ATLAS OF SUPRA-REGIONAL SURVEY IN CENTRAL SABAH, MALAYSIA

MARCH, 1994

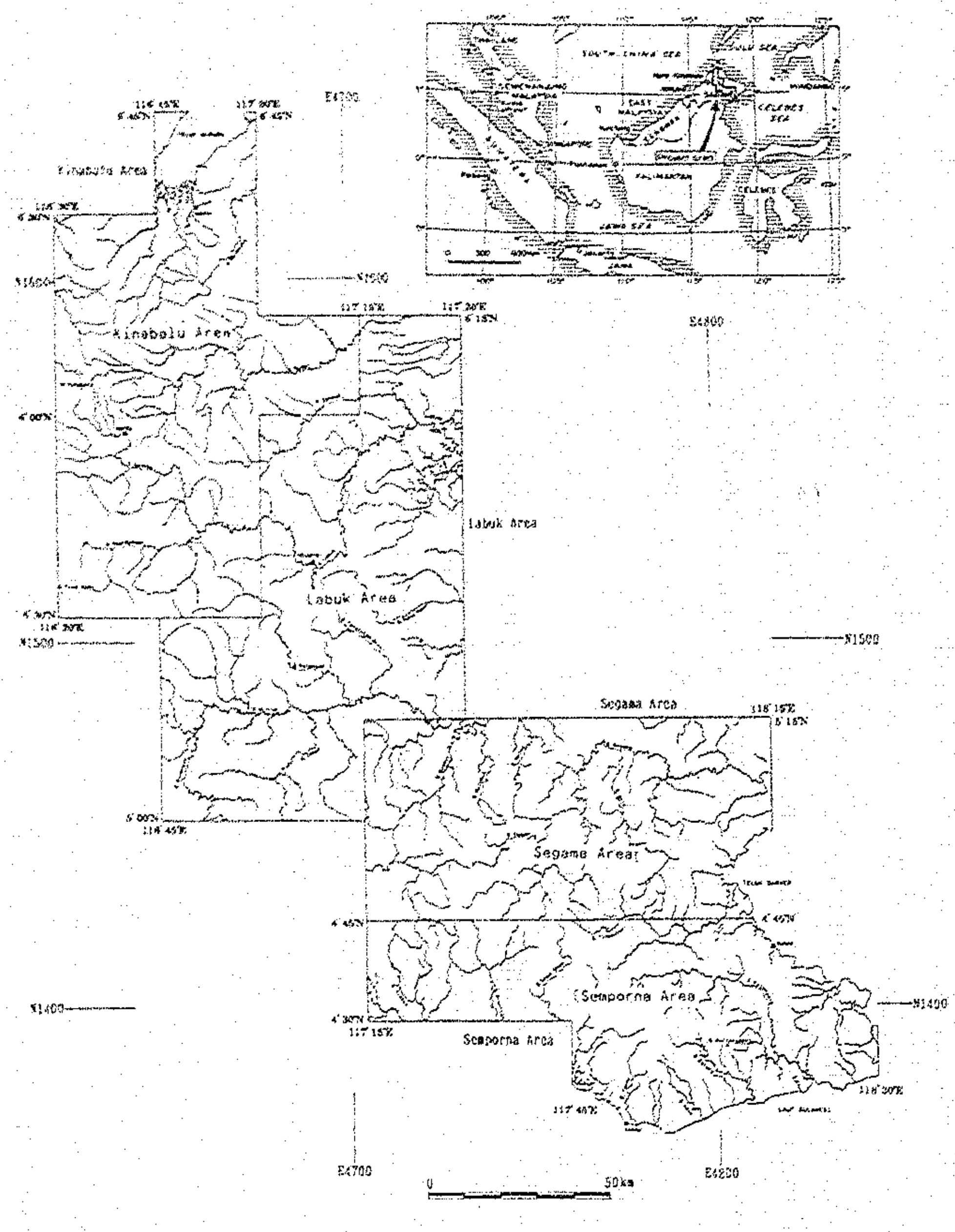
JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

ATLAS OF SUPRA-REGIONAL SURVEY IN CENTRAL SABAH, MALAYSIA
MARCH, 1994
JICA・MMAJ
MPN・JR・94-054

ATLAS OF SUPRA-REGIONAL SURVEY IN CENTRAL SABAH, MALAYSIA

MARCH, 1994

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN



Index map of the project area

1123941 [5]

PREFACE

In response to the request of the Government of Malaysia, the Japanese Government decided to conduct Supra-Regional Survey Project in the Sabah area and entrusted the survey to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

The JICA and MMAJ sent a survey team to Malaysia during the period from 1990 to 1993.

The team exchanged views with the officials concerned of the Government of Malaysia and conducted a field survey together with Malaysian counterparts in the central part of Sabah. After the team returned to Japan, further studies were made and report were prepared. This Atlas includes the regional survey results of the project.

We hope that this Atlas will serve as a useful guide for the development of mineral resources in the area and contribute to the promotion of friendly relations between our two countries.

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

ABSTRACT

The Government of Malaysia and the Government of Japan agreed on a four-year mineral exploration project, starting from 1990, in the central part of Sabah area. The Scope of Work for this project was signed by both governments on 1st August 1990. Objectives of this project are to identify the mineral potential and to obtain useful data for future development of the mineral resources in the area. This atlas includes the regional survey results from Phase I to Phase III of the project.

The regional surveys conducted in this project are satellite image analyses, heliborne geophysical survey and geochemical survey. The regional survey conducted under each phase are as below:

Phase I : Satellite image analyses, orientation geochemical and heliborne geophysical surveys.

Phase II : Regional geochemical survey in the Segama and Semporna areas and a heliborne geophysical survey.

Phase III : Regional geochemical survey in the Kinabalu and Labuk areas.

Based on the results of the regional geochemical survey, eighteen geochemical anomalous areas were delineated. These anomalous areas were investigated by a semi-detailed survey, where five areas were further identified as highly potential for mineral resources.

During this survey so many basic data were obtained. These data will cotribute for further exploration work more efficiently and could help to find new potential areas. These data should be treated by the following manner;

(1) The satellite images should be used for a geological survey and exploration work in order to understand the large scale structure.

(2) The heliborne survey data should be used to understand the hidden geological structure. It is also possible to delineate large scale altered zone.

(3) Some geochemical anomalous zones were not covered by the semi-detailed survey. These anomalous zone should be examined in future work.

All data obtained in this survey were input in magnetic tape, so that anybody could access to any part of the data for re-examination and further investigation. Because these data are the basic data for the exploration work in this area, the data should be used in order to carry out the exploration work more efficiently.

Chapter 1 Introduction

1-1 Objectives

Purpose of this survey is to apprise the mineral potential in this area for the future development of mineral resources. In order to execute this purpose, satellite image analyses, heliborne geophysical and regional geochemical surveys were conducted in most part of the area. Based on these survey results, a semi-detailed survey was conducted over eighteen selected areas where higher mineral potential was expected. This atlas includes the regional survey results of this project and form a part of the final report.

1-2 Outline of survey and work amounts

The project area is situated in the central region of the State of Sabah, stretching from the north corner to south eastern corner and covers covers an area of 26,500 km². The area is subdivided into four areas known as Kinabalu, Labuk, Segama and Semporna areas from the north west to the south east, respectively.

The work conducted in this project for each phase are as below:

Phase I : ① Geochemical orientation survey in order to select optimum geochemical survey method for the project area.
② Satellite image analyses in order to investigate the geology and geological structure.
③ Heliborne geophysical survey in order to examine the geological structure.

Phase II : ① Regional geochemical survey in the Segama and Semporna areas.
② Additional heliborne geophysical survey and interpretation.

Phase III : ① Regional geochemical survey in the Kinabalu and Labuk areas.
② Semi-detailed geochemical survey in eight selected areas in the Segama and Semporna areas.

Phase IV : ① Semi-detailed geochemical survey in ten selected areas in the Kinabalu and Labuk areas.
② Semi-detailed geological survey in one area in the Segama area.
③ Overall evaluation and preparation of final report.

The work amounts completed in this project are as follows:

Satellite image analysis

Coverage: MSS images 26,500 km², TM images 19,175 km²

Heliborne geophysical survey

Coverage: 13,350 km² Survey length: 27,576.4 line-km

Regional geochemical survey

Stream sediment sample:	11,636 samples,	244,356 elements
Soil sample	364 samples	2,184 elements
Rock sample	223 samples	4,687 elements
Pan concentrate sample:	697 samples	—

1-5 Survey period

The period of the field survey for each phase is as following:

Phase I :	16th October 1990	–	13th January 1991.
Phase II :	16th July 1991	–	20th January 1992.
Phase III :	7th July 1992	–	23th December 1992.
Phase IV :	21th June 1993	–	7th September 1993.

Chapter 2 Geography of survey area

2-1 Location and accessibility

The project area is situated in the central region of the State of Sabah stretching from the northwestern part to the southeastern part and covers an area of 26,500 km². The area is subdivided into four areas. These are named Kinabalu area, Labuk area, Segama area and Semporna area.

The capital of the State of Sabah is Kota Kinabalu on the west coast of the state. In Kota Kinabalu, international airline services are available. Regular flight lines are also available between Kota Kinabalu and some cities on the east coast of Sabah. Principal road connects Kota Kinabalu with Ranau and Sandakan and other main road connects Sandakan to Tawau through Lahad Datu. These roads pass through the central part of the Kinabalu and Labuk areas and eastern part of the Segama and Semporna areas. In the Kinabalu area, many roads branched out from Ranau. In the Labuk area, there are some roads for log transportation. However, it is accessible for vehicle at the southern and northern part of the area. In the Segama and Semporna areas, there are some roads used for the plantation estate and log transportation on the east coast area. In the western part of the Segama area, rivers are mainly used for transportation. In the eastern to southern part of the Semporna area, roads system for plantation estate are well developed.

2-2 Topography and drainage system

The State of Sabah is divided into three categories in terms of topographic features. Steep mountains trending north-northeast dominate in the western side along the coast. Hightlands occupy the eastern area and volcanic mountains are found in the southern part. Flat plains are found along rivers and their down streams. Mt. Kinabalu which is the highest mountain in the southeast Asia, rise up to 13,455 ft in the western end of the Kinabalu area which is occupied by steep topography. Highland dominates in the Labuk and Segama areas. Swamps are found at the mouth of main rivers and the rivers are meandered extreamely. Highland dominates in the Semporna area except the young volcanics region with volcanic topography.

The main drainage system in the project area are Sungai Pegalan, Sungai Sugut Sungai Labuk, Sungai Kinabatangan, Sungai Segama, Sungai Tingkayu, Sungai Kalumpang, Sungai Kalabakan etc. Among these river systems, Sungai Pegalan flows into the South China Sea, Sungai Kalumpang and Kinabatangan flows down to the Celebes Sea and other river systems are to the Sulu Sea at the east. These river systems form deep valley at the upper stream and extremely meandering at the down stream in general. The river also develops swampy area at the mouth of the river.

2-3 Climate and vegetation

The survey area is situated in the tropical monsoon region. From February to July, it is the dry to little rain season and from August to January it is the rainy season. Precipitation in the dry/little rain season is 100 - 250 mm in a month and in the rainy season is 350 - 450 mm in a month. Temperature is 22 C to 33 C throughout the year. East coast has more rainfall than the west coast.

Vegetation in the survey area mainly consists of primary and secondary jungle except the area under plantation. The project area is mostly situated in the secondary jungle.

