1980
- Mindoro area (mineral exploration survey)

1981-1983

- Bisayas area (mineral resources basic mapping survey) 1984-1989
- Palawan-Panay area (mineral exploration survey) 1990-1992
- Catanduanes area (mineral exploration survey) 1993-1995
- Bicol area (mineral resources regional survey) 1997-1998

The survey of the Bicol North area implementation of which will start this year is in response to a request by the government of the Philippines made in May 1999. The survey was adopted as a Regional survey for mineral resources for 1999. On July 21, 1999, the "Implementing Arrangement" (I/A) was signed by Mr. Toshihiko HAYASHI, Director of the Metal Mining Agency of Japan, and Mr. Mario Rono, Undersecretary of the Department of Environment and Natural Resources (DENR), and Mr. Horacio C. RAMOS, Director of the Mines and Geosciences Bureau (MGB) of the Republic of the Philippines.

1-3 An outline of Phase I survey

1-3-1 Survey Area

The survey area covers an area 750 km2 in the provinces of Camarines Norte, Camarines Sur, Queson on the Bicol Peninsula of southeastern Luzon (see opening page and Fig.1). In the area there is a fault running NW-SE, along with many volcanoes are to be found. One of them is the famous Mayon Volcano, which soars nearby the city of Legazpi, the largest in the area. Much is expected of this survey in view of the fact that many places in it could not be entered in the past because of guerilla activity and hence not much progress has been made before now in surveying it.

1-3-2 Survey Methods

(1) Airborne Geophysical Survey

Selection of areas on the basis of the results of analysis of existing data, analysis of satellite images and the ground traces and implementation of airborne geophysical survey for the purpose of determining geological structure under the surface of the ground. Aeromagnetic and aeroradiometric measurement with flight line intervals of 200m using helicopters (only acquisition of data in the first year).

1-3-3 Members Participating for the Survey

(1) Members participating in planning and negotiation

a) Japanese side

Toshihiko HAYASHI	(Leader of the team, Director, Metal Mining Agency of Japan: MMAJ)
Masashi KASAI	(Energy & Mining Development Study Division, Japan International Cooperation Agency: JICA)
Hiroshi SHIBASAKI	(Mineral Resource Survey Department, MMAJ)
Yoshiharu KIDA	(Representative of Bangkok Office, MMAJ)

b) Philippine side

Mario RONO	(Undersecretary, Department of Environment and Natural Resources: DENR)
Pedro C. CALEON	(Assistant Secretary, DENR)
Horacio C. RAMOS	(Director, Mines & Geosciences Bureau; MGB)
Edwin G. DOMINGO	(Assistant Director, MGB)
Romeo L. ALMEDA	(Chief, Lands Geology Division; LGD, MGB)
Roland PENA	(Chief, Planing and Policy Division, MGB)
Claro Jose MANIPON	(Project manager, MGB)
Arnel F. JUSI	(Chief geologist for Region V, MGB)

(2) Members participating in the Airborne Geophysical Survey in the Philippines

a) Japanese side

Hiroshi SHIBASAKI	(Mineral Resource Survey Department, MMAJ)
Takeshi MORIYA	(Representative of Bangkok Office, MMAJ)
Yoshiharu KIDA	(Representative of Bangkok Office, MMAJ)

b) Philippine side

Lomeo L. ALMEDA	(Chief, LGD, MGB, DENR)
Claro Jose MANIPON	(Project manager, MGB)
Arnel F. JUSI	(Chief geologist for Region V, MGB)

Data acquisition

William CHURCHWARD	(Field Manager / Data Processing, World Geoscience Corporation Limited (WGC))
Paul Anthony SEGHEZZI	(Airborne Instruments Operator, WGC)

Helicopter Flight

Mapagtapat ONGCHANGCO, Jr. (Helicopter pilot, JAKA Transport)

Danilo JOSE (Helicopter maintenance crew, JAKA Transport)

Perciva GANZALES (Helicopter maintenance crew, JAKA Transport)

(5) Preliminary Interpretation (in Japan)

Toshihiko HAYASHI (Director, Mineral Resources Survey Department, MMAJ)

Claro Jose MANIPON (Project manager, MGB)

1-3-4 Period and Performance of the Survey

(1) Planning and negotiation

1997.5.25.(Sun)~1997.5.31.(Sat)

(2) Airborne Geophysical Survey (Data Acquisition)

1999.2.2.(Wed)~1999.3.6.(Mon)

Flight lines 4,216.4km

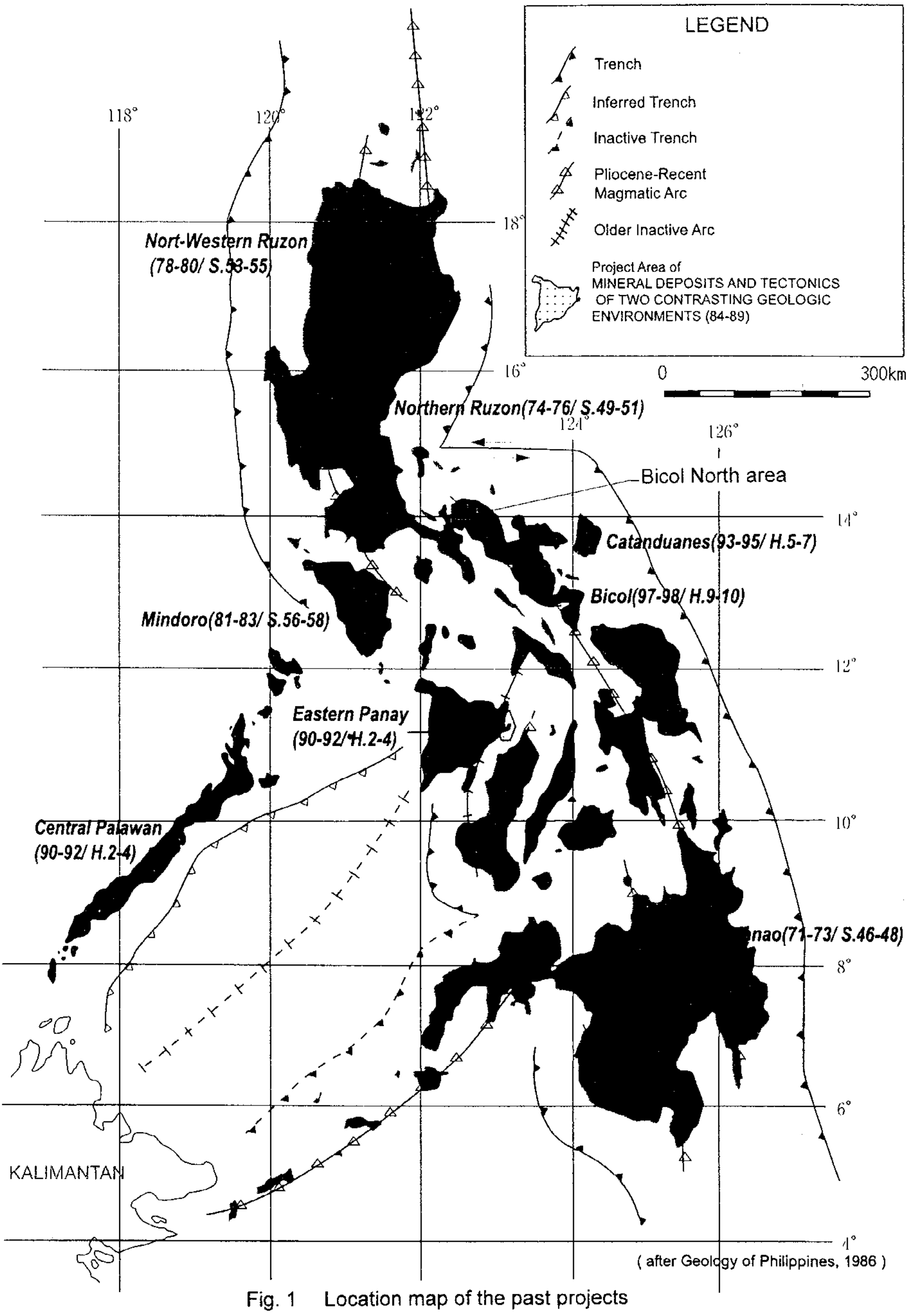


Fig. 1 Location map of the past projects

Chapter 2 Geography of the Survey Area

2-1 Location and Accessibility

The survey area is located in the northwestern part of the Bicol peninsula. It is bounded by the following coordinates (Fig. 3);

122° 32' 10" E	14° 08' 35" N
122° 48' 50" E	14° 08' 35" N
122° 32' 10" E	13° 55' 00" N
122° 48' 50" E	13° 55' 00" N

The survey area includes four provinces of Camarines Norte, Camarines Sur, and Queson. (opening page and Fig. 1)

The cities of Labo and Daet are located in the Camarines Norte on the northeast part of the survey areas. It takes about 5.30 hours by car from Manila to Labo, about 265 km. apart. The southern part of the survey area are located the city of Tagkawayan (Queson province) and Del Gallego (Camarines Sur province). It is about 260 km. from Manila to Tagkawayan, or about 5 hours by car.

Roads are very rare in the survey area except access roads near Mapulot on the southwest. Therefore, the areas must be entered independently from the national road of the north and the south.

2-2 Topography

Labo volcano (1,572m) is located on the east of the survey areas. More than ten dacite domes with 1.5km in diameter, 200-400m height are scattering at the foot of Mt. Labo. On the west of Labo volcano, the Susungdalaga Mountains is located. Its elevation ranges from 300m to 600m. The mountains has relatively gentle slope with dissected valleys. The mountains ridge develops WNW – ESE in direction, and it becomes watershed between the north basin and the south basin. The southern part of the Susungdalaga Mountains is the low land with elevation of 100m or less.

2-3 Drainage

Labo River system is on the north of the survey area, and Bosigon River system on the northwest position. Both rivers flow northerly. Kilbay River flows southerly. is on the south that is surrounding the mountainous Susungdalaga. Kilbay river is naturally controlled to flow into northerly west-west and southerly east-east on the south of the Susungdalaga Mountains.

2-4 Climate

Climate is characterized by rainfall which is more or less evenly distributed throughout the year except for the occurrences of tropical typhoon in the vicinity which causes rainfall abnormalities.

Data from Philippine Atmospheric, Geophysical and Astronomical Sciences Administration (PAGASA) showed that the hottest months are May and June with temperatures ranging from 28.1 to 29.4 degrees centigrade and the coldest months are January and February with temperature from 20.8 to 25.3 degrees centigrade based on1951 to 1985 records.

The occurrence of tropical typhoons in the Region-V from 1990 to 1996 totals 61 mostly during the 4th quarter. The annual average number of typhoons that passes the Philippine area of responsibility is 9 and 2 of these are expected to cross the Bicol region.

2-5 Vegetation

In general, the survey area is covered by secondary trees growth, bushes, shrubs, and agricultural plants such as coconut, abaca, rice, corn and various types of grasses. Primary forestation is limited and sporadically distributed at higher elevations and ridges

A considerable part of the survey area is unutilized or unproductive. It is covered with cogon and other grasses. Barren areas are limited owing to the high rainfall the region is receiving. Outcrops are mostly confined along the river banks or at very steep slopes.

Chapter 3 Existing data on the Geology and Ore deposits of the Survey Area

3-1 Geological Outlines of the Bicol North Area

The Bicol area can be divided into the following three zones by its geology, the age, distribution, and occurrence of mineralization and alteration as shown in Fig. 2 (JICA/MMAJ, 1999).

Northeastern Belt
Central Belt
Southwestern Belt

These zones can be recognized as metallogenic belts.

The Central Belt is defined as a zone in which Pliocene to recent volcanic rocks distributed in the central part of the Bicol Peninsula. Northeastern Belt and Southwestern Belts are the zones, not including the Central Belt, where Pre-Cretaceous and Cretaceous basements including the ophiolite sequence is distributed with the Tertiary intrusive. In these Belts, the northeast part of the Bicol area is called the Northeastern Belt, and the area lying along southwest coast is called the Southwestern Belt. Of these Belts, the Southwestern Belt is covered with the Tertiary sedimentary rocks, so that its distribution area is intermittent and narrow.

The Bicol North area is located on the northwest end of the Central Belt (Fig. 2). Most of the area is underlain by volcanic rock from Pliocene to Holocene. The south and the southwest parts are located on the Southwestern Belt (Fig.2).

Geological map of north Bicol is in Fig. 3. This map has been compiled under reference of the following publications.

- Geological Map of Bicol Region (1:250,000) by BMG Regional Office V
- Geological Map Quadrangles (1:50,000) of Sheet No. 3462-I, II; 3561-I, Iv; 3562-I, II, III, IV; 3563-II, III; 3661-III, IV; 3662-II, III.

The vicinity of Labo volcano is the geothermal development project of PNOC. PNOC are conducting boring exploration and physical exploration (Zeide-Delfin et al., 1995; Banos et al., 1996).

In the mineral resources regional survey in the Bicol area implemented in 1997-1998 (JICA/MMAJ, 1999), the south zone of Susungdalaga Mountains was investigated as 'Kilbay area' and the western lowland as 'Tuba South area' (JICA/MMAJ, 1999). In this reconnaissance survey, the Susungdalaga Mountains consists of hornblende-biotite deictic lava and volcaniclastic rocks. The K-Ar ages of the volcanic rock are 4.32±0.48 Ma, 3.75±0.42 Ma, and 3.45±0.39 Ma, which indicate early Pliocene age. The volcanic rocks of Labo volcano and the Susungdalaga Mountains are showed as the same rock unit in Figure 3. However, the previous reconnaissance survey discriminated between the volcanic rocks of Mt. Labo and Susungdalaga Mountains. The survey also clarified that the hydrothermal alteration and mineralization distributed in 'Kilbay area' is hosted in early Pliocene volcanic rocks.

In the 'Tuba South area', Granodiorite of Early Oligocene is said to have intruded in Tigbinan Formation of Late Cretaceous mainly consisting of mudstone, sandstone, and tuff (Fernandez, 1984). They are covered, especially in southern part, with sedimentary rocks (Bosigon Formation) of Early Miocene and intruded andesite dike whose age is unknown. Sedimentary rock is not observed as exposure in the north of Mapulot but distribution of andesite is superior. The Tertiary intrusive rocks, which delineated in the existing geological map (Fig. 3) on the west of the survey area, could not be recognized in the previous survey.

3-2 Ore Deposits and Mineral Showings in the Bicol North Area

As shown in Fig. 2, the Bicol North Area locates both on the Central Belt and the Southwestern Belt (JICA/MMAJ, 1999). It is possible that the epithermal deposit to the porphyry deposit exists as, for instance, proved as the Nalesbitan ore zone on the north of this region. In addition, the mesothermal deposit or the ore vein of intrusive rock in Paracale region is expected because of similarity in geological settings. This example is proved as old Tuba mineral deposit on the west of this region.

The Nalesbitan deposit exemplifies the possible mineral deposit that may be discovered in the survey area. It is classified as a high sulfidation gold deposit that had been developed by a major mining company. Nalesbitan mineralization is controlled by left-lateral faults of NW-SE direction (Sillitoe et al., 1990). The same type or porphyry type mineralization might be formed at along the extension of the faults (Sillitoe et al., 1990). Numerous small-scale miners are now exploiting it and have recently uncovered the occurrence of enargite minerals in quartz veins. A junior US-based company is now closely studying the deposit for possible porphyry-type mineralization at depth. Nalesbitan is located inside the Central Belt but very near the Northeastern Belt.

The other known occurrences of gold-bearing veins in the survey area are found in Matanlang (Northeastern Belt), Tuba and Mapulot (Southwestern Belt). The streams in the Kilbay area, located inside the Central Belt, have been panned for gold. Recent field observations revealed the presence of strong hydrothermal alteration in the Kilbay area (JICA/MMAJ, 1999). According to JICA/MMAJ (1999), an outline of the hydrothermal alteration and mineralization in the Kilbay area is as follows.

- Alteration and mineralization zones in the Kilbay area distributes in about 11km length on WNW-ESE direction from Alawihaw-Kilbay creek to Tonton River. These alteration distributions are illustrated on the tentative analytic map on appendix 1.
- Many quartz veins or faults are observed both in WNW-NW direction and NE-ENE direction. Fault topography in WNW direction is observed on the south of Susungdalaga Mountains. It is thought that the hydrothermal activity is controlled on these fractures.
- The alteration zone is widely occupied with quartz-interstratified illite/smectite clay zone with quartz veins. The style of gold mineralization is low-sulfidation epithermal.
- The assay of the quartz veins and altered rocks in Layaton creek returned 180ppb - 275 ppb Au, 500ppm - 830ppm Cu, 34ppm Mo, and 3260ppm P.
- The 45°C to 80°C hot spring are found in Alawihaw-Kilbay creek on the east of Layaton creek. The quartz veins and altered rocks in the creek have geochemical anomalies e.g. Au (max. 535ppb), As (max. > 10000ppm), Hg (max. 69ppm), Sb (max. 350ppm), Ti (max. 140ppm), Mo (54ppm) and Zn (688ppm).
- Gold mineralization and alteration zone are found in Tonton River on the west of the Susungdalaga Mountains. Intensely silicified rocks are discovered in the Tonton River. Black to gray colored chalcedonic quartz veinlets are observed in silicified boulders. The assay data returned 590-830ppb Au and 690-2500ppm As.

According to JICA/MMAJ (1999), an outline of the hydrothermal alteration and mineralization in the Tuba South area is as follows.

- The alteration exposure of 1km width, 2.5km width is observed as the mild tails expanding to north-eastern direction.
- Silicified rock is observable intermittently as exposure head at about 700m length, and accumulation of rock is on 500m south from the exposure head.
- Cr-bearing white mica (fuchsite) in the alteration rock is recognized. Quartz vein is also observed in the silicified rock (Au: 210 ppb, Ag: 10.4ppm, As: 112ppm).

- Quartz vein width maximum is 10cm with direction of N80° W, dipping 65° S. The vein is composed of transparent and coarse-grained quartz with minor disseminated pyrite.
- Fluid inclusion temperature of the vein quartz is 226-273°C and salinity of 1.57-3.23 wt% NaCl equivalent.

Quartz vein with Cr-bearing white mica (fuchsite) is also recognized in Santa Barbara quartz vein of Paracale. Ultramafic rock is expected to distribute in the surrounding basement rocks, and the geological setting and mineralization are similar to those of Paracale district. Thus the Tuba area may have potential for the same type gold mineralization distributed in Paracale district.

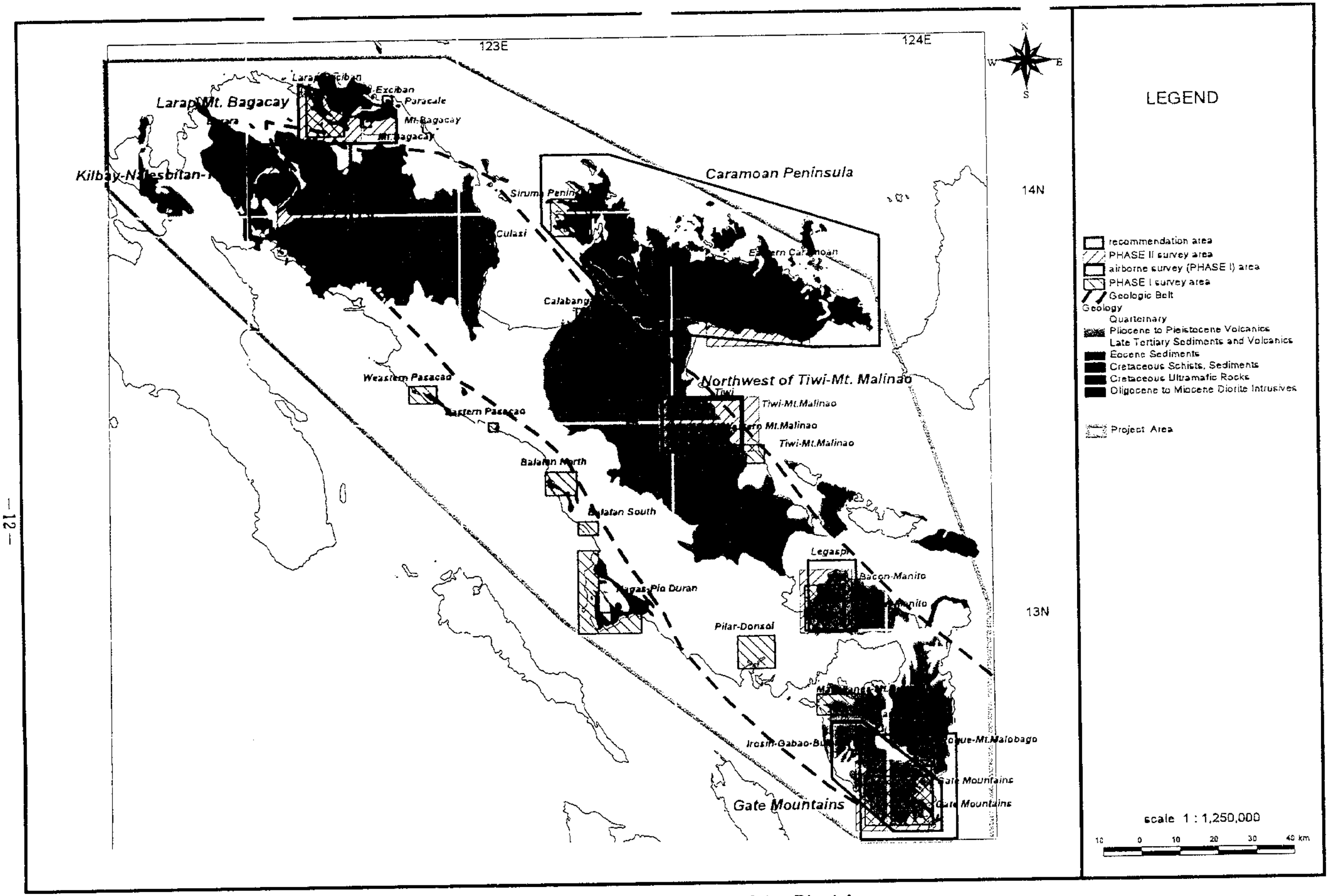


Fig. 2 Metallogenic belts of the Bicol Area

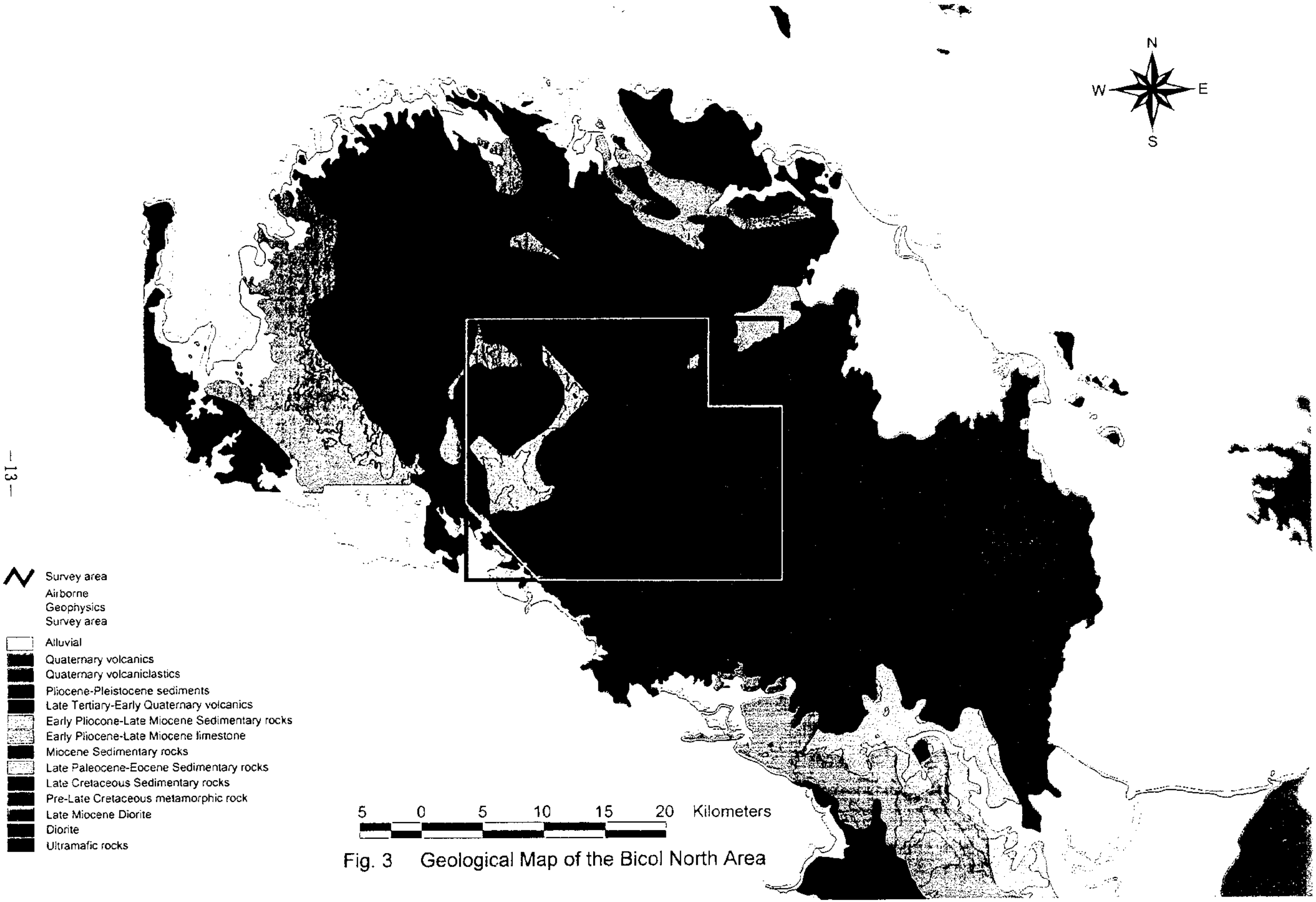


Fig. 3 Geological Map of the Bicol North Area

Chapter 4 Airborne Geophysical Survey

4-1 Objective

The prime objective of this study has been to produce a detailed geological map from a combination of airborne magnetic and radiometric data. A solid geological interpretation map that shows the structure and possible zones of alteration has been produced, at the scale of 1:50,000. However, in Phase I survey, due to the schedule, acquisition of the data

4-2 Survey Area

Measurement locations are indicated in Fig. 3 and Fig. 4 while their coordinates are given below.

14° 08' 35" N	122° 32' 10" E
14° 08' 35" N	122° 45' 00" E
14° 04' 00" N	122° 45' 00" E
14° 04' 00" N	122° 48' 50" E
13° 55' 00" N	122° 48' 50" E
13° 55' 00" N	122° 36' 00" E
13° 59' 00" N	122° 32' 10" E

4-3 Specification

To obtain accurate data, measurement must be made close to the ground with constant altitude. Measurement was made with helicopter since topography of the peninsula region with various volcanoes is mountainous. Measurement is not only made to aerial magnet but also 3-dimensional aerial radioactivity. Measurement was mat at 80m altitude with 200m flight interval. Specifications of measurement are given as follows.

Flight line spacing: 200m
Flight line direction: North-South
Tie line spacing: 1,000m
Tie line direction: East-West
Sensor height: 80m

Magnetometer sample interval : ~5m
Magnetometer cycle rate: 0.1 seconds
Magnetometer resolution: 0.001 nT
Radiometric sample interval : ~50m
Radiometric cycle rate: 1 second
GPS cycle rate: 1 second

Data Acquisition Company

Measurement was requested to World Geoscience Co., Ltd. (WGC) of Australia. The helicopter was hired from JAKA Transport of the Philippines.

4-4 Instrumentation

Measuring instrumentation is given below.

- Scintrex VIW2321/CS2 split beam: magnetic gauge with cesium and amplifying unit. It was installed to the boom (stinger mount) on the helicopter.
- Picodas PDAS 1000 data collection system: to compensate for data at real time or after readings against magnetic noise from helicopter flight.
- Picodas PGAM 256 channel automatic compensated spectrometer
- 16.75 liter NaI crystal sensor (1 unit)
- Electromagnetic altimometer
- Pressure altimometer
- Flight tracing video system of WGC
- Differential GPS satellite navigation system
- Picodas PNAV 2001 navigation system
- Pentium 486 PC with DC 2120 cartridge drive/floppy disk and color printer.
- Data quality control/supervision software of WGC
- Picodas differential compensation software

4-5 Collected Data Set

The following data have been collected.

1) Radiometric Total count: color	(Fig. 5, Fig. 6)
2) Radioactive U-count: color	(Fig. 7, Fig. 8)
3) Radioactive Th-count: color	(Fig. 9, Fig. 10)
4) Radioactive K-count: color	(Fig. 11, Fig. 12)

5) Radioactive U-Th-K ternary: color (Fig. 13)
6) Digital terrain model (DTM): color (Fig. 14)
7) Total magnetic intensity (TMI): color (Fig. 15)
8) Total Magnetic Intensity: Reduced to Pole (RTP): gray scale (Fig. 16)

4-6 Preliminary Interpretation

It is mentioned above that activity schedule of this year is only data collection from aerial physical exploration while analysis will be made in the following year. Therefore, we tried to make a preliminary interpretation based on data obtained above by comparison with features of topography, geology, mineral distribution and mineralization as obtained from the mineral resources regional survey in the Bicol area conducted in 1997-1998 (JICA/MMAJ, 1999). The results are indicated in appendix 1.