Chapter 3 Geology and mineralization

3-1 Geology

The survey area is underlain by pre-Triassic crystalline rocks, Cretaceous to Tertiary ultra-basic to basic rocks, Tertiary to Quaternary sedimentary rocks and Pliocene to Holocene volcanic rocks according to Y.E. Heng; 1985. A geological map is shown in Plate 1 compiled using the previous geological data and the data obtained from this survey.

The crystalline rocks (Cb) widely occur as the basement rocks from the eastern part of the Segama area to the northern marginal part of the Semporna area. Basement rocks are also found in small area in the eastern part of Labuk area along Sungai Tungud. These rocks compose mainly of gneiss, schist and amphibolite with subordinate tonalite, granodiorite and granite.

Pre-Cretaceous limestone occurs in a small area of the north eastern part of the Segama area.

Cretaceous to Tertiary ultra-basic to basic rocks (Ub) are found in the surrounding zones of the crystalline rocks in the Segama area and occurred as the basement rocks in the Kinabalu and Semporna areas. Ultra-basic rocks are also found trending in a N-S direction in the central part of the Labuk area. The ultra-basic rocks compose mainly of serpentinite, serpentinized peridotite and amphibolite. The basic rocks compose of dolerite and gabbro. Chert-Spilite formation (KPCs) is found in the surrounding zones of the ultra-basic to basic rocks and compose of sedimentary rocks with associated basaltic lavas. The Chert-Spilite formation consists of sandstone, chert, basaltic pillow lavas and basaltic pyroclastic rocks deposited during Cretaceous to Eocene.

The Sapulut formation (KPSp), which is Late Cretaceous to Late Eocene in age, occurs in the southern part of the Labuk area and trends WNW-ESE. This formation consists of mudstone with subordinate sandstone, chert and conglomerate.

In the southern part of the Kinabalu area, the Trusmadi formation (P_1Ts) occurs extensively. This formation consists of phyllite and shale with subordinate siltstone and sandstone. The river systems in this formation form extremely steep topography.

The eastern part of the Labuk area is mainly occupied by the Kulapis formation (P_2Ks) of Eocene to Oligocene age. This formation consists mainly of massive sandstone. The Crocker formation (P_2Cr) of Eocene to Oligocene age occupied most parts of Kinabalu area and the northern to eastern part of the Labuk area. This formation consists mainly of sandstone with intercalation of shale and siltstone beds.

Eocene to Oligocene formations are covered by the Oligocene formations of the Labang formation (P_3Lb) and Kudat formation (P_3Kd). The Labang formation is distributed in the southwestern margin of the Labuk area and northwestern part of the Segama area. This formation consists of siltstone, shale, mudstone and conglomerate. From the northern part of the Labuk area to the eastern part of the Kinabalu area, the Kudat formation (P_3Kd) is found in a small area. This formation also consists of sandstone, siltstone, shale, mudstone and conglomerate.

Sedimentary rocks of Oligocene to Middle Miocene in age are classified into Wariu formation (P_4Wr), Garinono formation (P_4Gr), Ayer formation (P_4Ay), Kuamut (P_4Km), Kalabakan (P_4Kl) and Kalumpang formation (P_4Kg). The Wariu formation (P_4Wr) is found in a small area of northwestern part of the Kinabalu area and consists of sandstone and mudstone with minor intercalation of tuff. The Garinono formation occurs in the east central part of the Labuk area and consists of slump breccia, mudstone , tuff, sandstone and shale. The Ayer formation occurs at the northeastern margin of the Segama area and compose of tuff, slump breccia, mudstone and sandstone. The Kuamut formation covers a wide area, extending the Segama to the Semporna areas. This formation consists of conglomerate, sandstone and siltstone and is characterized by slump breccia. At the western part of the Semporna area, the Kalabakan formation is found to occur and is formed by sandstone, siltstone mudstone and shale. The eastern part of the Semporna area is widely occupied by the Kalumpang formation consisting of tuff, tuffaceous sandstone, shale and mudstone.

From southern part of the Labuk area to the western part of Semporna area through the western part of the Segama area, the Tanjong formation (N_1Tj) of Early to Middle Miocene age is found. This formation consists of mudstone, sandstone, siltstone and conglomerate. At the western part of the Semporna area, the Kapilit formation (N_1Kp), which is of same age with the Tanjong formation, is distributed in a small area. This formation consists mainly of mudstone and siltstone.

At the northeastern margin of the Labuk area, the Bongaya formation (N_2By) of Middle Miocene to Pliocene age underlain the area. This formation consists of sandstone, mudstone, siltstone and conglomerate. In the central part of the Semporna area, the Umas Umas formation (N_2Um) is distributed in a small area. This formation composes of sandstone, shale and mudstone. In a small area along Sungai Balung in the Semporna area, the Balung formation (N_2B) occurs. This formation consists of ash, tuff, mudstone and shale.

The south central to southeastern part of the Semporna area is widely covered with Pliocene volcanics (T_1) and Pleistocene to Holocene volcanics. The Pliocene volcanics are classified into an andesite dominated part and a dacite dominated part. The Pleistocene to Holocene volcanics consists of dacite, basalt and their pyroclastics.

Small intrusive bodies of Oligocene to Late Miocene in age including adamellite, granodiorite, andesite porphyry and dacite porphyry are distributed in the central part of the Kinabalu area. A small body of andesite porphyry of Oligocene age occurs at the southern margin of the Labuk area. Mineralization and alteration are found in this body. In the volcanic zones of the Semporna area, small bodies of fine-grained diorite and granodiorite are found.

Pleistocene terrace deposits (Q_1) are found along the rivers and alluvium sediments (Q_2) are found along the coast and the estuary of rivers. Terrace deposits are widely distributed from southern central to southeastern part of the Semporna area.

The most significant fault system is the N-S system and other systems including ENE-WSW, NE-SW and NNW-SSE systems are also recognized (Y.E. Heng; 1985) in the Kinabalu area. However, in the Labuk area, a NE-SW system is dominant and N-S and NNW-SSE system faults are also observed. Many different systems are found in the Segama area and the systems form complicated geological stricture. The Semporna area is characterized by a trend of ENE-WSW which is the general trend of the volcanics in the area. The fault system, NNW-SSE and NNE-SSW are dominated in the Semporna area. A ring structure is found at the marginal part of the volcanic zone.

3-2 Mineralization and mining activities

Principal metallic ore deposits in the survey area comprise porphyry copper deposit closely related with plutonic rocks, Cyprus-type massive sulfide deposit related to spilite effusion and hydrothermal gold-silver deposits closely related with volcanic rocks. Chromium or platinum deposits related with ultra-basic rocks, lateritic aluminum and nickel deposits and manganese deposits in sedimentary rocks are also known.

The Mamut copper mine is situated north of Ranau in the Kinabalu area and is the only active mine in the project area. The Mamut deposit is porphyry copper type ore deposits hosted by adamellite of Pliocene to late Miocene age. This ore deposit was discovered by a geochemical survey conducted by the United Nations Development Program (UNDP). Overseas Mineral Resources Development Co., Ltd., Japan, obtained the exploration right on the Mamut area through international tender in 1968, and carried out further exploration work from 1968 to 1972, before development work in 1973. The mine has been operating since May, 1975. The current production of crude ore is 20 thousand tons per day with the grade of 0.47 % Cu. The number of staffs and workers of the Mamut Copper Mining Sdn. Bhd. is about 1,300.

The Bidu Bidu Hill ore deposit is in the final stage of exploration work and the development will be made in near future. This ore deposit is Cyprus-type massive sulfide deposits emplaced in spilitic effusive rocks. Exploration work for this ore deposit has been carried out by Leadstar Sdn. Bhd. Ore reserves of 3,600 thousand tons with 3.6 % Cu, 1 - 2 g/t Au and 8-15 g/t Ag have been confirmed by drilling work (approximately 40,000 m) for this deposit.

Exploration work for gold-silver deposits occured in volcanic rocks in the Semporna area has been carried out by Zamia Sdn. Bhd. The survey area by this company covers wide area from the west of Semporna to northern Tawau. The survey consists of mainly soil geochemical survey and trenching. A few drill holes have been completed in the Mentri area.

Chromite showings have been recognized in ultra-basic rocks, but known showings are small in scale. In the area of ultra-basic rocks, lateritic soil are found. Potential of lateritic nickel deposits is possible in the area.

From the results of this survey, mineralized zones of copper were delineated in the upper stream of Sungai Danum in the Segama area. Another significant mineralized zones were recognized at the southern marginal part of the Labuk area.

Chapter 4 Orientation geochemical survey

An orientation geochemical survey was conducted to select the optimum geochemical survey method in this project area. The survey was conducted in three separate areas where different type of mineral deposits occurred. These types are porphyry copper type ore deposits (Nungkok ore deposits), Cyprus type massive sulfide deposits (Bidu Bidu Hill ore deposits) and epithermal type gold deposits (Mentri ore deposits. Existing data indicate that these types of ore deposits have a higher potential in the project area.

In this orientation survey, stream sediments, pan concentrates and soil were tested as the sample media. Chemical analyses were conducted for stream sediments (19 elements), pan concentrates (32 elements) and soil (23 elements) in order to select the optimum pathfinder elements. Several kinds of method were applied for the data processing and analyses to select the optimum data treatment method.

Based on the results of the orientation survey, the optimum survey methods in this project area were selected. The regional and semi-detailed surveys were then conducted using these methods.

Chapter 5 Satellite image analyses

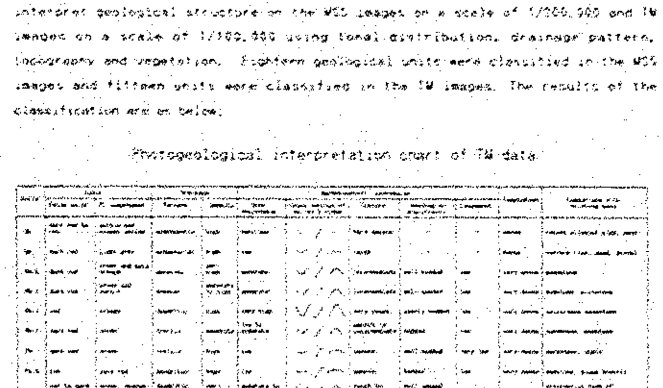
5-1 Data used and image generation

The satellite image analyses were completed in Phase I using five scenes of Landsat MSS data and one scene of Landsat TM data. The false color image generated by TM data is shown in Plate 3.

5-2 Methodology

Integrated analyses were executed to identify geological units and to interpret geological structure on the MSS images on a scale of 1/200,000 and TM images on a scale of 1/100,000 using tonal distribution, drainage pattern, topography and vegetation. Eighteen geological units were classified in the MSS images and fifteen units were classified in the TM images. The results of the classification are as below;

Photogeological interpretation chart of TM data



Interpretation map drawn by TM images is shown in Plate 2.

5-3 Interpretation of TM images

As the ground resolution of the TM data is 30 m, images generated in this survey using TM data give more accurate images for the interpretation as compare with the MSS images with ground resolution of 80 m. In this survey, the principal component compressed image was generated. As this image contains the information of spectrum and topography, it was suitable for the photogeological interpretation.

Results of the interpretation were summarized as follows;

① A new major fault zone trending N-S in the east of Ranau in the Kinabalu area was delineated. Geology of the east and west sides of this fault zone show significant differences. This fault zone is large in scale and possibly play important role for the mineralization in this area.