4-6-1 Methodology

The following components are identified from the airborne geophysical data to develop a litho-structural framework.

- Structural information such as the identification of magnetic linear trends, e.g. bedding/ volcanic layering and the subsequent truncations and offsets of these trends which may indicate, faults and fractures. Recognition of normal, strike-slip or thrust faults in airborne geophysical data is often possible through recognition of associated structures and analysis of overall geometry of a survey area.
- Magnetic and radiometric units which comprise geological bodies with uniform or characteristic magnetization or radiometric signature. These units may or may not coincide precisely with rock units that outcrop, as magnetic volcanic flows may be overlapped by successive non-magnetic volcanic flows.
- Discrete sub-circular magnetic highs believed to reflect intrusive plugs.
- Sub-circular features, often having subdued magnetic response that may correlate to volcanic centers.
- Broad areas of demagnetization ('magnetic flat region': Irvine and Smith (1990)), which may represent extensive areas of magnetite destructive alteration.
- The radiometric data is a record of the natural radioactive decay of exposed rocks as well as in-situ and transported weathering products. The biggest restriction with radiometric data is that emissions are only detected from the top 10 to 100cm of soil/ rock. A number of factors can therefore radically alter the apparent radiometric

character of a rock unit.

- Field of view of the sensor decreases with lower flying height, increasing quality.
- Speed of aircraft-slow, count rates more accurate.
- Degree of transportation of overlying material: if soils are in-situ for long periods and/or derived directly from the underlying rock they will reflect the relative differences between different rock types. However, if soils are transported then they may bare little to no resemblance to the underlying rock unit.
- Thickness of soil: due to the limited depth penetration of this survey technique, an increase in the thickness of burial will reduce the relative intensity of the radiometric signal.
- Survey conditions: survey clearance should be at a consistent flying height. However, an error of ± 20m is usually allowed and the results within these parameters are considered acceptable. If for example the aircraft is at the lower flying height (-20m) due to passing over a ridge or peak then the relative radiometric value may increase. The reverse would occur with an increase in flying height.

- Radiometric Th- and U-count may reflect the underlying rock units. According to the airborne geophysical survey in the mineral resources regional survey in the Bicol area conducted in 1997-1998 (JICA/MMAJ, 1999), U- and Th-count identifies the geological distribution.
- High K-count: In epithermal gold and porphyry copper-gold systems, It is generally expected that high potassium counts could show the alteration zone, because high K content minerals often occur in the epithermal and porphyry copper environment. Adularia, illite, and alunite often occur in the epithermal environment. K silicate alteration often occurs in the center of porphyry deposit. K silicate alteration in porphyry copper deposits commonly contains abundant hydrothermal magnetite in both veinlet and disseminated forms (Sillitoe, 1979). Thus, it is expected that high magnetic responses may be accompanied with the radioactive potassium counts in K silicate alteration zone in the porphyry copper system.

  However, according to the airborne geophysical survey in the mineral resources regional survey in the Bicol area conducted in 1997-1998, the radioactive potassium counts in the thick soil area like Bicol could not indicate the alteration zone but indicate the degree of exposure of rocks (JICA/MMAJ, 1999). This can be explained that potassium contents have much difference in rock and soil, while the contents of uranium and thorium in rock and soil are similar level. Since vegetation in the hydrothermal alteration area, especially in acid alteration, is generally weak and soil is not very developed. Consequently, some high K-counts might indicate the hydrothermal alteration zone.

4-6-2 Radiometric counts

Radioactive Total count and radioactive U-count, Th-count and K-count were observed to have the following features.

a. Higher response region of the Total count is distributed in southern part of the survey area (Fig. 5 and 6).

b. High responses of the Total count are observed in the following areas (Fig. 5 and 6):
   1) 122° 37' 30" E, 13° 55' N on the south: about 3km×4km.
   2) 122° 37' 30" E, 14° 00' N on western side of the central area: two eclipses of 2km×2km and 1.5km×1km.
   3) 122° 35' E, 14° 05' N on the northwest: about 1km diameter circle.
   4) 122° 42'30" E, 13° 59' N on south of the central area

c. Among the three elements, K-count gives the largest count. Next are Th-count and U-count in descending order. Variation amplitude of K-count is 7 to 54 (Fig. 12). Th-count ranges in its half or 7 to 33 (Fig. 10). U-count still ranges at its half or 4 to 17 counts (Fig. 8).

d. Distribution pattern of U- and Th-count are similar but differs from those of K-count.

e. The area with high U-count and Th-count concentrates on the south of central zone in the survey area (Fig. 8 and 10). The counts are low at east side (Labo volcano) and west side (older sedimentary rock) (Fig. 8 and 10).

f. Low Th-count at the east side (Labo volcano) is slightly higher than that at in the west side (Fig. 9). While low U-counts are almost same level both at west and east (Fig. 7).

g. The three zones with largest count of U and Th are
   1) Near 122° 37' 30" E, 13° 55' N on the south: about 3km×4km.
   2) Near 122° 37' 30" E, 14° 00' N on western side of the central area: two eclipses of 2km×2km and 1.5km×1km.
   3) Near 122° 35' E, 14° 05' N on the northwest: about 1km diameter circle.

   Those three areas correspond to the 1), 2), and 3) at high Total counts area, respectively.

h. Among these, area 2) gives high K-count as well (item ② of j. below), that is, high counts for the three elements. Therefore, feature in the Radiometric Ternary (Fig. 13) is indicated as white color.

i. Most of high K-count areas distribute along with tributary, stream or ridge (Fig. 12, Fig.

14)

j. Main high K-counts areas are distributed as follows (Fig. 11 and 12):

① South of the central area: 122° 42' 30" E, 13° 58' 30" N: Alawihaw - Kilbay creek

② West of the central area: 122° 37' 30" E, 14° 00' N: dome terrain of Susungdalaga mountains

③ West end of the south 122° 34' E, 13° 57' N

④ North of the central area: 122° 38' E, 14° 06' 30" N: Nalesbitan ore deposits.

⑤ North of the central area: 122° 40' E, 14° 07' N

⑥ North-west end: 122° 33' 30" E, 14° 09' N:

⑦ South of the central area: Susungdalaga mountains between ① and ②.

⑧ Center of the west: 122° 36' E, 14° 04' N:

⑨Center of the east: 122° 46' E, 14° 02' N: Labo volcano

⑩ North-east end: 122° 43' E, 14° 07' 30" N:

⑪ Center: 122° 42' E, 14° 03' N:

⑫ South-east end: 122° 44' E, 13° 55' 30" N:

k. In ③, ⑥, ⑧and ⑩ above, high K-counts are observed even on the relatively flat topography, where soil is expected to develop thickly.

l. In Radiometric Ternary map (Fig. 13), the central high U-count and Th-count of ③, ⑥ and ⑧above, are seen as the continuous red to pink belt with about 3.5km width along the west edge of blue color area, where high U- and Th-count locate.

Based on the above observation, the following interpretation could be possible.

A. From observation in c., e. and f. above, distribution pattern of U-count and Th-count, in particular Th-count, in the three elements is effectively indicating the lithology in the survey area.

B. The high K-count from observation d. and i. above basically reflects the stream and tributary where soil formation is not developed.

C. g.-2) and h.-② are expected to be intrusive rock, because both have high magnetic responses. Hydrothermal alteration zone distributes at the stream nearby, and magnetic flat region is also recognized at the alteration zone. However, since the both high K-counts areas have high magnetic responses (Fig. 15), they are expected to be intrusive bodies with no hydrothermal alteration and/or post hydrothermal intrusions.

D. g.-3) is expected as intrusive body since it matches with equal size dome topography (about 1km diameter), and high magnetic response is also observed. (Fig. 15).

E. Since hydrothermal alteration zone is exposed in j.-1) and-7), the high K-counts are explained as the extensive exposure of hydrothermal alteration zone (see JICA/MMAJ, 1999 and appendix 1). These areas are also the magnetic flat regions (Fig. 15 and appendix 1).

F. High K-count of j.-④ is also explained as the exposure of the hydrothermal alteration zone which includes the Nalesbitan high-sulfidation epithermal deposit. The high K-count stretches in the northwest direction, and it corresponds very well with topographical lineament and magnetic lineament. In addition, magnetic flat region distributes southerly from the Nalesbitan deposit.

G. Zone j.-⑤ is located at about 4km east from the Nalesbitan. According to topography, the sharp ridge around the mild hill is high K-count. The high K-count places on magnetic flat region. Therefore, hydrothermal alteration will possibly distribute.

H. Zone j.-⑨ almost corresponds to the distribution of the Labo volcanic rocks. High K-count distributes along the ravines and creeks. Zone j.-⑫ also corresponds to ravines and creeks.

I. Zone j.-⑪ distributes on location similar to zone j.-⑤. At the same time, the high K-count zone corresponds to the magnetic flat region. It is expected that hydrothermal alteration zone is spreading. In addition, the location of the high K-count is at intersection of the southeast extension of Nalesbitan trend, and southwest extension of alteration zone along Labo River.

J. From item k. and l. above, j.-③, ⑥, ⑧, and ⑩ might be located in the rocks with relatively high contents of potassium. Since the location and shape of this zone are similar to the sedimentary rock of late Miocene to early Pliocene in the existing geological map (Fig. 3), they can possibly indicate distribution of the sedimentary rocks.

Based on the interpretation above, the lithological classification of the areas is tentatively made as shown in Fig. 17.

4-6-3 Magnetic response

We chose the areas of low magnetic response with broad and rough magnetic contour ('magnetic flat region': Irvine and Smith (1990)) and the lineament being read from magnetic response distribution based on the Total magnetic intensity. Similar analysis is required on the reduction-to-the-pole total magnetic contour map in the future. Individual magnetic response anomaly zone and magnetic flat region are discussed in the abovementioned radioactive counts.

The magnetic flat regions (poor magnetic response) occur in many areas as small and large patches from less than 1 square kilometer to more than three square kilometers. A relatively dense concentration occurs from the northwestern-most corner in Tuba area then south to Tagkawayan. This concentration then trends southeast to Kilbay. A few patches occur at the mid-section of Labo River and at the slopes of Mt. Labo as well.

Some of these magnetic flat regions are coincident with high potassium count areas. A good example of such phenomena may be found in Kilbay and Nalesbitan areas. The coinciding occurrence of both high potassic count and flat magnetic response may be a stronger indication of hydrothermal alteration zones.

The magnetic lineaments seem to be concentrated along a corridor from Nalesbitan to Kilbay (appendix 1). Most lineaments strike northwest-southeast, which conforms to the dominant trend of the topographic lineaments. Many topographical lineaments correspond to magnetic lineament (appendix 1). Both topographic and magnetic lineament distributes in close relationship with the radioactive high K-counts. On many occasions, the high potassium count zones are bordered by either lineament. On other occasions, the high potassium count zones are bisected by lineaments. This strengthens the notion of structural control on the potential hydrothermal alteration zones in the survey area. This strengthens the notion of structural control on the potential hydrothermal alteration zones in the survey area.

4-6-4 Selection of Promising areas

The survey area is known to host at least five areas of mineralization, four of which are confirmed to have active small-scale gold mining activity. Such areas are in Mapulot, Tuba, Nalesbitan and Matanlang (Matanlang was not covered by the aerial survey due to military restrictions). The fifth area in Kilbay (Layaton Creek) is reportedly panned occasionally. All these areas are in one way or another, marked by the following signatures:

1. A flat magnetic terrain marks Mapulot area (although this has been observed as a general feature in the gently rolling terrain area north of Tagkawayan).
2. The Nalesbitan deposit is centered on a huge high K-count anomaly (about 3 sq. km), which we know to be due to both hydrothermal alteration and barren vegetation (although the barren vegetation is limited in the mine site with an area

of less than 1 square kilometer). The same high K-count anomaly contains a magnetic flat region to its south and bordered by northwest trending topographic and magnetic lineaments.

3. The Tuba deposit is centered on a northwest trending high K-count anomaly with an adjacent magnetic flat response zone. It is also bordered by northwest trending topographic and magnetic lineaments.
4. The Kilbay area is marked by a huge magnetic flat region, which coincides with high K-count anomalies. The area is also traversed by northwest trending magnetic and topographic lineaments.

The radiometric, magnetic and structural signatures over known mineralized sites occur in many other sites in the survey area. Principally, five sub-areas should receive high potential ratings and therefore, special attention. These are the Nalesbitan Zone (which also encompasses the Tuba area), Tagkawayan Zone, Kilbay Zone, Mt. Labo Zone and Labo River Zone (appendix 1).

1. Nalesbitan zone

   This zone also includes Tuba zone. We need to check for the existence of alteration on the southeast of Nalesbitan and around zone in G. (j.-⑤) above.
2. Labo River zone

   It extends from Labo river upstream to Kilbay zone. We must pay special attention to vicinity of I. (j.-⑪) above.
3. Kilbay zone

   This zone continues at about 10km on WNW-ESE direction under results of the mineral resources regional survey in the Bicol area conducted in 1997-1998 (JICA/MMAJ, 1999). As mentioned in C. above, it must be verified that any intrusive rock from radioactive Ternary anomaly may due to intrusive rocks, and relationship with hydrothermal alteration process.
4. Mt. Labo zone

   On the south slope of Labo volcano, older igneous rock possibly exposes on the lower side of Labo dacite.
5. Tagkawayan zone

   High K-count anomaly zone is rarely superimposed on magnetic flat region in this zone. However, the older geological units distributed in the north and the northwest of this zone might have some 'mesothermal lode' gold mineralization as seen in Mapulot.

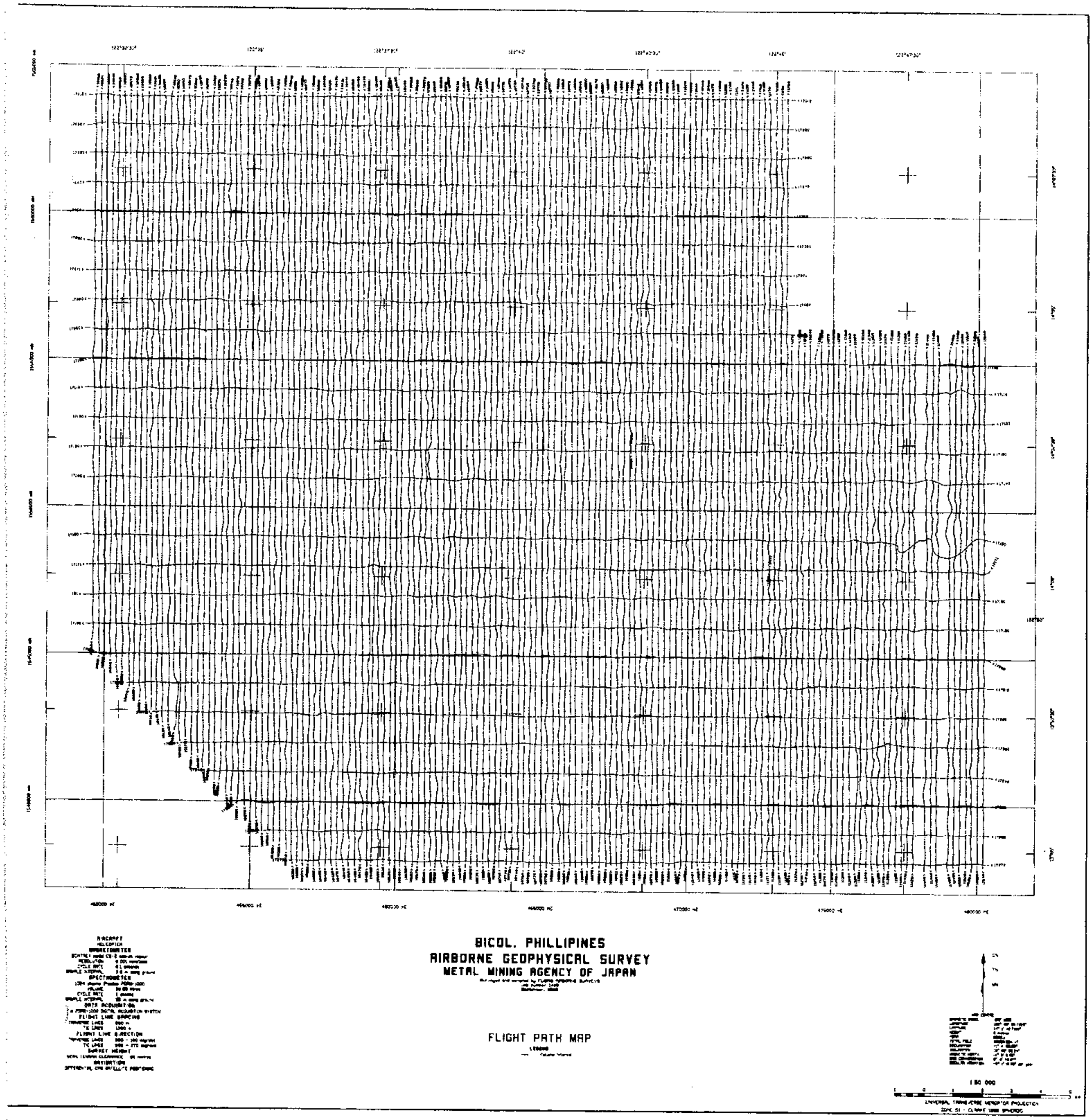


Fig. 4　Flight Path Map

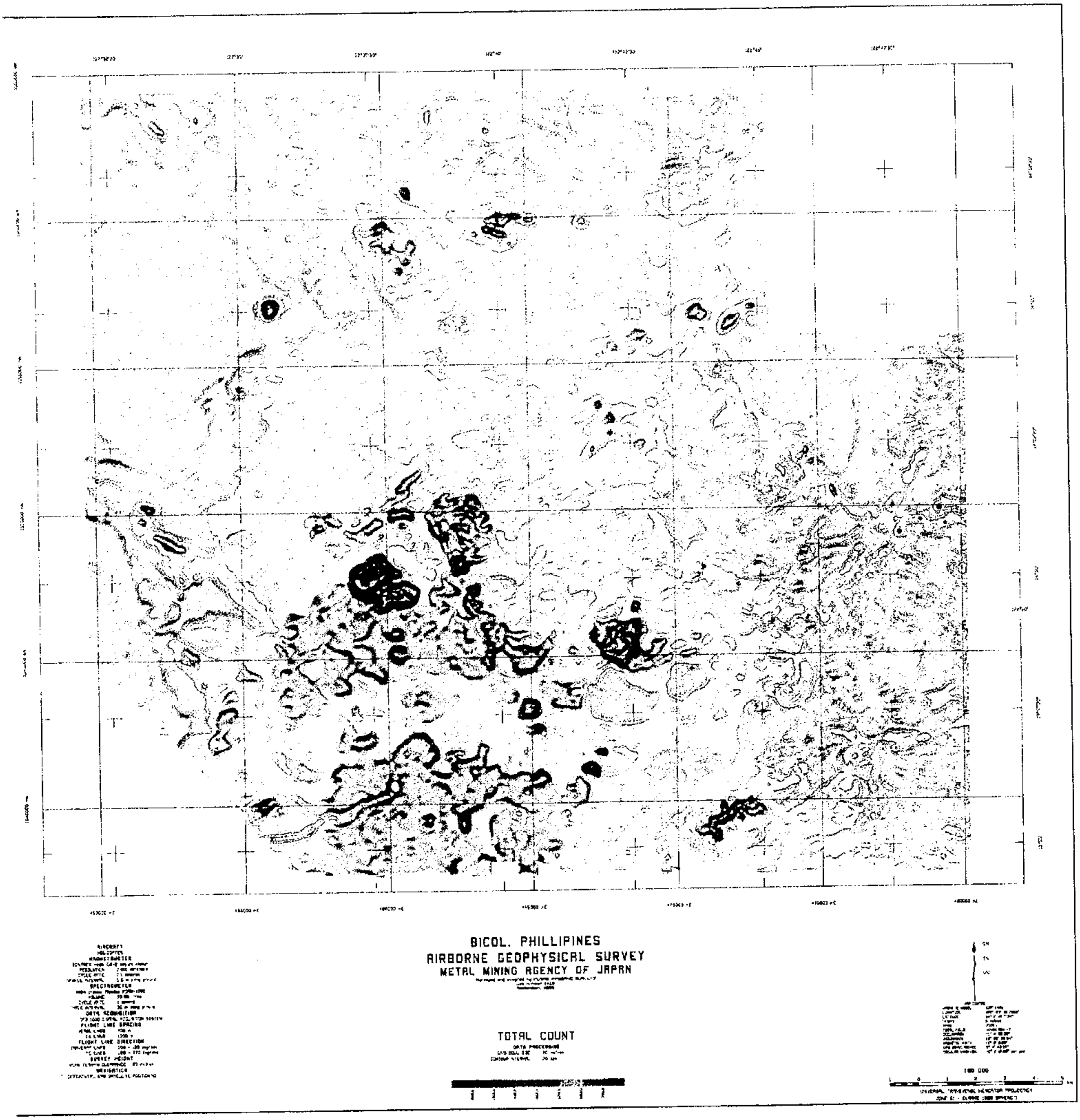


Fig. 5 Radiometric Total Count. Contour Map

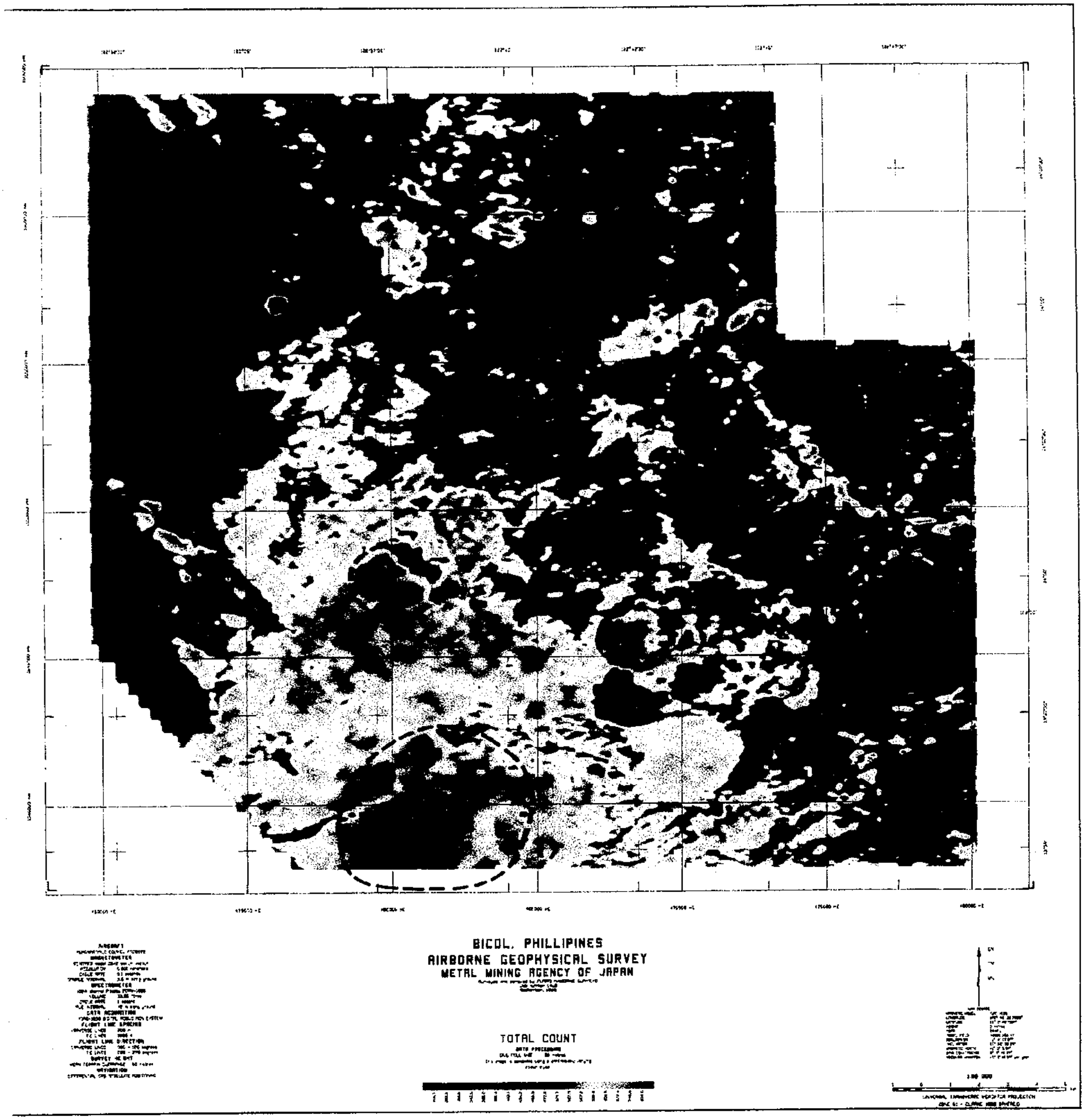


Fig. 6 Radiometric Total Count.

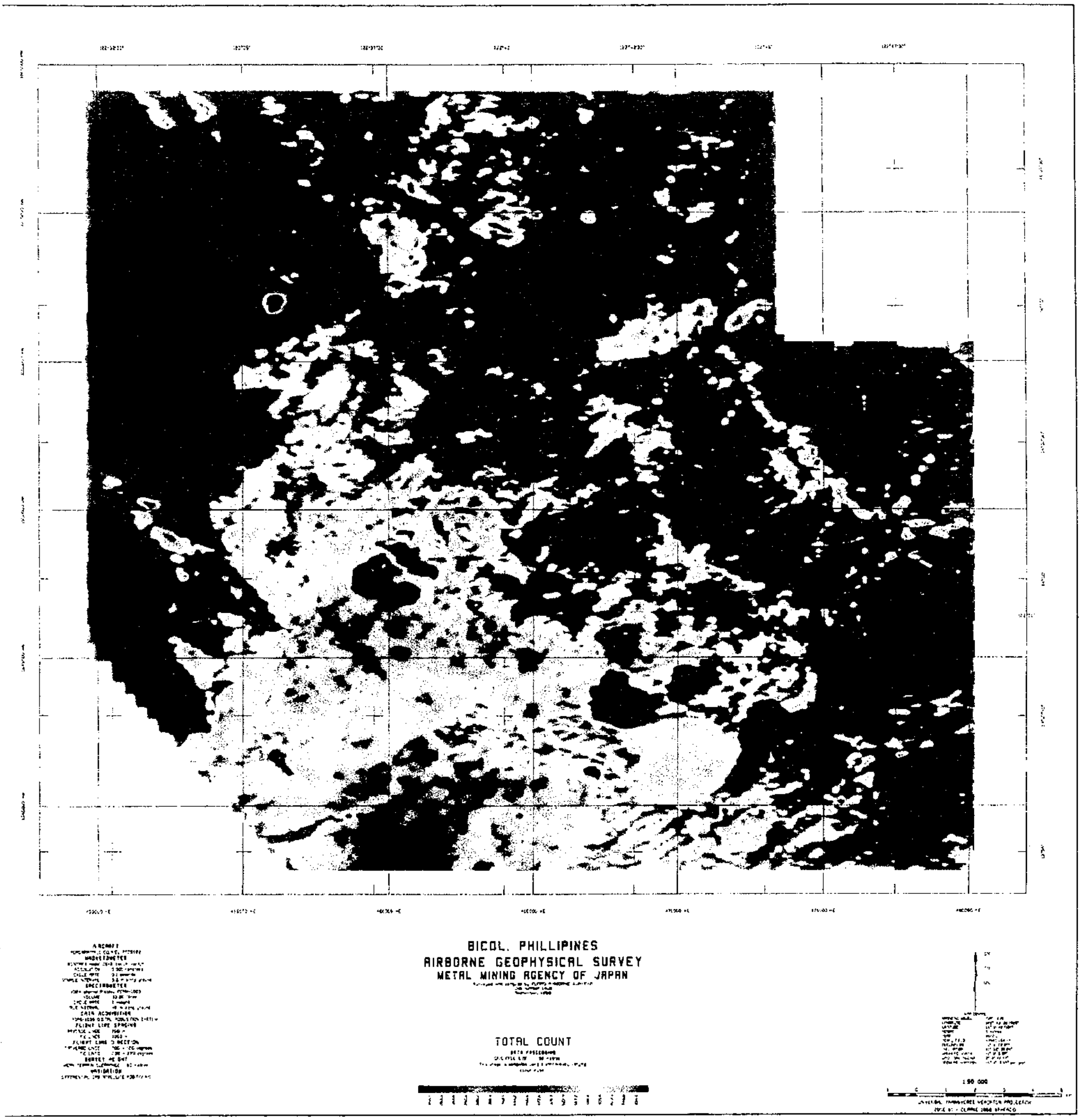


Fig. 6 Radiometric Total Count.