② A number of ring structure were delineated near Ranau and have close relationship with the distribution of intrusive bodies. As mineralization was confirmed in these intrusive bodies, the ring structure in this area is important for future exploration work.

③ The area along Sungai Labuk was delineated as the area showing similar geological setting of the Bidi Bidu Hill ore deposit area. Further geological survey in this area is needed in order to understand the relationship between the geology and mineralization.

The best available data have been used in this survey, but cloud covers a part of thesurvey area, and the interpretation for the Semporna area was difficult. It is suggested to use Synthetic Aperture Radar image for the interpretation in the area in future.

Chapter 6 Heliborne geophysical survey

6-1 Coverage of work

Heliborne survey was separately conducted for the six sub-divided areas which include the Northern Kinabalu, Southern Kinabalu, Labuk, Segama, Northern Semporna and Southern Semporna areas. Magnetic susceptibility and radioactivities for the representative rocks in the survey area were measured and the results were used for interpretation. This survey covers most of the known mineral occurrences in the area.

6-2 Methodology

The heliborne survey consists of magnetics and gamma-ray radiometrics. The measurement and data processing were made by Aerodat Limited of Canada.

Specification of this survey are as follows;

①	Method	Heliborne geophysical survey
②	Items	Total intensity of geomagnetic field
		Gamma-ray radiometrics (U, Th, K and total count)
③	Flight level	150 m ± 30 meters terrain clearance
		Magnetometer Sensor 150 m terrain clearance
		Spectrometer Sensor 180 m terrain clearance
④	Line spacing	Traverse line 500 m, Tie line 10 km
⑤	Navigation	GPS (Global Positioning System)
⑥	Traverse ground speed	Approximately 75 knots (135 km/h)

Operation bases were established near the survey area for the field survey. A magnetometer was operated at each operation base to record diurnal variations of the earth's magnetic field.

The data were interpolated on to a regular grid using Akima spline technique (Akima H., 1970). A grid cell size of 250 m was used for the maps in this Atlas.

Map of total field magnetics (Plate 5), shadow map of total field magnetics (Plate 6), map of total count radiometrics (Plate 8), and a radiometric ternary map (Plate 9) were prepared for interpretation. Based on the interpretation, magnetic anomaly map (Plate 4) and radiometric anomaly map (Plate 7) were prepared and the relationship between the anomalies and the geology was studied.

6-3 Ground survey

Magnetic susceptibilities and radioactivities were measured for the representative rocks in the area. Rocks of high magnetic susceptibility of more than 10^{-3} CGSemu are gabbro, serpentinite, basalt, andesite, amphibolite, biotite hornfels, adamellite, granodiorite and tuff. High count radiometric rocks of more than 100 cps are sandstone, shale, biotite hornfels, adamellite and granodiorite.

High magnetic and high count rocks such as biotite hornfels, adamellite and granodiorite will result in large-amplitude magnetic anomalies and high-count radiometric anomalies at the same location.

6-4 Survey results

The survey results are interpreted as follows;

① In the Northern Kinabalu area, N-S trending magnetic discontinuity lineaments are dominante and high-count anomalies which are mainly contributed by potassium are also aligned in the N-S direction. This N-S trend is the same as the strikes of the faults inferred by the satellite image analyses, and that these lineaments seem to reflect main geological structure. In the northern part of this area, magnetic anomalies of large amplitude and short wave-length which aligned in the E-W and ENE-WSW directions and are due to highly magnetized Chert-Spilite formation which is near surface. These highly magnetized bodies are divided by N-S trending magnetic discontinuity lineaments.

② In the western margin at the central part of the Northern Kinabalu area, low magnetic anomalies of long wave-length and relatively large amplitude are due to the highly magnetized rocks at depth. At the southwestern part of the Northern Kinabalu area, a number of large amplitude magnetic anomalies of relatively short wave-length aligned in a NW-SE direction are caused by highly magnetized rocks including ultra-basic rocks, adamelite, granodiorite and Chert-Spilite formation near surface. These highly magnetized rocks are separated by N-S trending magnetic discontinuity lineaments. Very high radiometric anomalous zones showing large contribution of uranium and thorium are located on low magnetic anomalous zones.

③ Non-magnetized and high radiometric zones are widely distributed in the area of sedimentary rocks (mainly sandstone) in the Southern Kinabalu area. On the other hand, high magnetized and low radiometric zones are found in the area of the Chert-Spilite formation (KPCs) and ultra-basic rocks (Ub) in the Labuk area. The survey results correspond to the geology of both the areas.

④ In the Southern Kinabalu area, magnetic anomalies of relatively long wave-length and small amplitude are aligned in the directions of NW-SE at the western part, N-S at the central to southeastern part, and E-W at the southern part, which are caused by dacite and/or gabbro of magnetic susceptibility of 0.2 to 0.7×10^{-2} CGSemu and the depth of 1 to 2 km below ground level. These parts which show high total counts on the radiometrics total count map, indicate that these magnetic anomalies are undoubtedly to deeper sources.

⑤ In the Labuk area, N-S trending magnetic discontinuity lineaments cut main lineaments of different directions and block the high magnetic bodies. Radiometric discontinuity lineaments also indicate a N-S direction. The N-S system in the Southern Kinabalu and Labuk area is interpreted to be the latest structure in both the areas.

⑥ Distributions of magnetic and radiometric anomalous zones correspond well to the geology in the Segama area, and Northern and Southern Semporna areas. These distributions suggest that highly magnetized and low radiometric ultra-basic rocks occupy the Segama area, low magnetic and high radiometric sedimentary rocks crop out in the Northern Semporna area, and high magnetic and comparetively low radiometric volcanic rocks are distributed in the Southern Semporna area.

⑦ Many magnetic anomalies of small amplitude and relatively long wave-length are distributed in the high magnetic zone at the southwestern part of the Segama area, and these are caused by intrusive rocks such as ultra-basic rocks at the shallow depth (surface to 500m below ground level).

⑤ Many magnetic anomalies of small amplitude and relatively long wave-length are found at the central to eastern part of the Northern Semporna area, and these are due to shallower intrusive rocks such as ultra-basic rocks, because low radiometric count anomalies spot in high count zone at the same locations.

⑥ According to a geologic map, andesite is distributed broadly in the circular zone of the Southern Semporna area, but highly magnetized bodies corresponding to andesite are denoted by low and/or non magnetized bodies and radiometric total count anomalies are found at the same spot. Then, the existence of altered zones with low magnetization are suggested at the same spots.

Chapter 7 Regional geochemical survey

7-1 Coverage of work

A regional geochemical survey using stream sediments, pan concentrates and rocks as the sample media was completed for the entire project area. In order to determine the potential of nickel ore deposits, lateritic soil samples were collected from the area of ultra-basic rocks. Geological reconnaissance survey was simultaneously carried out along the geochemical sampling route, and rock samples were collected for the laboratorial studies. Overall interpretation was made using all the data collected.

7-2 Methodology

Following elements were adopted as pathfinder elements in this survey.

- Stream sediments (21 elements)

  As, Au, Ba, Co, Cr, Cu, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, S, Sb, Sr, Ti, U, W, Zn

- Soil (6 elements)

  Al, Co, Fe, Cr, Ni, Pt

In order to examine the composition of heavy minerals in the pan concentrate sample Qualitative Mineral Examination (QME) were conducted.

Representative rock samples collected in this survey were chemically analyzed for 21 elements, same as for the stream sediments, in order to examine the geochemical nature of the background rocks.

7-3 Data processing and analyses

The analytical data were treated statistically by computer, and distribution maps of each element were generated. For the data analyses, single element analysis and multi element analysis methods were utilized. Exploratory Data Analysis (EDA) method (Kurzl H., 1988) was used for the single element analysis. Cluster and factor analyses were applied as the multi element analysis.

EDA method can delineate the threshold value without consideration on the distribution pattern of each element. The cluster analysis is a grouping method of the elements using correlations among the elements. The factor analysis is the method to delineate the factor that contribute a relationship among the samples.

In case of the stream sediment survey, distribution maps of each element were generated. Weight average interpolation method was applied and a grid cell size of 200 m was used. Radius which is search circle to estimate a grid value, is 2,000 m.

The data treatment was made together for the samples collected in the four survey areas.

7-4 Survey results

Geological reconnaissance survey was simultaneously carried out during the regional geochemical survey.
The survey results are summarized as follows:

<u>Stream sediment geochemical survey</u>

Locations of the samples are shown in Plate 10. The statistics calculated are as follows;

Statistics of stream sediment geochemical survey

Element	Statistics						EDA method*3		
	Below detection limit (%)	Maximum value	Minimum value	Mean*1 value (b)	Standard deviation	b + 2S.D. *2	Median	Upper Wisker	Upper Fence
As (ppm)	53.5	929	< 1	1.7	0.622	32.1	5.1	10.0	368.7
Au (ppb)	81.9	9,220	< 1	0.8	0.325	3.5	0.5	0.5	0.5
Ba (ppm)	2.1	1,478	< 2	81.6	0.382	477.9	55.0	164.2	559.1
Co (ppm)	4.5	1,058	< 1	10.2	0.579	145.5	10.0	32.0	352.7
Cr (ppm)	—	117,528	42	325.2	0.549	4,245.7	244.0	560.3	1,011.9
Cu (ppm)	0.2	2,632	< 1	13.9	0.335	66.1	13.0	27.0	124.7
Hg (ppb)	26.5	24,734	< 10	19.7	0.525	215.4	18.0	45.0	744.4
K (%)	0.2	4.55	< 0.01	0.271	0.527	3.068	0.330	0.700	3.653
Mg (%)	0.6	22.60	< 0.01	0.485	0.656	9.103	0.450	1.010	31.342
Mn (ppm)	19.9	12,354	< 1	165.0	0.302	10,787.0	245.0	1,160.0	70,266.4
Mo (ppm)	81.1	54	< 1	0.6	0.223	1.7	0.5	1.0	5.5
Na (%)	1.5	0.53	< 0.01	0.175	0.598	2.786	0.200	0.550	6.615
Ni (ppm)	0.0	6,775	< 1	45.2	0.572	666.0	37.1	114.0	663.8
Pb (ppm)	44.0	790	< 2	2.9	0.476	25.2	3.0	9.0	129.6
S (%)	—	6.108	0.003	0.025	0.353	0.114	0.024	0.046	0.574
Sb (ppm)	10.9	3,468.0	< 0.2	0.32	0.705	75.12	0.50	9.45	76.12
Sr (ppm)	0.9	1,257	< 1	31.2	0.459	253.6	29.0	67.0	250.1
Ti (%)	—	51.07	0.01	0.333	0.442	2.545	0.250	0.900	4.725
U (ppm)	4.8	43.2	< 0.2	1.10	0.353	5.62	1.40	2.05	5.25
W (ppm)	33.5	122	< 2	1.1	0.167	2.3	1.0	1.0	1.0
Zn (ppm)	5.6	747	< 1	32.6	0.404	525.4	41.0	91.0	703.6

*1: geometric mean, *2: background value + 2 x standard deviation, *3: Exploratory Data Analysis (Kurzl H., 1988)

Distribution maps of each element are shown from Plate 11 to Plate 29.

The data processing and the distribution maps give the following results.

① Among the elements, the maximum values of Au (9,220 ppb), Cr (11.75 %), Hg (24,734 ppb), Sb (3,468.0 ppm) and Ti (51.07 %) give extremely high values comparing to general geochemical survey in other areas.

② High correlation coefficients are found among the elements including Co, Cr, Mg, Mn, Ni and Zn due to wide distribution of ultra-basic rocks and Chert-Spilite formation. No elements have good correlation with Au. The elements which indicate good correlation (more than 0.500 correlation coefficient) with Co are Mg, Mn, Na, Ni, S and Zn.

③ According to the distribution maps of each element, the anomalous and samples with high content of Co, Cr, Mg, Ni, Sb and Zn are found in the area of ultra-basic rocks. In the area of ultra-basic rocks, Ba and K characteristically show low values.

④ High contents of As, Ba, K, S and U are found in the area of argillaceous rocks.

⑤ High contents of Co, Mn, Na and Zn are found in the area of Chert-Spilite formation.

⑥ In the area of volcanics in the Semporna area, contents of Ba, Cu, K, Sr, Ti, U and Zn show comparatively high values.

⑦ Crystalline basements have higher contents of Sr, Ti and Zn.

Judging from the results of the regional geochemical survey, the followings can be concluded.

① A number of high contents and anomalous samples of Au, Cu, Hg, Mo, Pb, S and Sb are found in and around Mamut mine in the central part of the Kinabalu area. The most conspicuous anomalous zone was detected in this area.

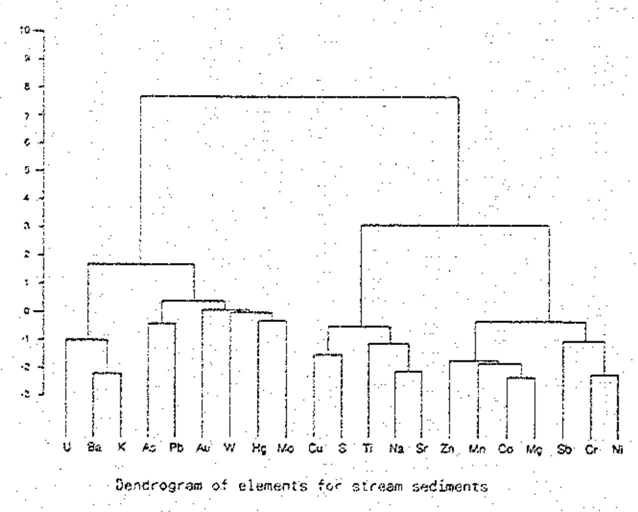
② Significant anomalous zones of Au are found at the tributary of Sungai Imbak in the Labuk area and the surrounding area of Mt. Wullersdorf in the Semporna area. Anomalous zones of As, Hg and Pb are also found in the anomalous zones of Au in the Sungai Imbak area. Diorite porphyry dykes with mineralization were found in this area. The area of Mt. Wullersdorf includes the Mantri deposit area where the orientation survey was conducted. In this area, gold mineralization occurs together with anomalous zones of As and Pb.

③ The most conspicuous anomalous zones of Cu is found in the surroundings of Mamut copper mine. The Bidu Bidu Hill copper deposits in the Labuk area is delineated as the conspicuous Cu anomalous zone. Other than these anomalous zones, significant anomalous zone of Cu was also delineated in the Sungai Karamuak area. During this survey mineralized zones were confirmed in the upper stream of Sungai Danum. This area was also delineated as Cu anomalous zone. However, it is not conspicuous.

④ Hydrothermally altered zones are found in many places in the volcanic zone of the Semporna area. These altered zones are argillized and correspond to the anomalous zones of Hg.

⑤ A sample collected from tributary of Sungai Karamuak at the southern margin part of the Kinabalu area shows extremely high contents of Ti (51.07 %) in the Chert-Spilite formation. The minerals in the sample are mainly ilmenite and potential for titanium is expected.

The result of the cluster analysis is as follows;



Dendrogram of elements for stream sediments

Results of the analysis clearly divide elements into the clusters related to volcanics, sedimentary rocks, alteration, gold mineralization, copper mineralization, crystalline basements and ultra-basic rocks.

Results of the factor analysis delineated six factors. Distribution maps of factor scores of factor 1 to factor 5 are shown in Plate 30 and 31. Among these factors, factor 1 seems to be related to ultra-basic rocks. Factor 2 have relation with sedimentary and volcanic rocks. Factor 3 seems to be related to mineralization. Factor 4 have relation with Chert-Spilite formation, crystalline basements and volcanic rocks. Factor 5 has relation with mineralization and argillaceous rocks. But factor 6 does not show any clear relationship with mineralization.

A conspicuous high factor score (negative factor) zone of factor 3, which has some relation with mineralization, is found in the area of Mamut mine. Following this high factor score zones, significant high factor score zones are found in the areas of Sungai Tabak in the Labuk area, area surrounding Mt. Wullersdorf and the most of the upper stream of Sungai Kalumpang in the Semporna area. Within these areas, mineralization and alteration are confirmed in this survey. Judging from the results of factor analysis, high factor score zones of factor 3 are important for the future exploration work.

Pan concentrate survey

Significant amount of concentrates were collected in the area of ultra-basic to basic rocks, but small amount of concentrates were collected from the area of sedimentary rocks.

The heavy minerals detected in this survey include magnetite, chromite, hematite, ilmenite, goethite, pyrite and zircon. Other than these minerals, a minor amounts of leucoxene, rutile, monazite, tourmaline and native gold were observed. Some samples contain comparatively large amount of pyroxenes and hornblende. The samples with small amount collected in the area of sedimentary rocks contain mainly quartz and plagioclase. Among these heavy minerals, a large volume of magnetite and chromite were found in the area of ultra-basic rocks. Pyrite and ilmenite were found in the samples from the Chert-Spilite formation and volcanics. Comparatively large amounts of goethite and zircon were found in the area of sedimentary rocks. The samples with native gold are mostly found in the area of the Mantri deposits in the Semporna area.

Rock geochemical survey

Representative rock samples were collected in this survey in order to understand the geochemical nature of the background geology. The followings were confirmed in this survey.

① The elements of Co, Cr, Mg, Ni and Zn show higher values in the ultra-basic rocks.
② Basic rocks such as the Chert-Spilite formation and basalt lavas show higher values of Cu, Sb, Zn and Ti.
③ The elements including As, Hg, Pb and U indicate higher values in sedimentary rock samples.
④ The elements of As, Au, Cu, Hg, Pb and S show higher values in the altered zones of volcanics in the Semporna area.
⑤ Normal relationship is found between the analytical results and the type of rocks.

Soil geochemical survey

In order to determine the potential of lateritic nickel deposits, a soil geochemical survey was carried out in the area of ultra-basic rocks.

The survey results are summarized as follows:

① A samples collected at 4 km northeast of Ranau in the Kinabalu area indicates high contents of Ni (10,797 ppm) and Co (1,212 ppm). The potential for lateritic nickel deposits is thought to be high.
② West of Telupid in the Labuk area, lateritic soil is developed in the ultra-basic rocks. The samples collected in the area show high values of Ni (maximum 11,382 ppm), Co (maximum 2,173 ppm) and Fe (maximum 46.37 %). This area also has a potential for lateritic nickel deposits.
③ The lateritic soil samples collected in the Segama and Semporna areas indicate approximately 3,000 ppm Ni. Because of poor development of laterite, potential for lateritic nickel deposits is thought to be low.

7-5 Delineation of potential areas

Judging from the results of the regional geochemical survey, eighteen areas including four areas from the Kinabalu area, six areas from the Labuk area, four areas from the Segama area and four areas from Semporna area, were selected as the potential areas for mineral resources. A semi-detailed geochemical survey was conducted in these selected areas. The targets of the semi-detailed survey are copper, gold, chromium, nickel and titanium ore deposits.

Chapter 8 Semi-detailed survey

A semi-detailed geochemical survey was carried out for the eighteen selected areas.

Coverage and the number of samples collected in this survey are as follows:

Coverage	1,072 km²
Stream sediments	725 samples
Soil	2,472 samples

Details of the survey results are given in Phase III and IV reports.

Chapter 9 Recommendations

Judging from all the survey results in this project, the following items are recommended for future exploration work in this project area:

(1) Results of the interpretation of satellite images confirmed N-S trending fault zones in the Kinabalu area and a number of ring structure in several places. The satellite image analysis is a useful tool to the understanding the entire geology and the relationship between the geology and mineralization. Consequently, the satellite images generated in this survey should be used for future exploration work in this area.

(2) Results of the heliborne geophysical survey reflected well the geology and the geological structure in this survey area. As the low magnetics and high total count radiometrics zones correspond to altered volcanic zones, it is possible to delineate hydrothermally altered zone. The data of this survey should be used to make more accurate interpretation of the geological structure in the future survey.

(3) Results of the regional geochemical survey clarify the distribution tendencies of each element over the entire survey area. In this survey, many geochemical anomalous zones of each element were delineated, but the semi-detailed survey was only conducted over the most significant anomalous zones. Therefore, remaining anomalous zones should be examined in the future. Significant anomalous zones were also detected in the known mineralized zones such as Bidu Bidu Hill ore deposits and Mantri area. These areas are excluded for the semi-detailed survey because exploration work has been conducted.

(4) The sample density in the semi-detailed survey was basically 4 samples/km². Because of scarce samples in the survey area, only the outline of the mineralized zones were confirmed in this survey. Therefore, detailed survey should be carried out for the newly discovered potential zones in this survey in the future.

(5) A huge amounts of heliborne geophysical and geochemical data obtained in this survey were input in the magnetic tapes. The drainage data of 1:50,000 scale were also input. These data are basic data in this area and anybody can access to any part of the data for re-examination and further investigation. If these data are used for the future exploration, the work can be carried out quite efficiently.

Survey Member

Japanese Counterpart	Malaysian Counterpart
Takehiko NAGAMATSU	Lim Peng SIONG
Masahiko NONO	Alexander YAN
Tsuyoshi SUZUKI	Joanes MUDA
Tadahiko MONMA	Paulus GODWIN
Yoshinori TSUGUMA	Allagu BARAGURU
Masatsugu OKAZAKI	Clefos TOTU
Motomu GOTO	Salleh ADANAN
Masayuki SAITO	Japili SAMIN
Manabu ISHII	Rojer TOTU
Jun-ichi YAMAGATA	Kamil KAMARUDDIN
Hiroshi HYODO	Jolouis SUPILIN
Kazutoshi SUGIYAMA	
Makoto KAWAMURA	
Susumu SASAKI	
Masatane KATO	

要約

本調査は、日本政府とマレイシア政府との間で平成2年5月1日に締結された実施細則に基づき、サバ州南東部地域において鉱物資源賦存の可能性を調査することを目的として、平成2年度より平成5年度の4か年間実施した。このレポートは、第1年次より第3年次までの間に実施した広域調査結果を取り纏めたものである。

本調査では、衛星画像解析、地質調査、空中物理探査及び地化学探査の手法を採用した。第1年次の調査では、衛星画像解析、最適の調査手法を明らかにするための地化学探査予察調査及び空中物理探査を行った。第2年次の調査では、第1年次に引き続き空中物理探査を実施するとともに、調査地域南部のセガマ地区及びセンポルナ地区の全域に対し広域地化学探査を行った。第3年次の調査では、前年度の広域地化学探査の結果抽出された有望地8地区に対して地化学探査の準精査を実施するとともに、調査地域北部のキナバル地区及びラブク地区に対して第2年次の調査と同様の広域地化学探査を行った。最終年次に当たる第4年次の調査では、第3年次にキナバル地区及びラブク地区で実施した広域地化学探査の結果抽出された有望地区10地区に対し地化学による準精査調査と第3年次の調査で鉱化帯の確認されたセガマ地区の1地区に対し精査調査を行った。

準精査調査の結果では、最終的に5か所が有望地として抽出された。これらの箇所に対しては引き続きその全貌を解明するための精密調査の実施が必要である。

本調査では今後の探査活動に必要な基礎的データを取得した。これらのデータを有効に利用することにより、今後の調査を効率的に実施すると共に新たな可能性を見いだすことが可能である。具体的には、以下の点に留意すべきである。

(1) 地質調査及び鉱床探査を実施する場合、全体構造を把握するために衛星画像を活用する。
(2) 地質構造の解明や変質帯の抽出に空中物理探査結果を活用する。
(3) 広域地化学探査の結果抽出された異常帯で準精査調査の実施されなかった箇所については将来の調査が望まれる。

本調査で取得されたデータは、その殆どをテープに入力してありコンピュータによる再処理が可能である。更に、入力されたデータは、範囲の指定や部分的な取り出しも可能である。今後の調査では、本調査により取得されたこの基礎的データを有効に活用することが効果的な調査を実施する上で重要である。

References

Akima H.(1978): A Method of Bivariate Interpolation and Smooth Surface Fitting for Irregularly Distributed Data Points. ACM Trans. Math. Software 4, pp.148-159

Akiyama Y. (1984): A case history - exploration, evaluation and development of the Mamut porphyry copper deposit, Geol. Soc. Malaysia, Bull. 17, pp.217-225

Chung S.K.(1971). Geological Map of the Upper Segama Valley and Darvel Bay Area. Geological Survey of Malaysia.