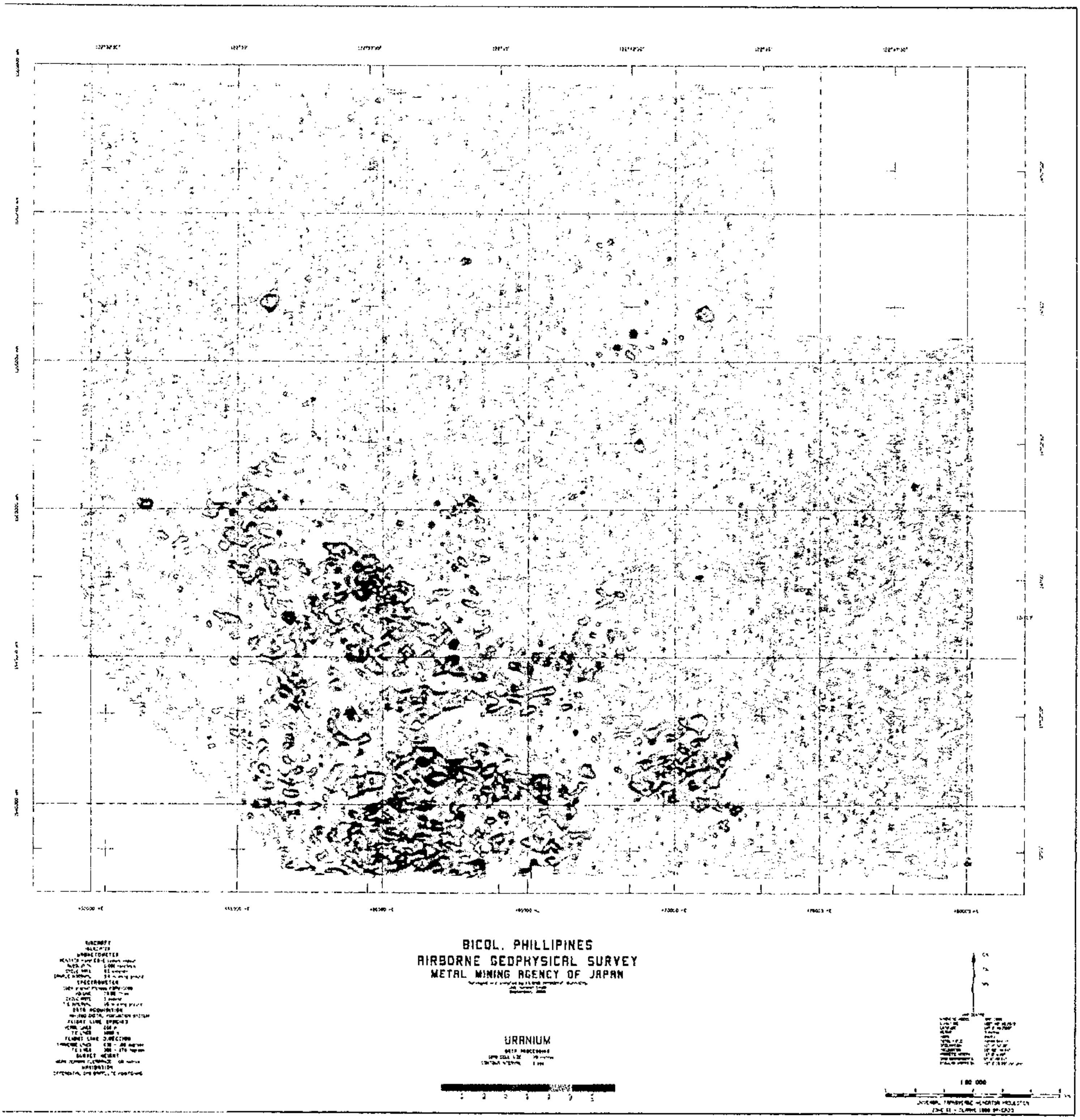


Fig. 7 Radiometric Uranium Counts. Contour Map

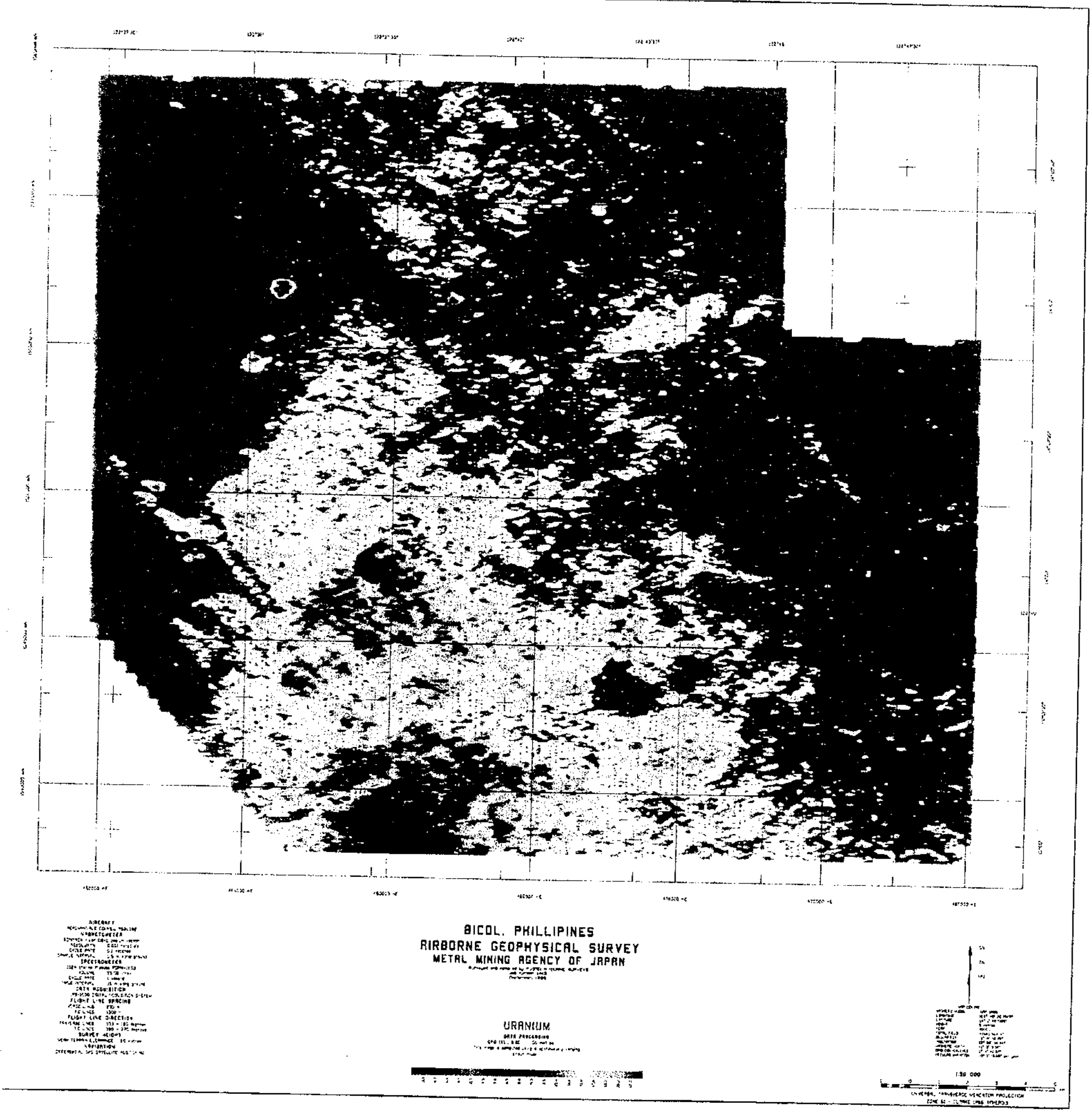


Fig. 8 Radiometric Uranium Counts.

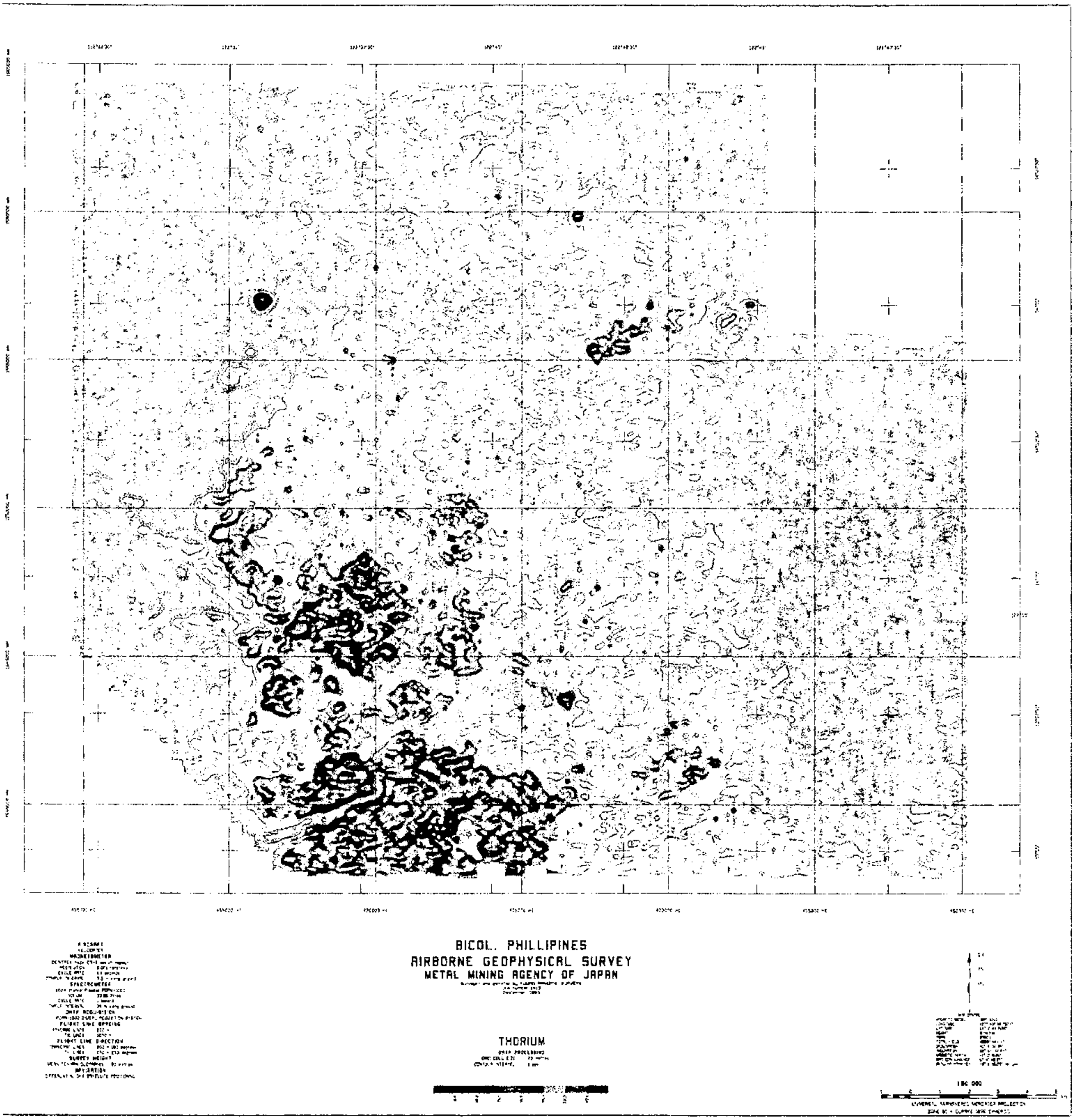


Fig. 9 Radiometric Thorium Counts. Contour Map

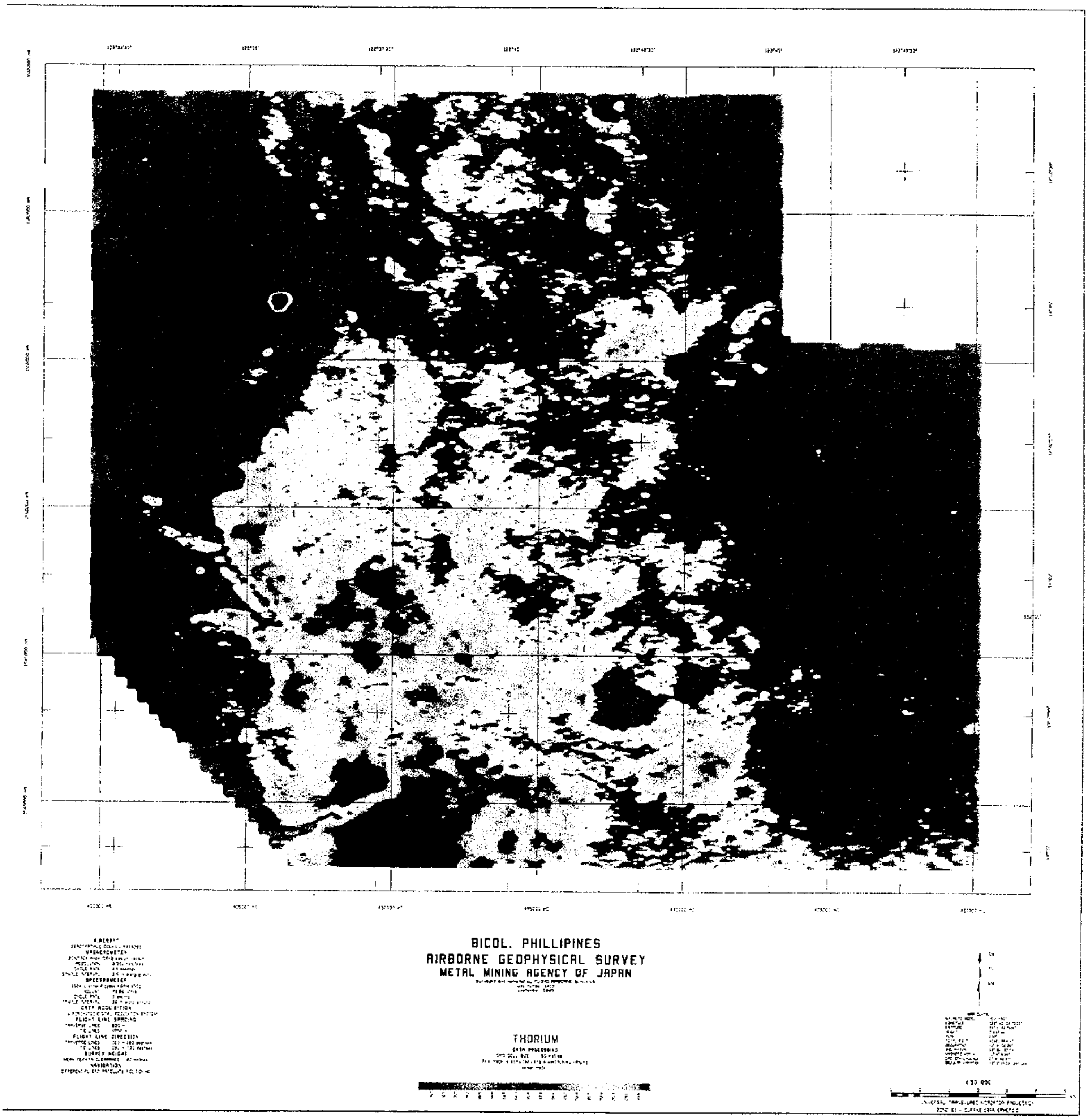


Fig. 10 Radiometric Thorium Counts.