Chung S.K.(1984): Annual Report 1982, Geological Survey of Malaysia, Ministry of Primary Industry.

Collenette P.(1965): Prospecting in Sabah by Borneo Mining Limited 1959 - 1963. Borneo Reg., Geological Survey of Malaysia Annual Report for 1964, pp.57-61

David T.C.Lee(1988): Gunung Pock area, Semporna Peninsula, Sabah Malaysia. Explanation of Sheet 4/118/10. Report 9. Geological Survey of Malaysia.

Fitch F.H.(1961): The geology and mineral resources of the Semporna Peninsula, Northern Borneo. Geological Survey Memoir 14, Geological Survey Dept., Malaysia.

Guilbert J.M. & Park C.F.Jr.(1986): The Geology of Ore Deposits. W.H. Freeman and Company/New York.

Heng E.H.(1985): Geological Map of Sabah, Third Edition, Geological Survey of Malaysia

JICA and MMAJ(1988): Report on the mineral exploration in Sabah, Malaysia. Consolidated Report.

Kurzl H.(1988): Exploratory data analysis: recent advances for the interpretation of geochemical data. Journal of Geochemical Exploration, vol. 30 pp. 309-322.

Hall N.S.(1968): The northwest Borneo geosyncline in its geotectonic setting. Geolo. Soc. Malaysia Bull. 1. p.59

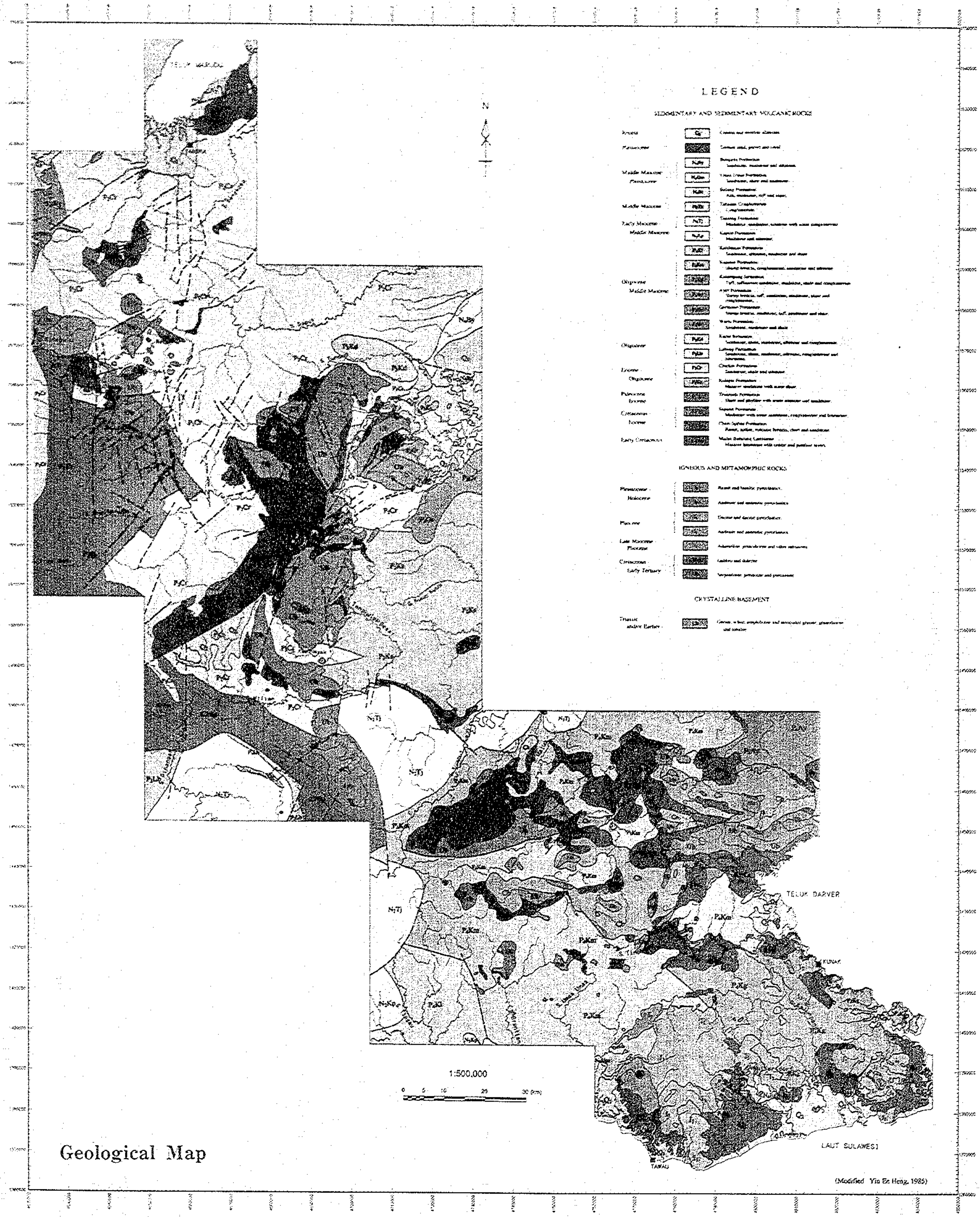
Lewis D.E.(1964): Case History of a Geochemical Anomalous Copper Zone at Pinundun, Sabah, Malaysia. Borneo Reg. Malaysia Geol. Survey Ann. Rept. 1964 pp.163-175.

Lim P.S.(1981): Wullersdorf Area, Sabah Malaysia. Report 15, Geological Survey of Malaysia.

Leong K.M.(1976): Mineral distribution map of Sabah, 1st edition. Geological Survey of Malaysia.

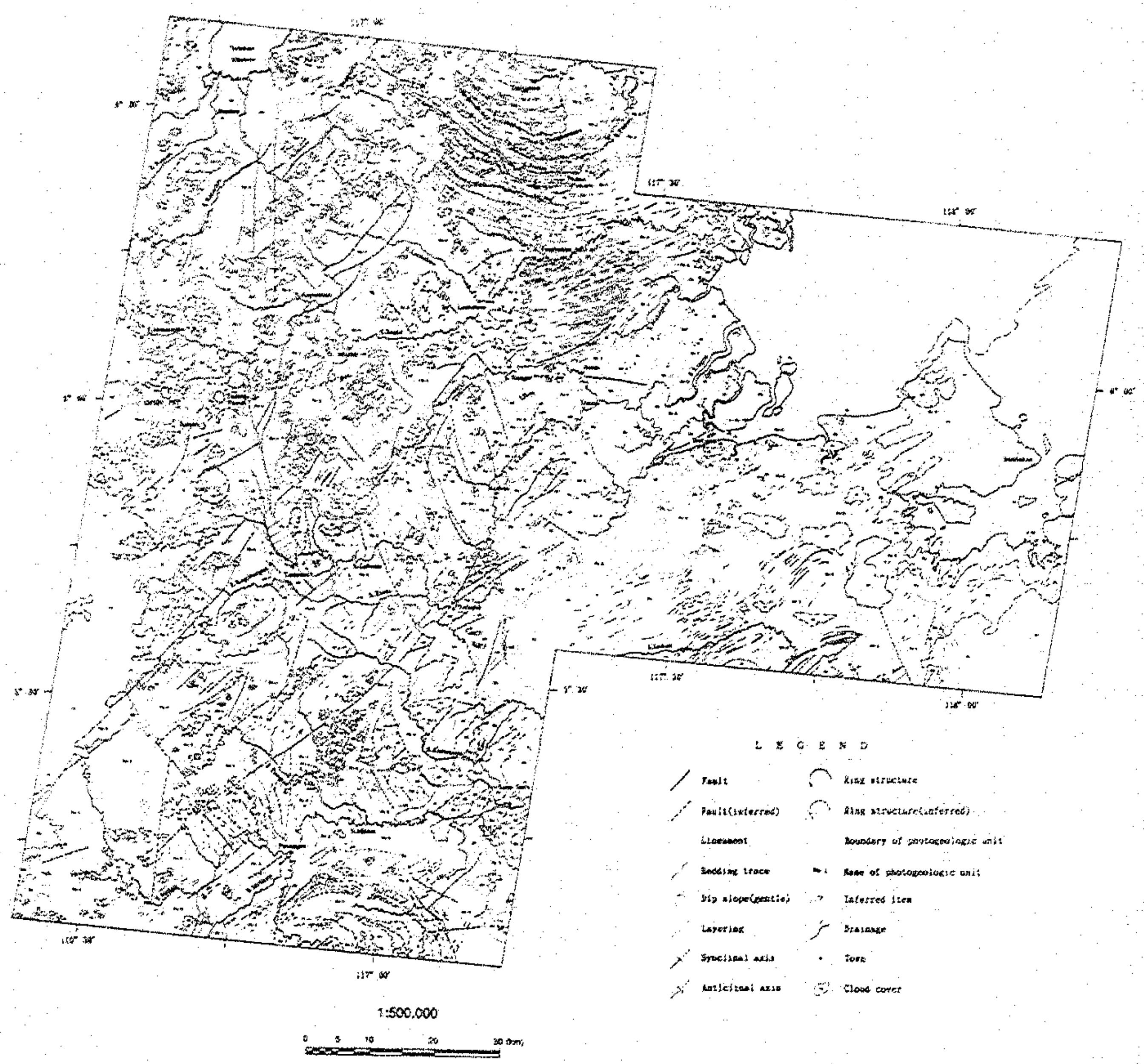
Newton-Smith J.(1967): Bidu Bidu Hill area, Sabah, East Malaysia. Exploration of Sheet 5-117-2 and part 5-117-1. Geological Survey of Malaysia.

Willson R.A.M.(1964): Annual Report of the Geological Survey, Borneo, Malaysia, Geological Survey of Malaysia.