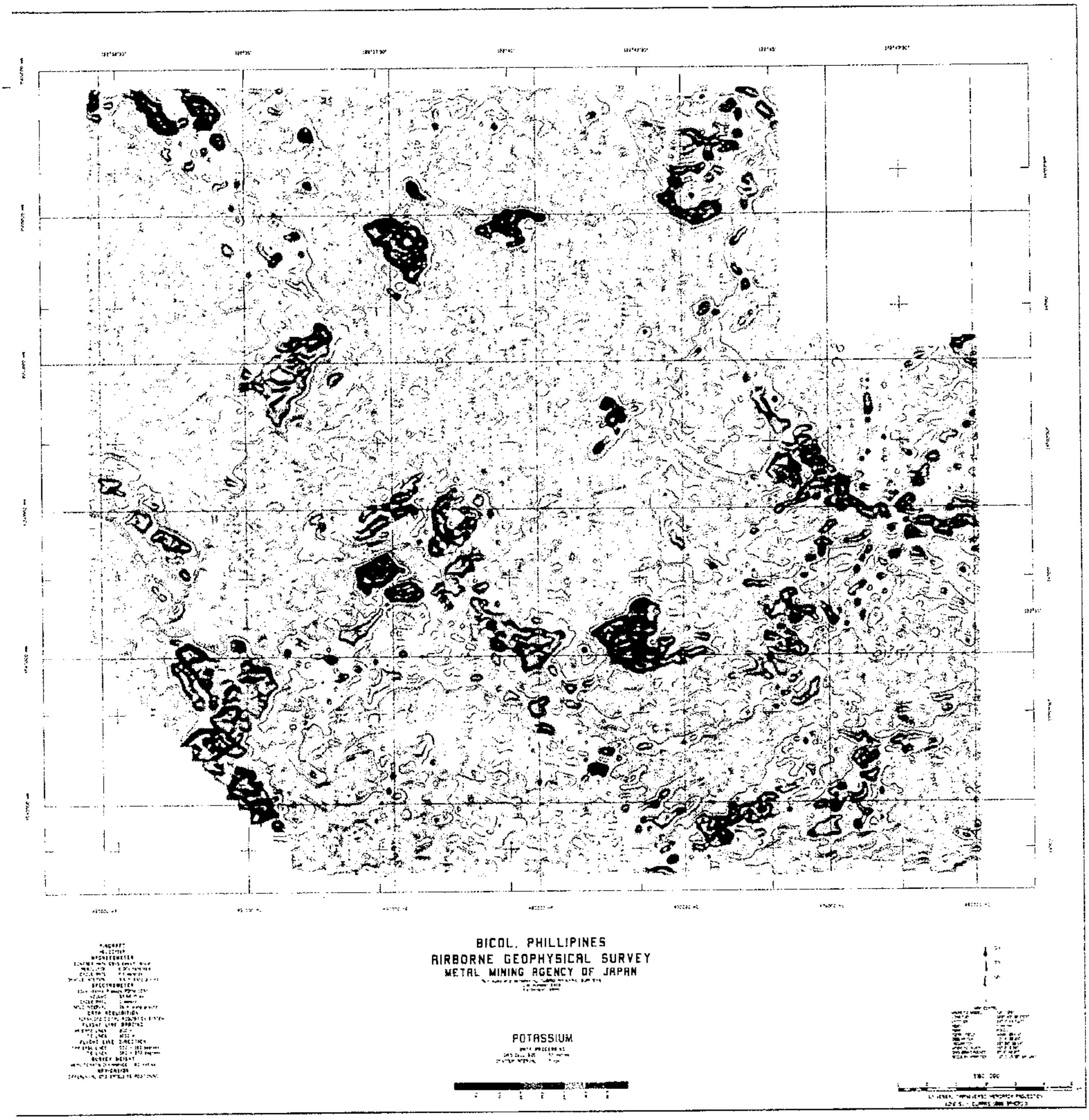


Fig. 11 Radiometric Potassium Counts. Contour Map

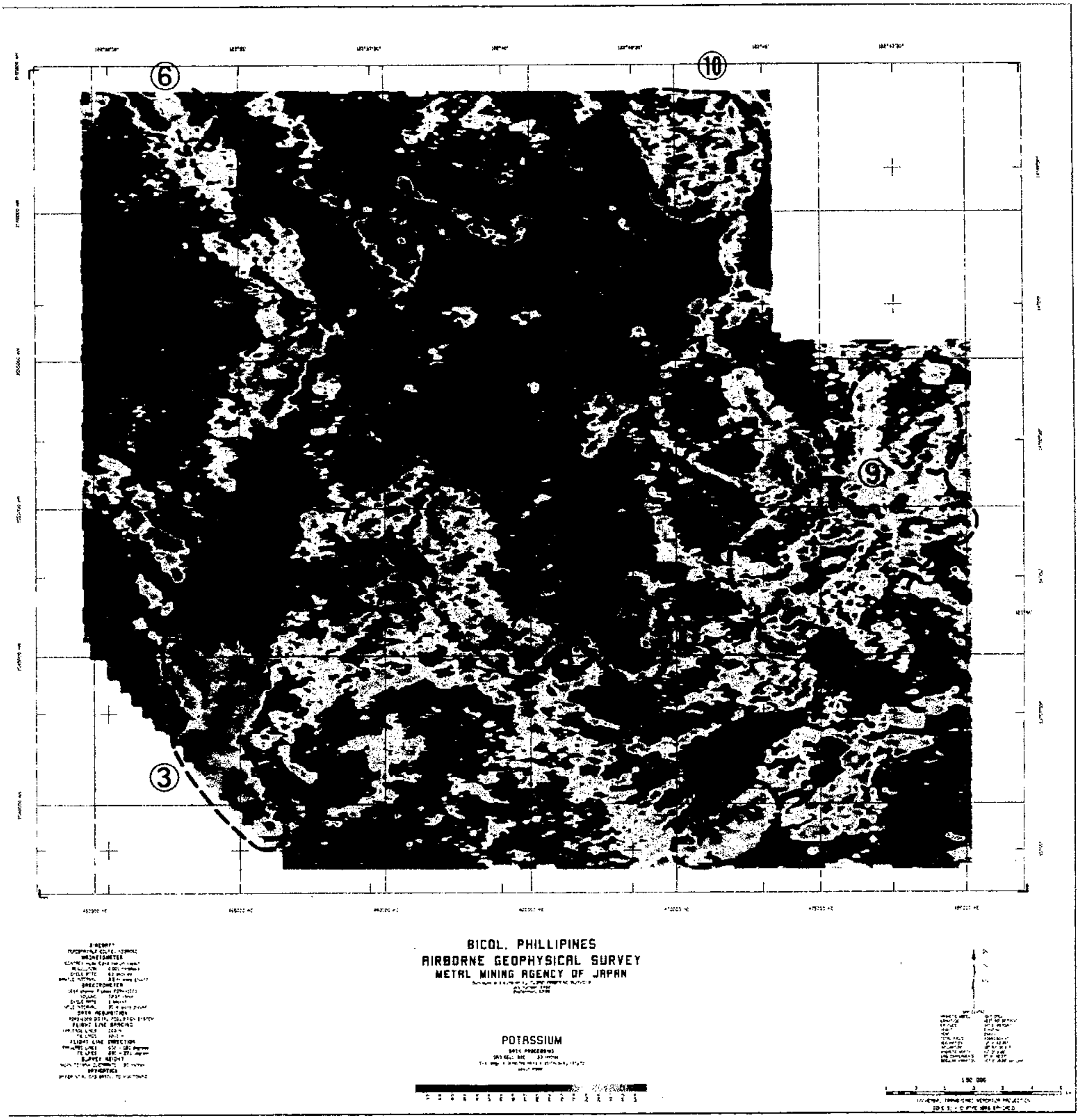


Fig. 12 Radiometric Potassium Counts.

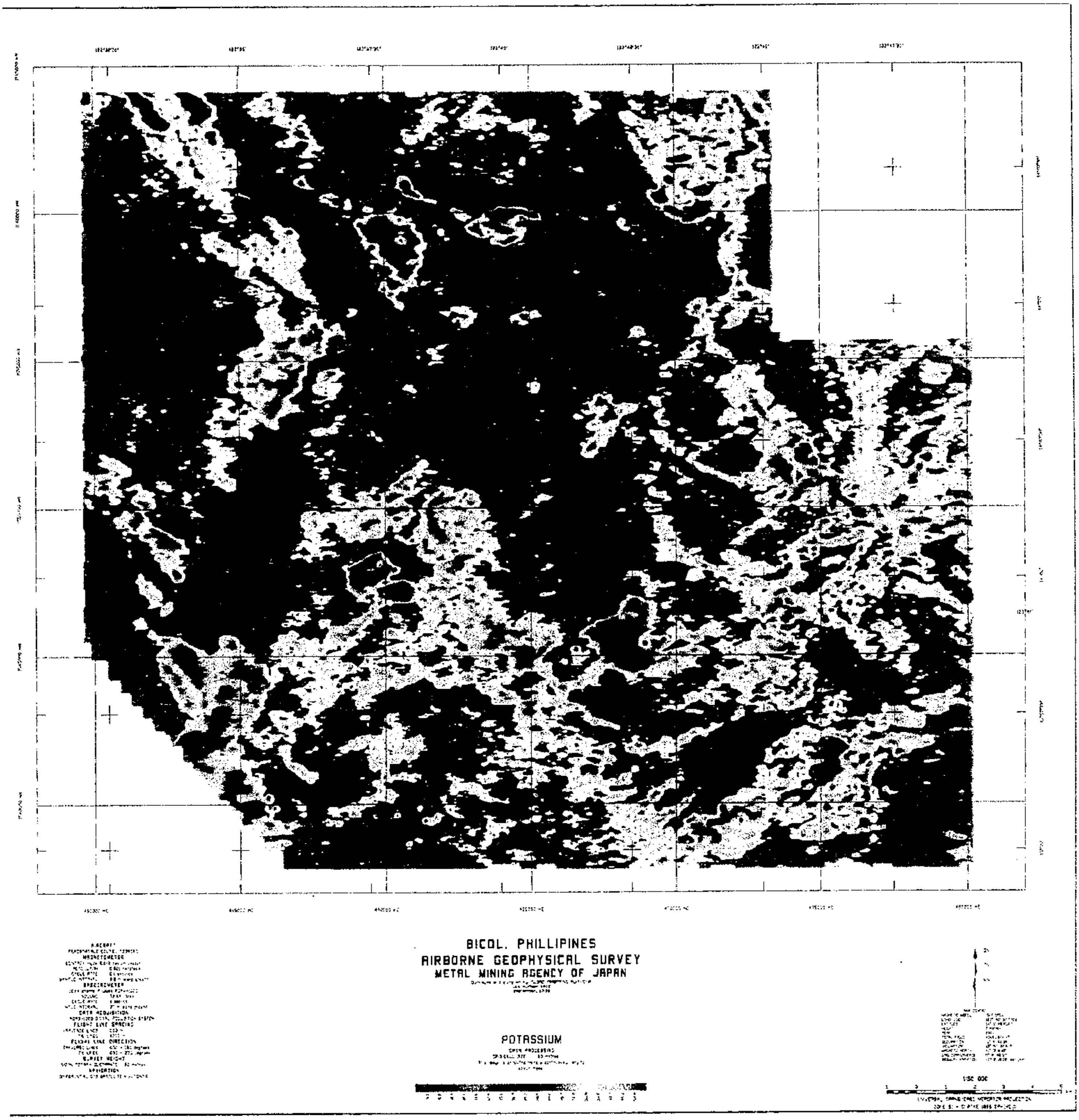


Fig. 12 Radiometric Potassium Counts.

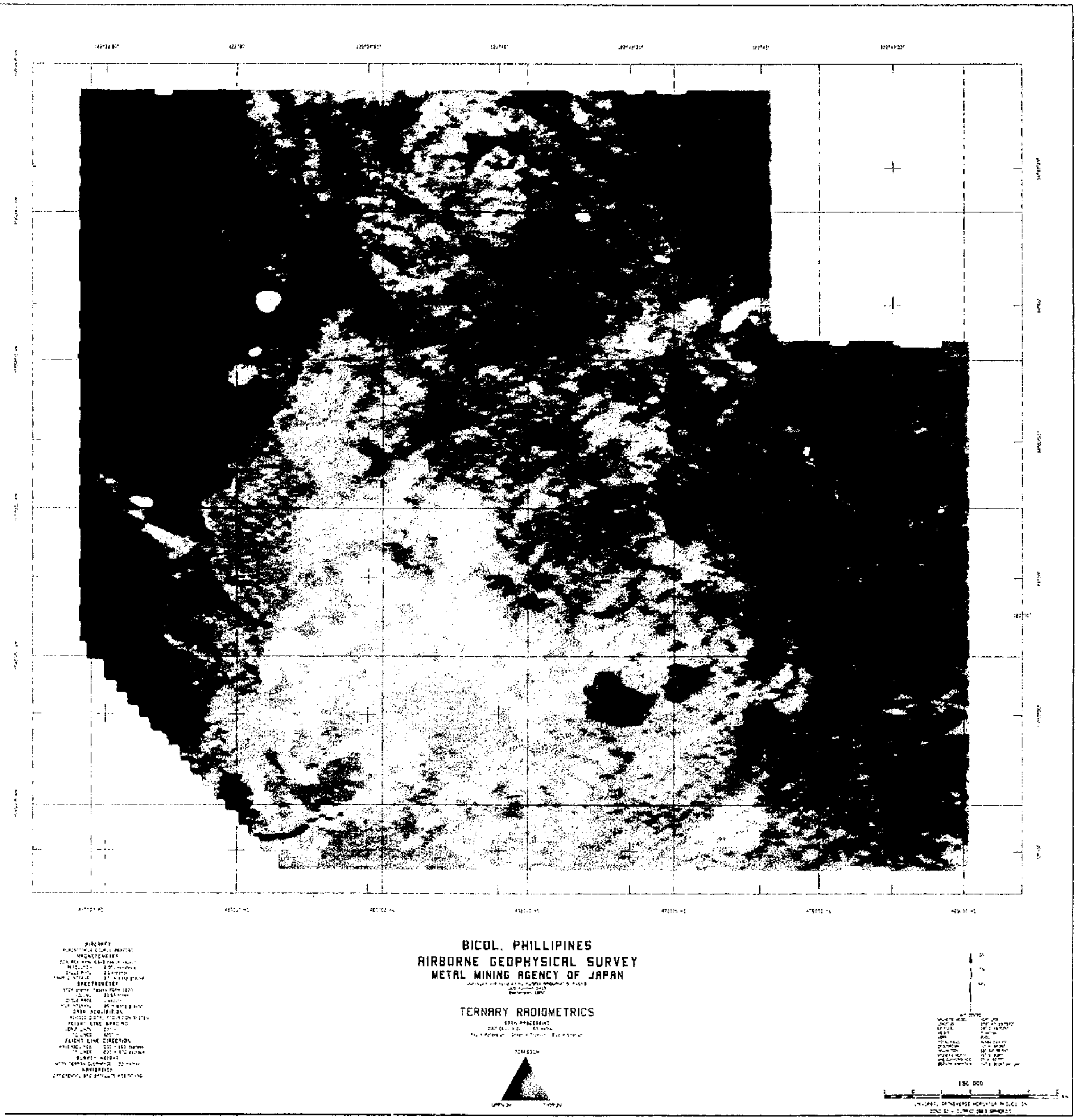


Fig. 13 Radiometric Ternary.