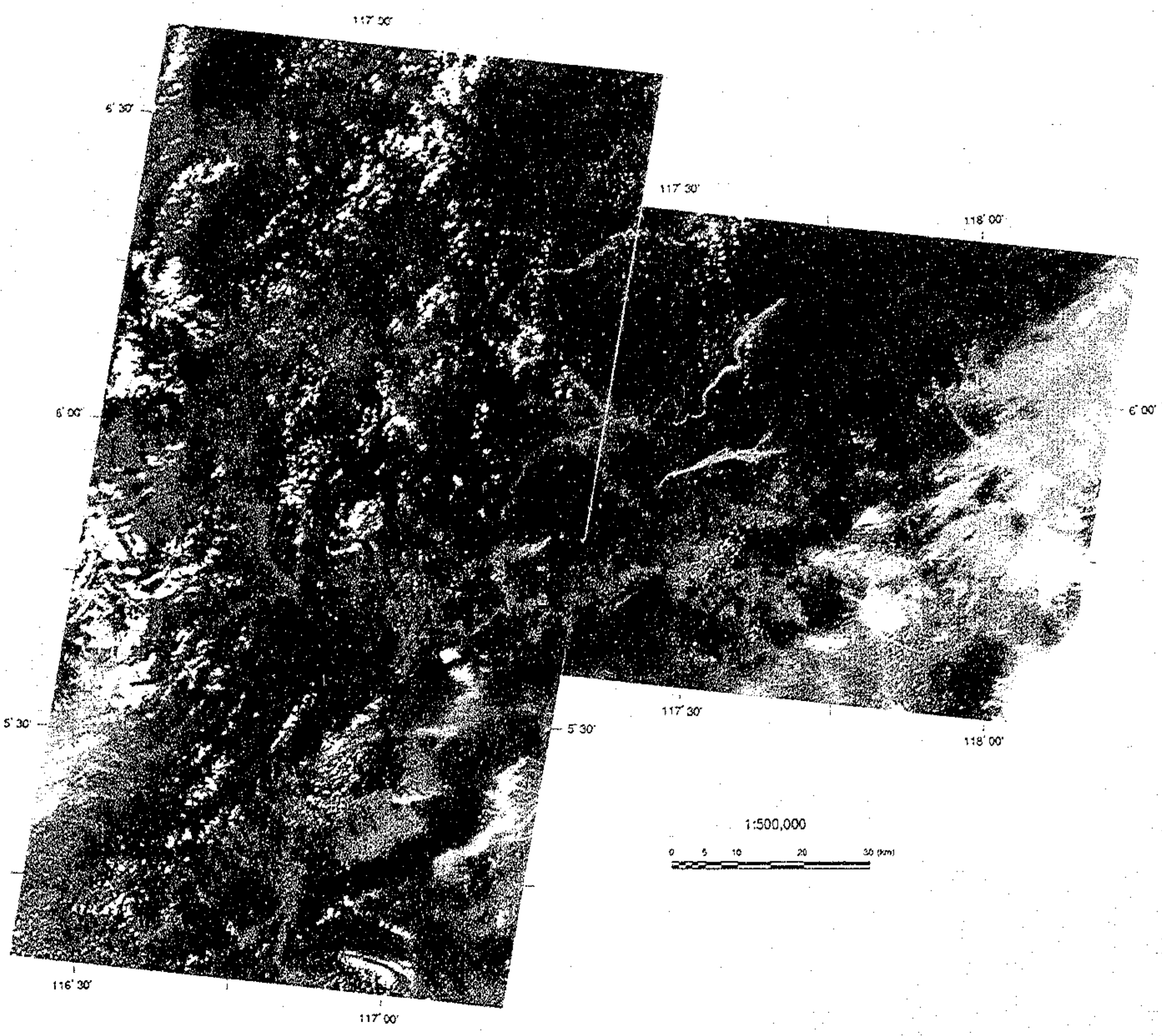


Geological Map

(Modified Yin Ee Heng, 1985)