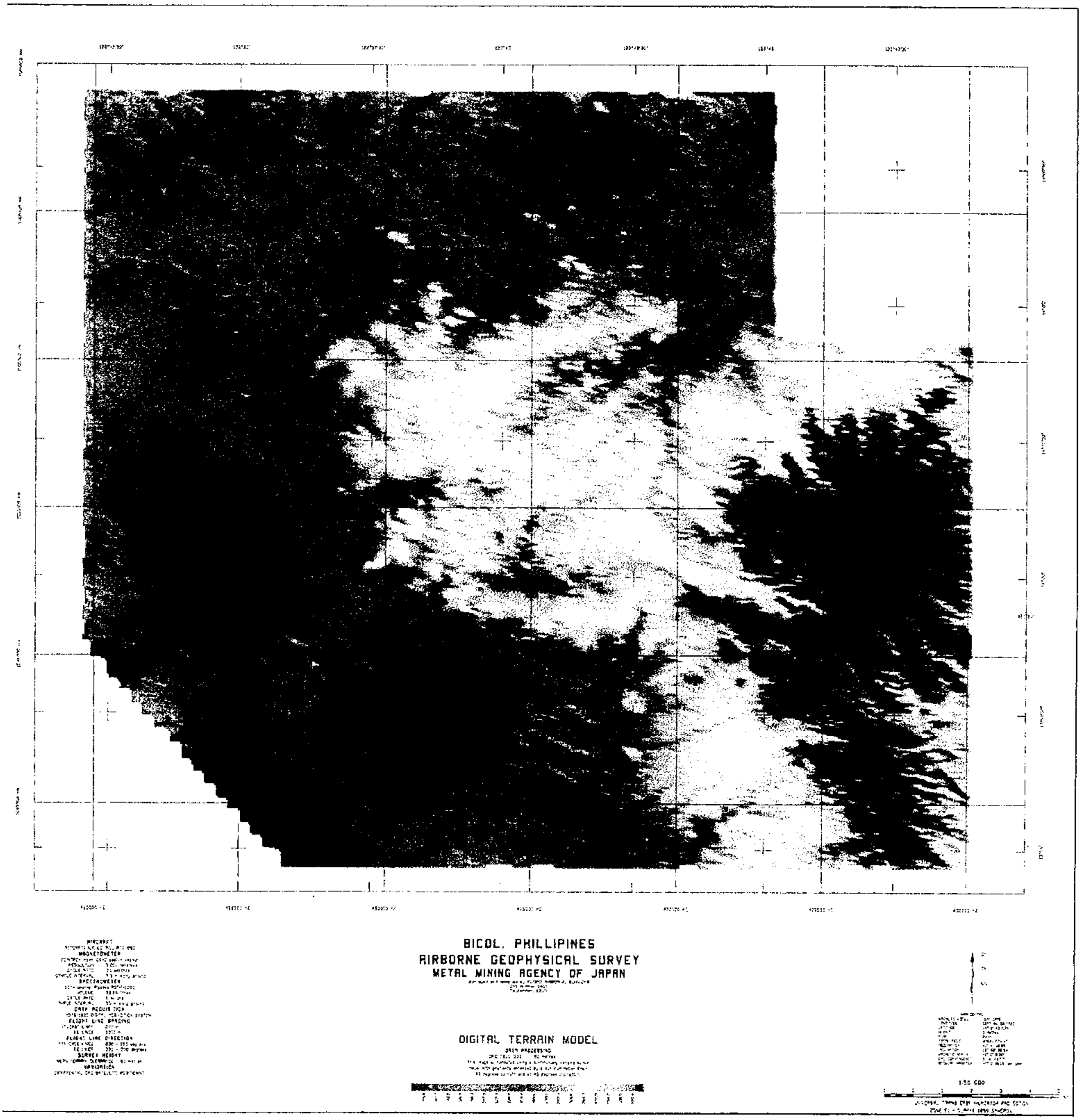


Fig. 14 Digital Terrain Model.

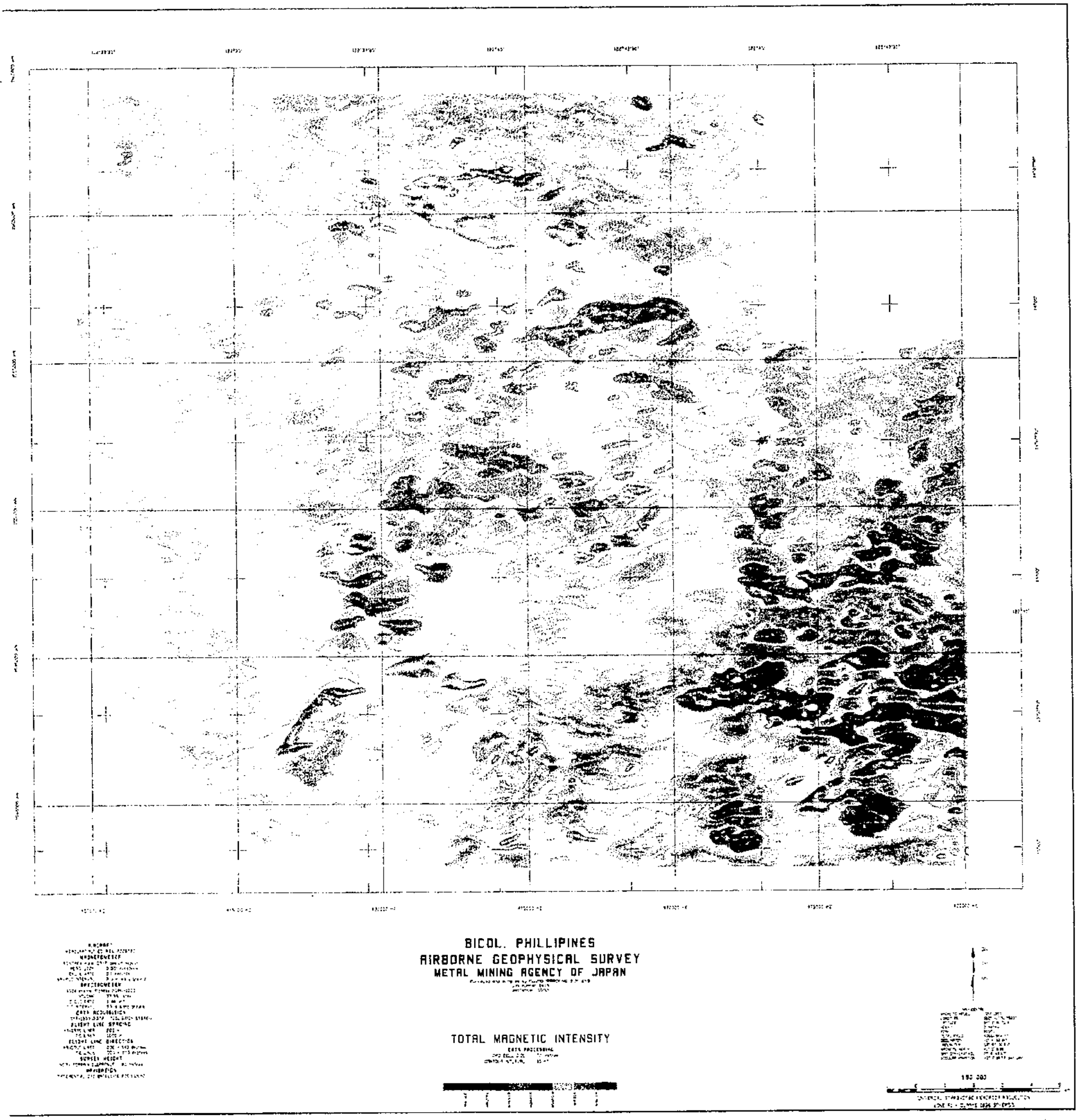


Fig. 15 Total Magnetic Intensity. Contour Map

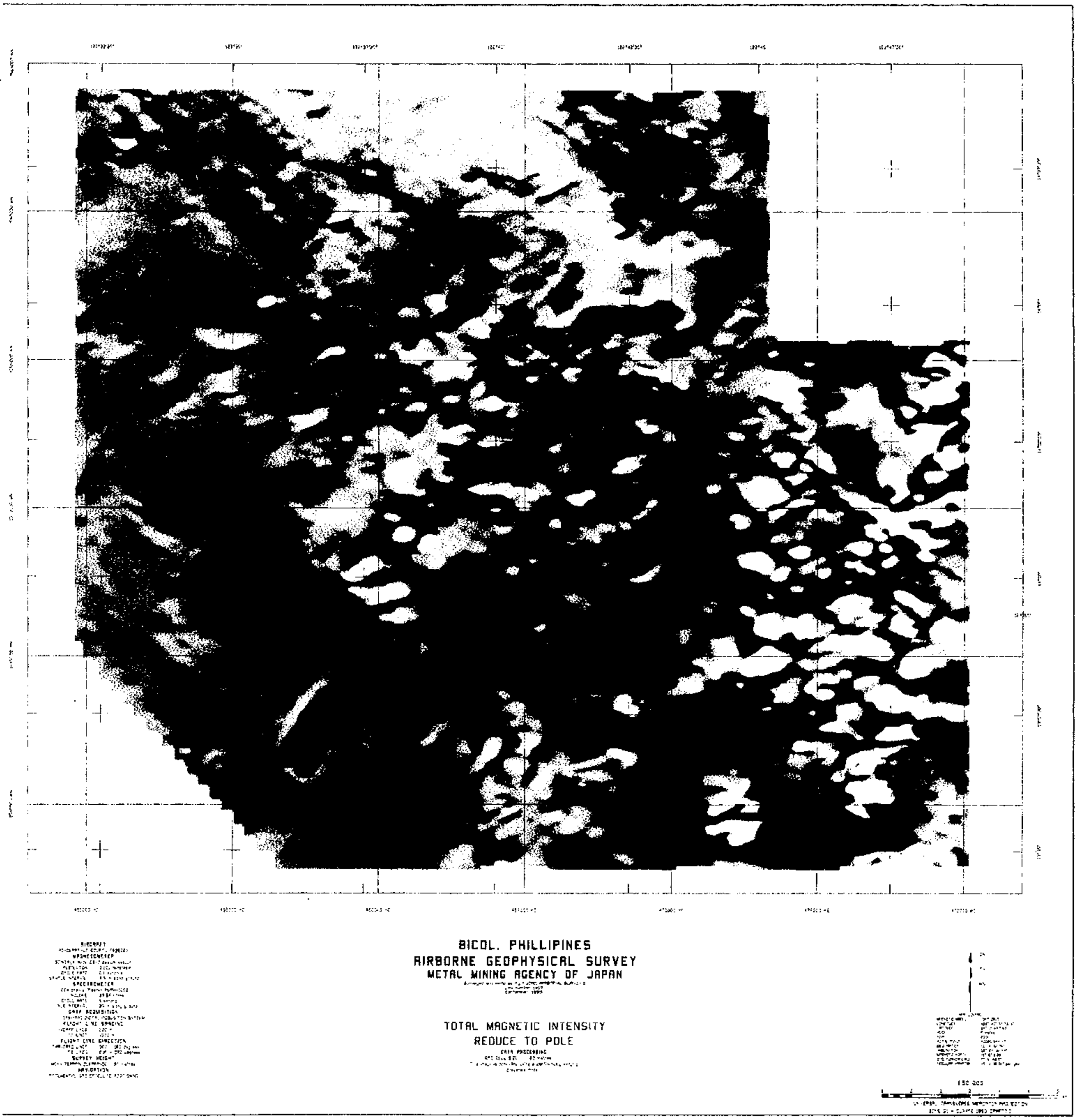


Fig. 16 Tota Magnetic Intensity: Reduced to Pole

A very high total radiometric signature. High magnetic signature. Sub - circular magnetic texture. Possible intrusive center.

A very high total radiometric signature. High magnetic signature. Circular magnetic texture. Possible intrusive center.

High radiometric potassium signature. Moderate radiometric thorium and uranium signature. Magnetic flat regions are partly overlapped. Possibly due to hydrothermal alteration and exposure of rocks.

High to moderate radiometric potassium signature with low radiometric thorium and uranium. High magnetic signature. Possible coincident with Labo Volcanic rocks.

High magnetic signature. Low total radiometric signature.

Moderate radiometric thorium and uranium. Partly moderate radiometric potassium. Magnetic low relief. Partially coincident with Susungdalaga volcanic rocks.

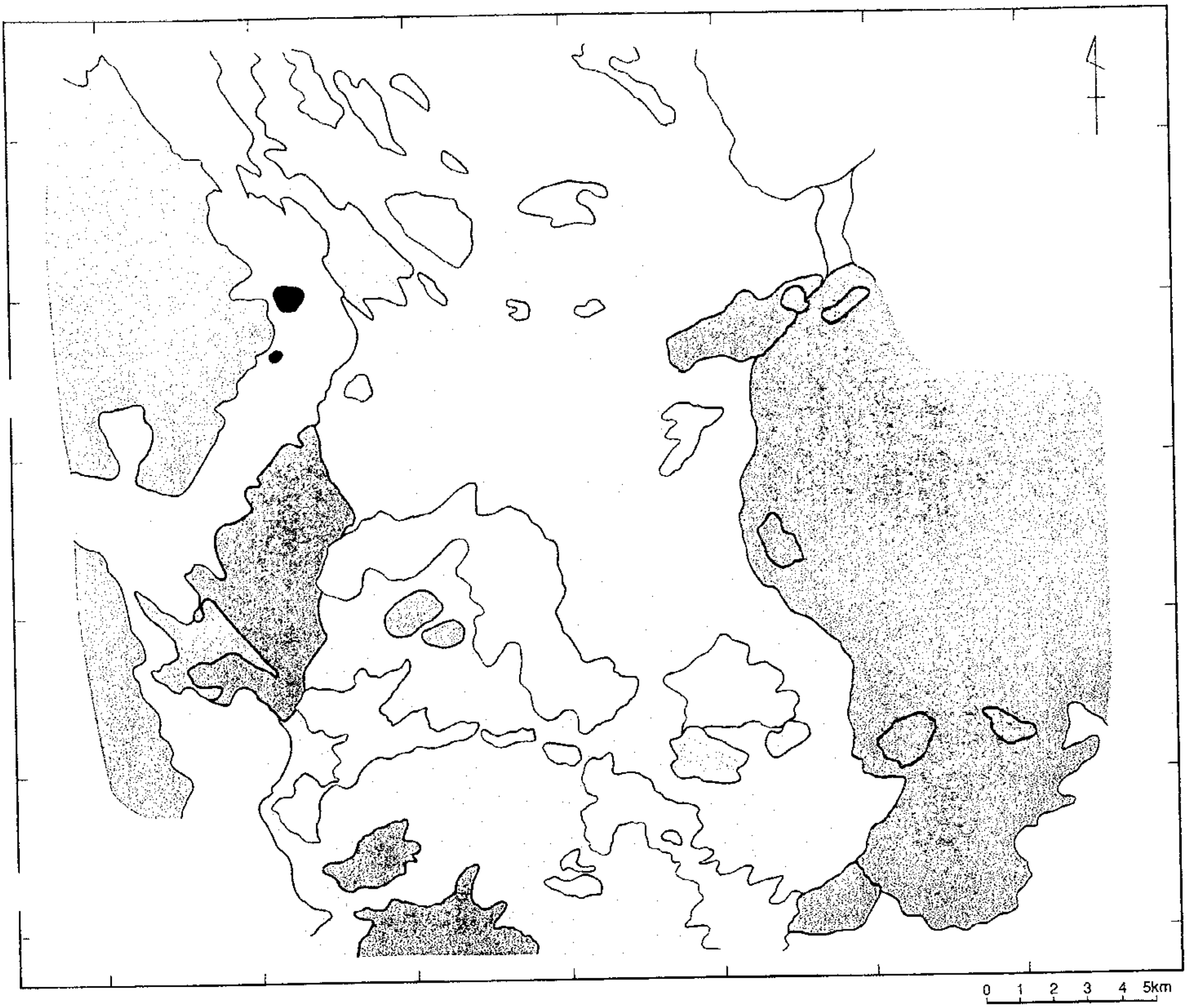
Very high radiometric thorium and uranium signature with low radiometric potassium signature. Magnetic low relief.

Moderate to high radiometric potassium with low radiometric thorium and uranium signature. Magnetic low relief. Possibly coincident with Late Miocene - Early Pliocene Sedimentary rocks.

Low total radiometric signature. Magnetic low relief.

Very low total radiometric signature. Magnetic low relief.

Fig. 17 Airborne Radiometric and Magnetic Units



- A very high total radiometric signature. High magnetic signature. Sub - circular magnetic texture. Possible intrusive center.
- A very high total radiometric signature. High magnetic signature. Circular magnetic texture. Possible intrusive center.
- High radiometric potassium signature. Moderate radiometric thorium and uranium signature. Magnetic flat regions are partly overlapped. Possibly due to hydrothermal aiteration and exposure of rocks.
- High to moderate radiometric potassium signature with low radiometric thorium and uranium. High magnetic signature. Possible coincident with Labo Volcanic rocks.
- High magnetic signature. Low total radiometric signature.
- Moderate radiometric thorium and uranium. Partly moderate radiometric potassium. Magnetic low relief. Partially coincident with Susungdalaga volcanic rocks.
- Very high radiometric thorium and uranium signature with low radiometric potassium signature. Magnetic low relief.
- Moderate to high radiometric potassium with low radiometric thorium and uranium signature. Magnetic low relief. Possibly coincident with Late Miocene - Early Pliocene Sedimentary rocks.
- Low total radiometric signature. Magnetic low relief.
- Very low total radiometric signature. Magnetic low relief.

Fig. 17 Airborne Radiometric and Magnetic Units

Chapter 5 Conclusion and Proposals

5-1 Conclusion

1. Among the three radioactive elements (uranium, thorium and potassium), the thorium count map delineated well the distribution pattern of the general rock types in the survey area.
2. The Ternary radioactive map is effective to classify the lithology and geological structure.
3. Some of the high K-count and magnetic flat regions may indicate hydrothermal alteration areas. These are seemingly controlled by magnetic lineaments and possible geologic structures (topographic lineaments).
4. Lineament on WNW-ESE direction is dominant. Next is mainly in the NE-SW direction.
5. Five areas contain the same signatures as the known mineralized sites and should therefore receive close attention during the ground survey. These are the Nalesbitan Zone, Labo River Zone, Kilbay Zone, Mt. Labo Zone and Tagkawayan Zone.

5-2 Proposals for the Phase II survey

1. The next phase of the project will involve geochemical sampling and geologic mapping.
2. Geological survey must be made to clarify the geology of the survey area. The previous survey in the Bicol area verified that the acidic igneous rocks, which constitute the Susungdalaga mountains, have about 4 Ma in K-Ar age of early Pliocene (JICA/MMAJ, 1999). However, the Tertiary intrusive rocks, which delineated in the existing geological map on the west of the survey area, could not be checked during the previous survey. In addition, this airborne geophysics does not support the existence of the intrusive rocks. It is necessary to confirm about igneous rock relating with hydrothermal activity.
3. Main faults in WNW-ESE and NE-SW directions as suggested in previous survey (JICA/MMAJ, 1999) was also delineated in this airborne geophysical survey. According to JICA/MMAJ (1999), WNW trending faults are left lateral, and they might be formed during formation of Legazpi lineament (e.g. Aurelio et al, 1997). These fault systems have potential for the pathways of hydrothermal fluids in the Central metallogenic belt. From the point of view, it would be important to conduct a

preliminary structural analysis of the area by aerial photograph and satellite imagery interpretation. This will not only give an understanding of the structural regime of the area and its relationship to known mineralization but it will also show additional structures not readily recognized by topographic map interpretation alone.

4. Alteration distribution and its zone features must be clarified during geological survey. In particular, the radiometric and magnetic data suggests larger areas of hydrothermal alteration than previously known. It is important therefore to have a comprehensive hydrothermal alteration map to delineate zones of possible hidden mineralization. A rapid and economical system of clay mineral identification like the use of Portable Spectral Analysis for Mineral Identification (POSAM) would provide onsite information on alteration patterns.
5. The geochemical survey should involve the use of rock, stream sediment and heavy mineral media. Fluid inclusion analysis is recommended for quartz vein samples, while selected heavy mineral concentrates should be studied for mineral assemblage and distribution patterns. For stream sediments, it is important to preserve the clay fraction and collect more samples at expected alteration and mineralized zones.

The following attentions should be paid for the five potential zones above:

<Nalesbitan zone>

This zone also includes Tuba zone. We need to check for the existence of alteration on the southeast of Nalesbitan and the high K-count zone at 4km east of Nalesbitan.

<Labo river zone>

This zone extends until Kilbay zone upstream of Labo River. High K-count anomaly zone on the center must be carefully checked.

<Kilbay zone>

This zone continues at about 10km on WNW-ESE direction (JICA/MMAJ, 1999). We must check the existence of intrusive body at the radioactive 3-element high counts anomaly, and relationship with hydrothermal activity.

<Mt. Labo zone>

On the south slope of Labo volcano, older igneous rock possibly exposes on the lower side of Labo dacite.

<Tagkawayan zone>

High K-count anomaly zone is rarely superimposed on magnetic flat region in this zone. However, the older geological units distributed in the north and the northwest of this zone might have some 'mesothermal lode' gold mineralization as seen in Mapulot.

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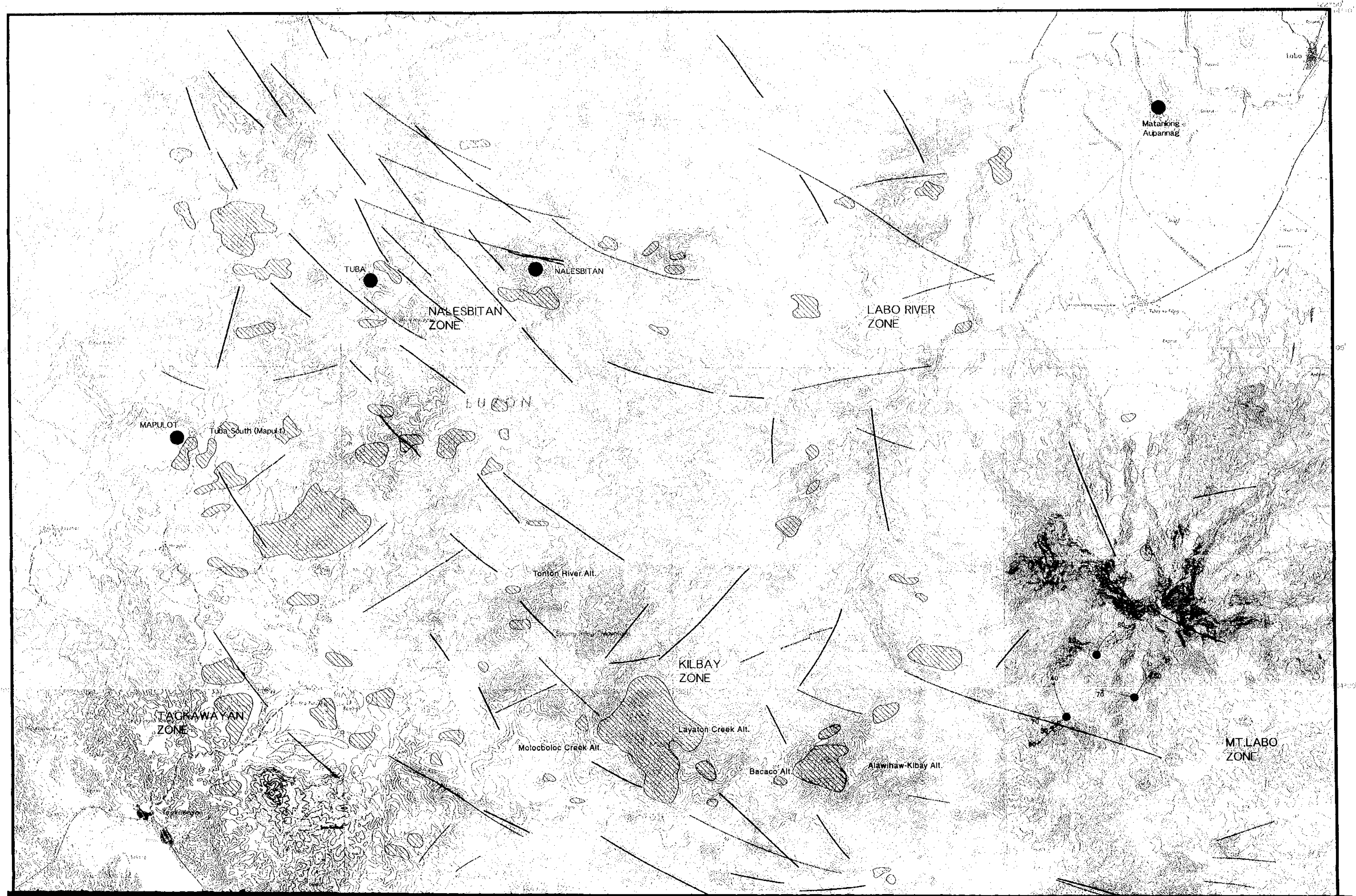
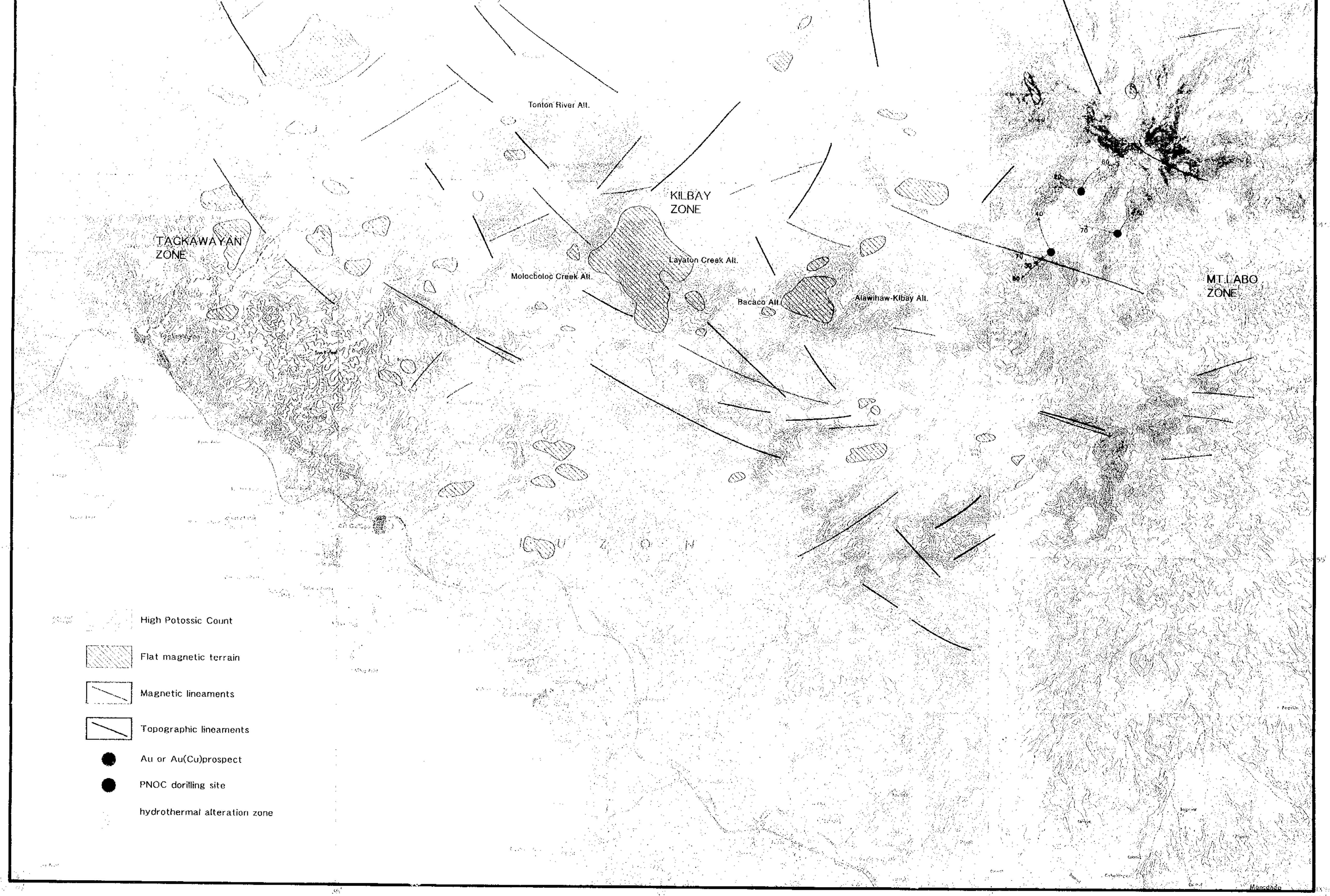
Bicol North Area, Republic of Philippines





Appendix 1 Preliminary aeromagnetic and radiometric interpretation map

JICA