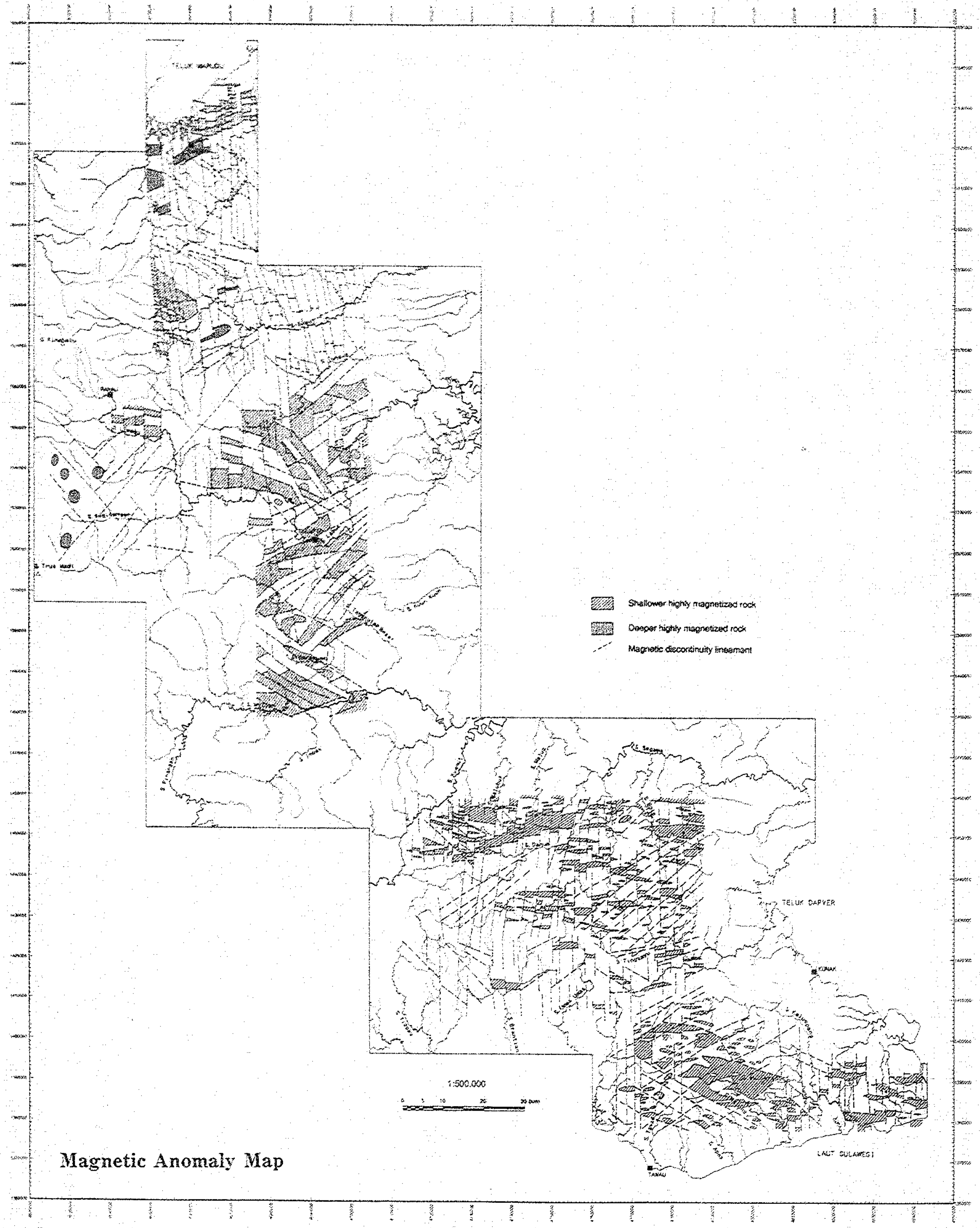


Interpretation Map of Landsat Images of TM Data

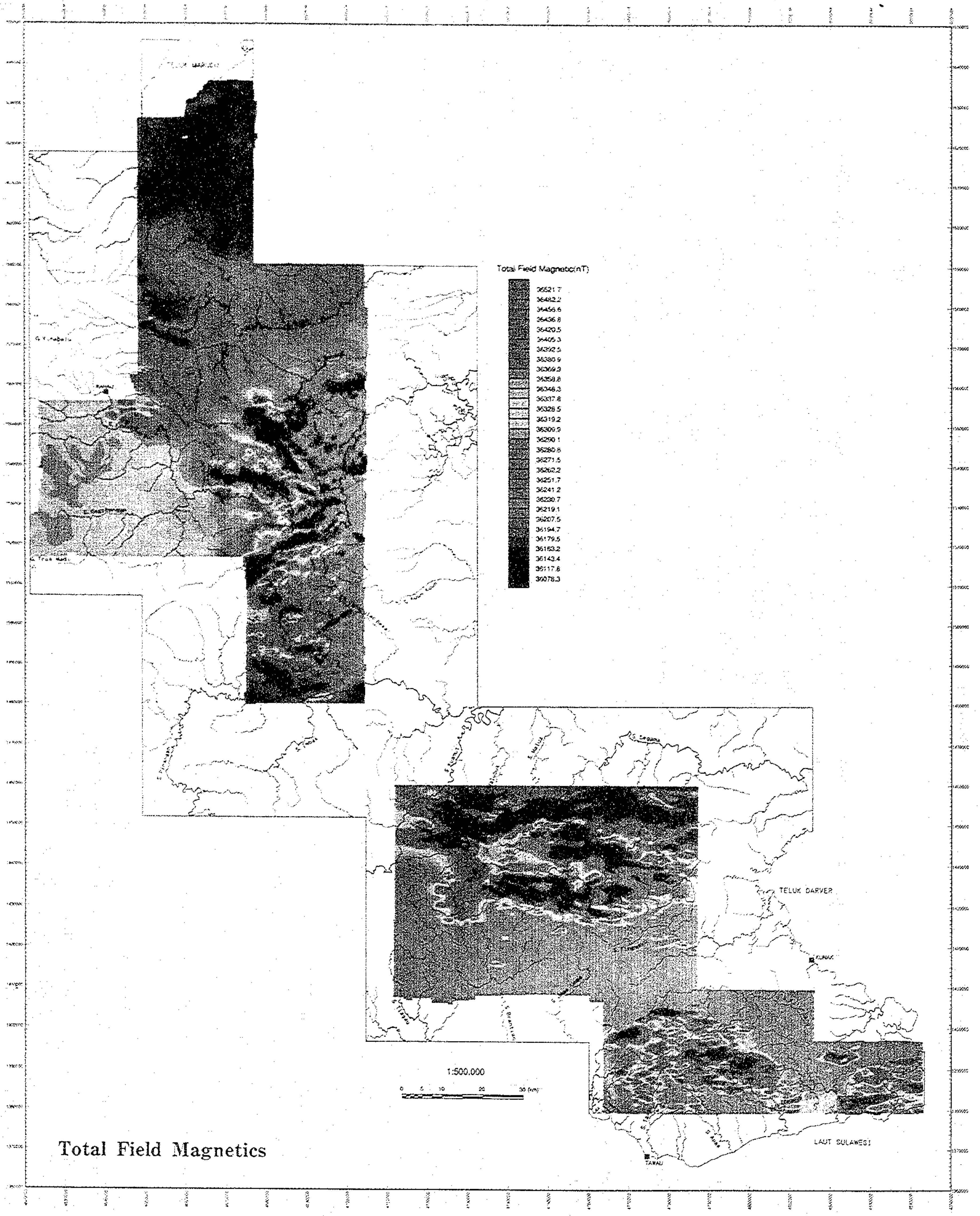


False Color Image of TM Data

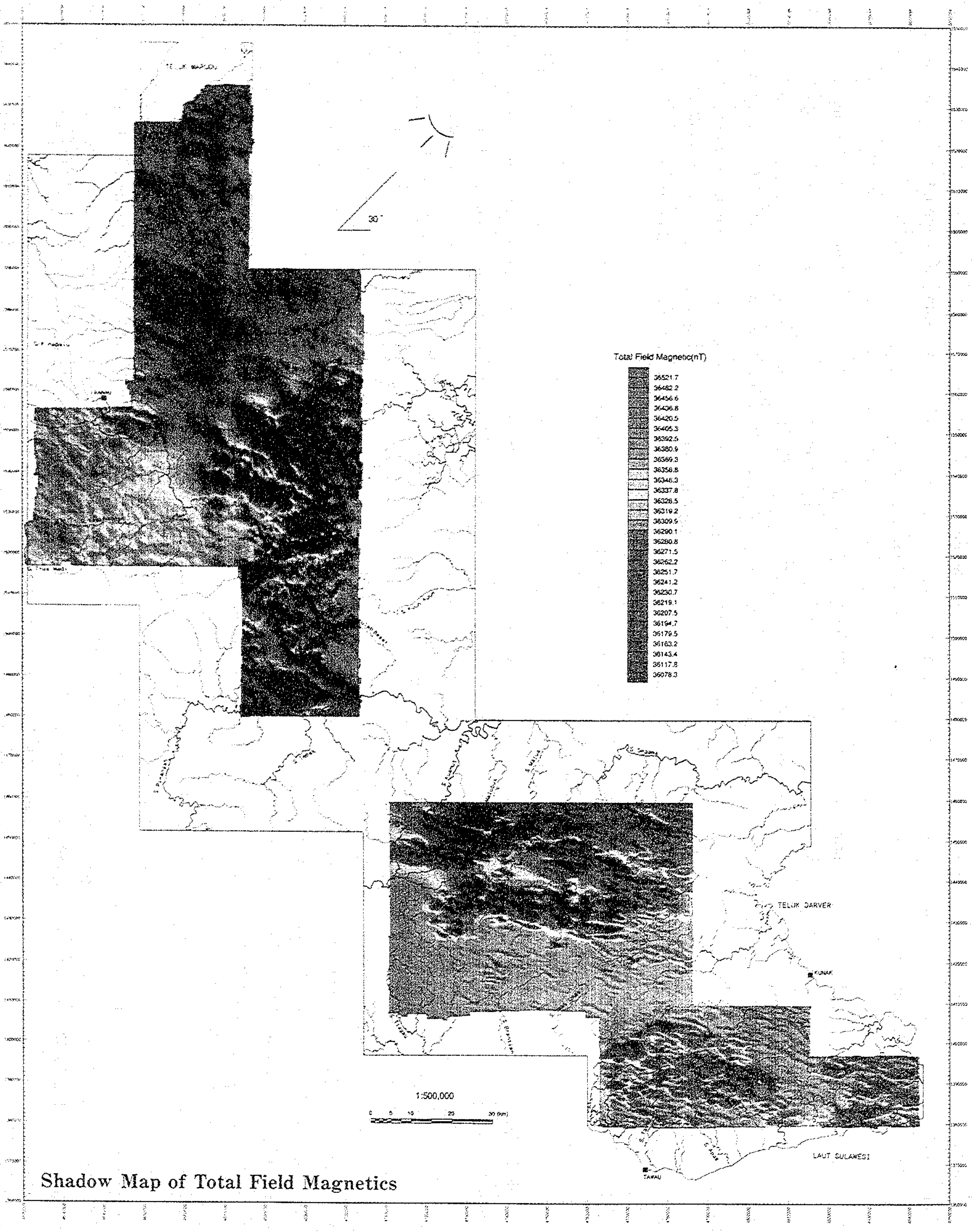
Plate 4



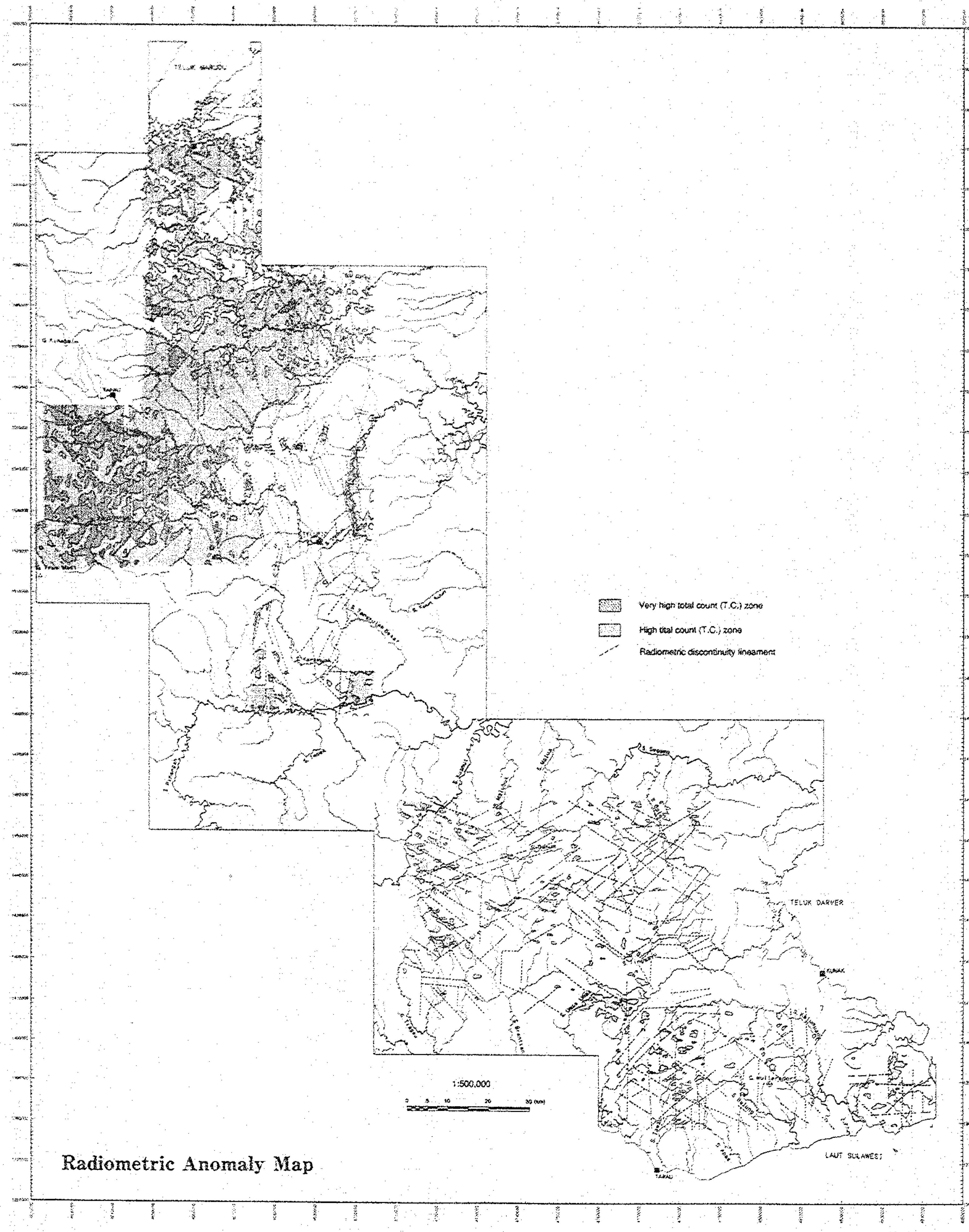
Magnetic Anomaly Map



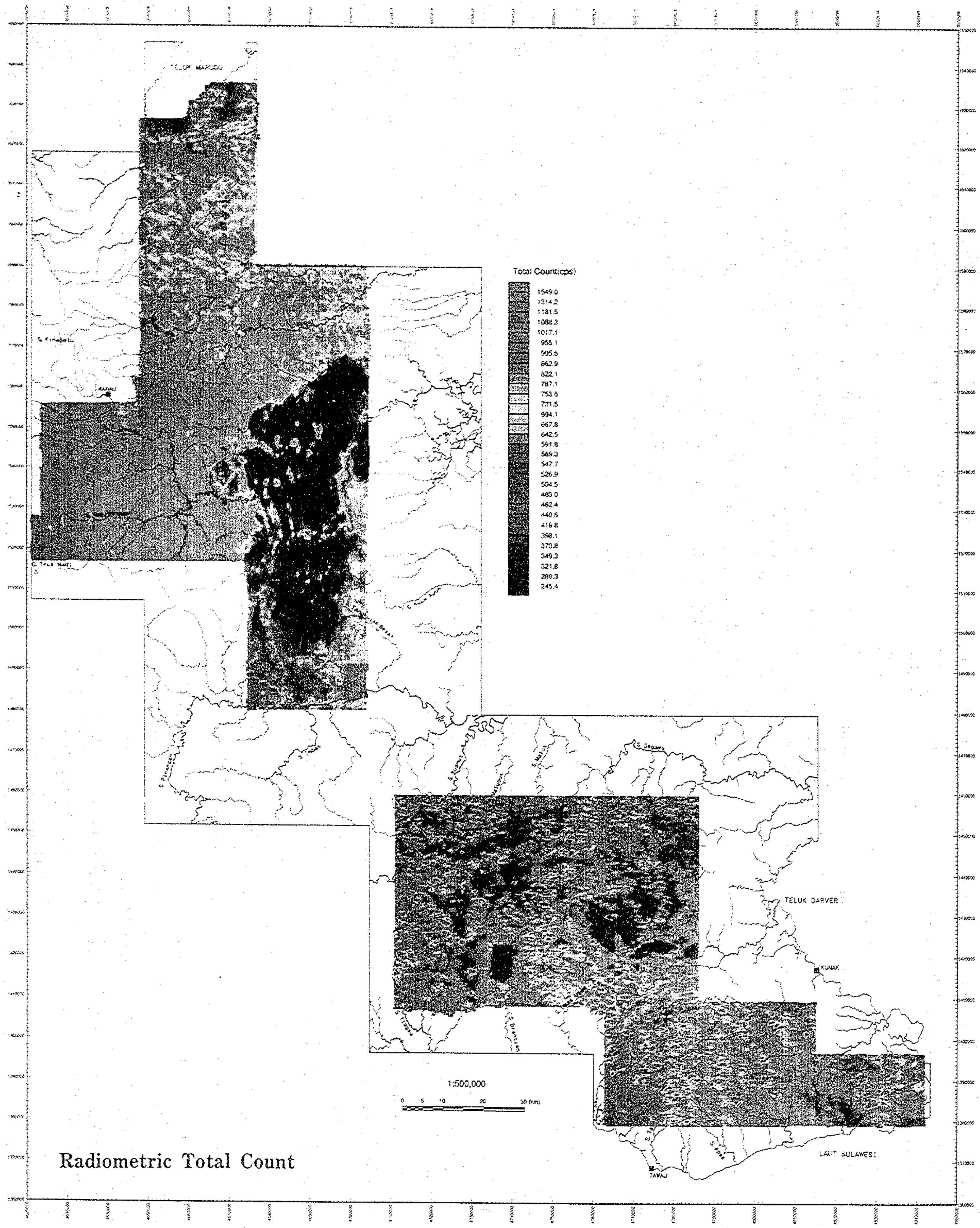
Total Field Magnetics



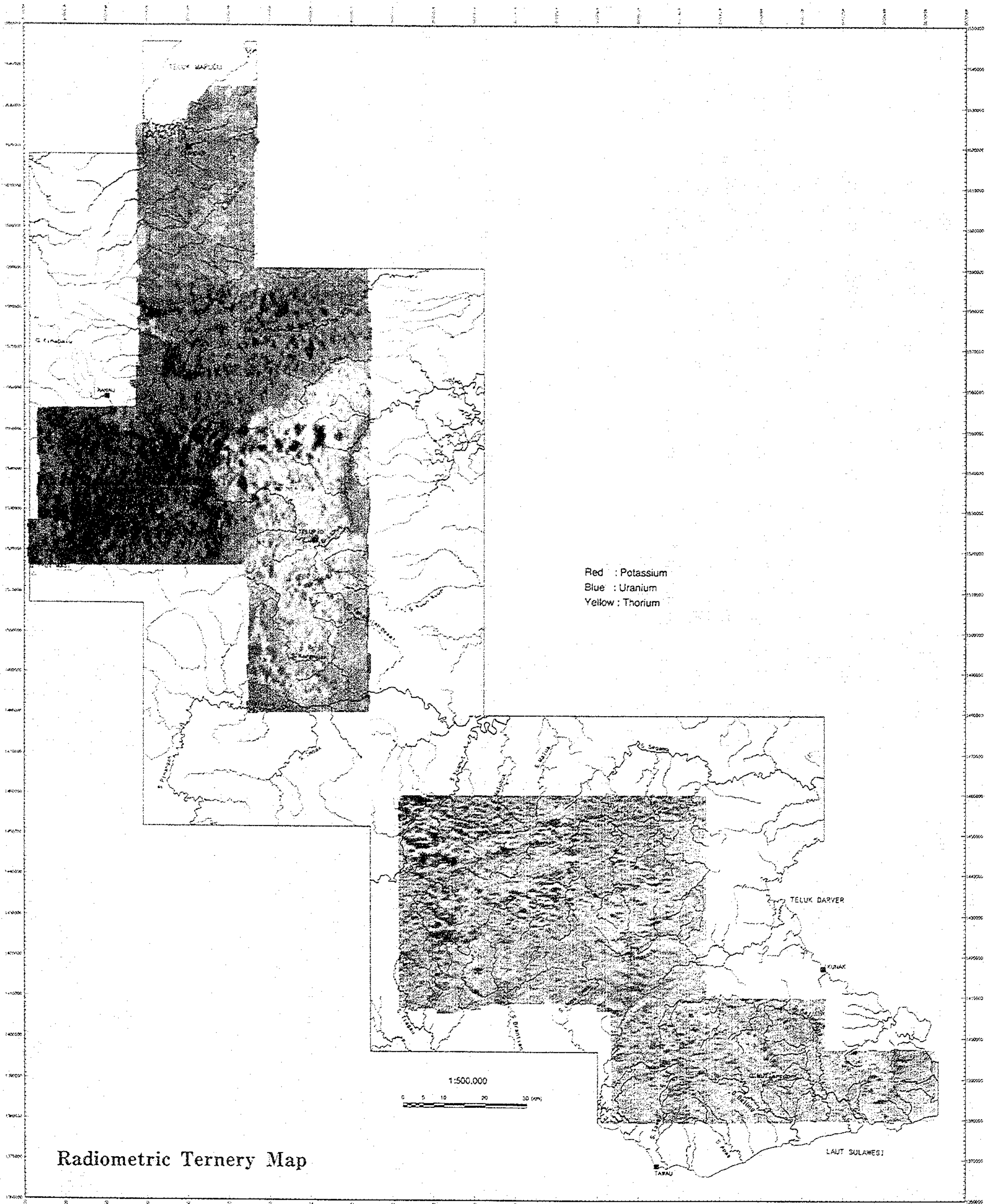
Shadow Map of Total Field Magnetics



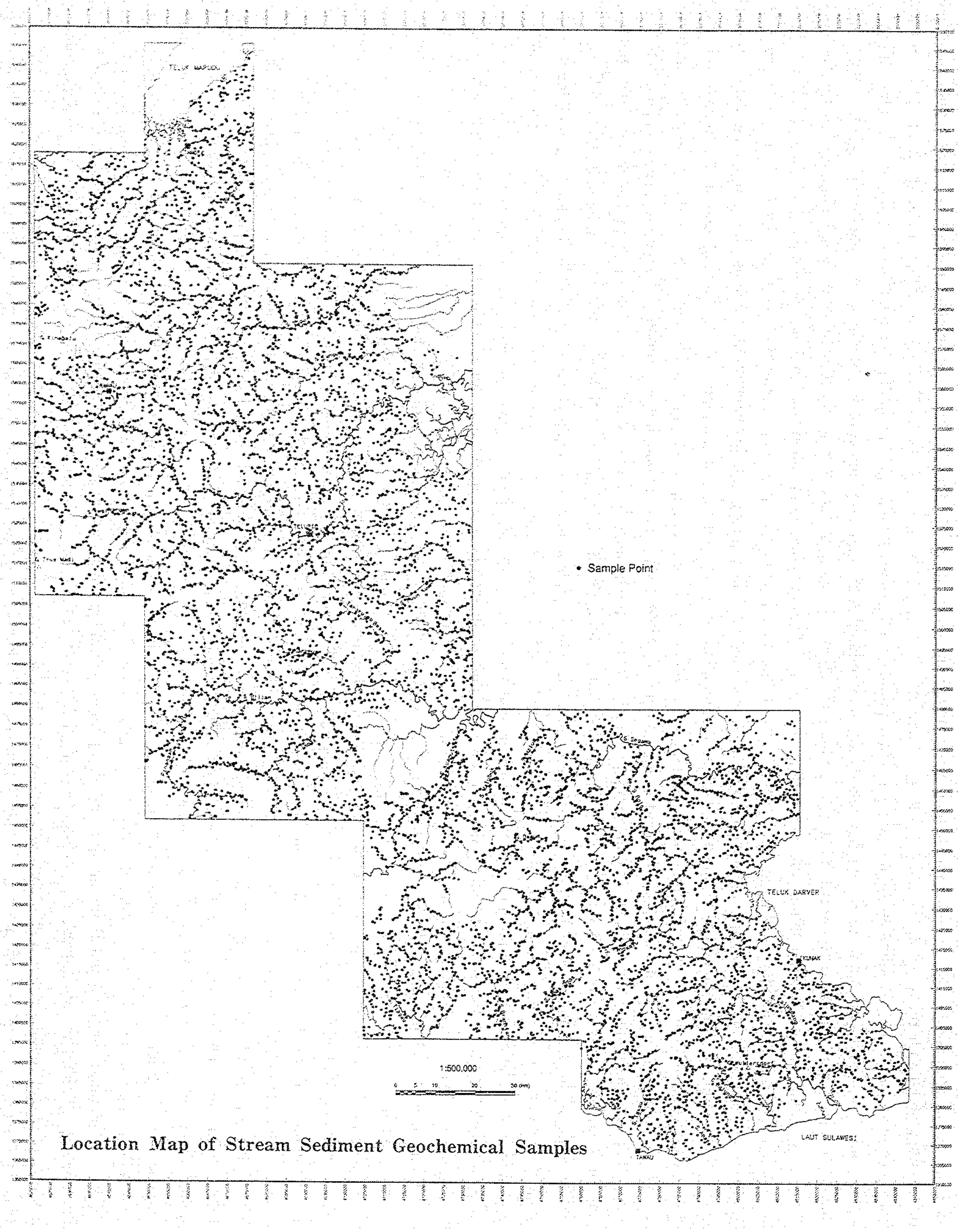
Radiometric Anomaly Map



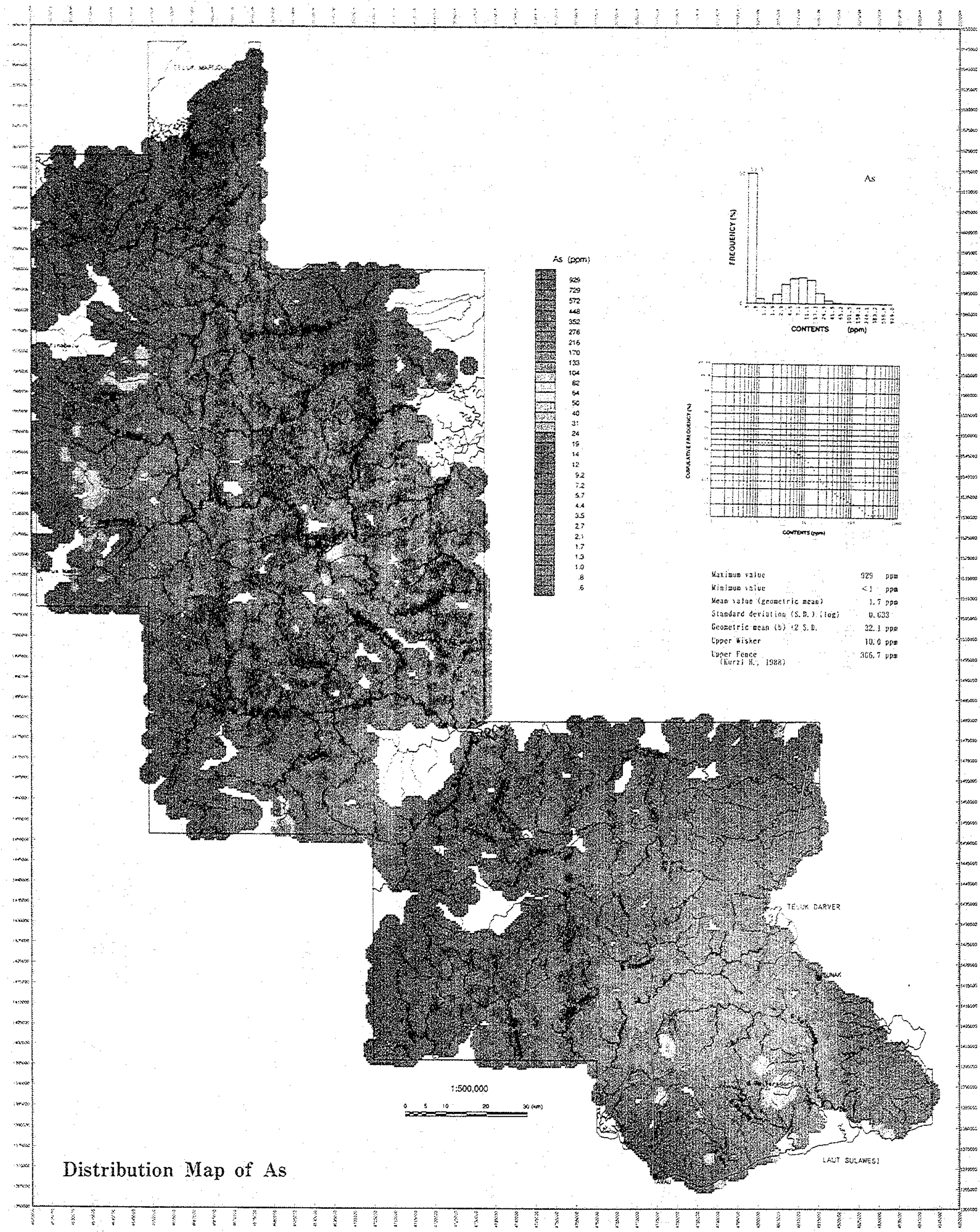
Radiometric Total Count



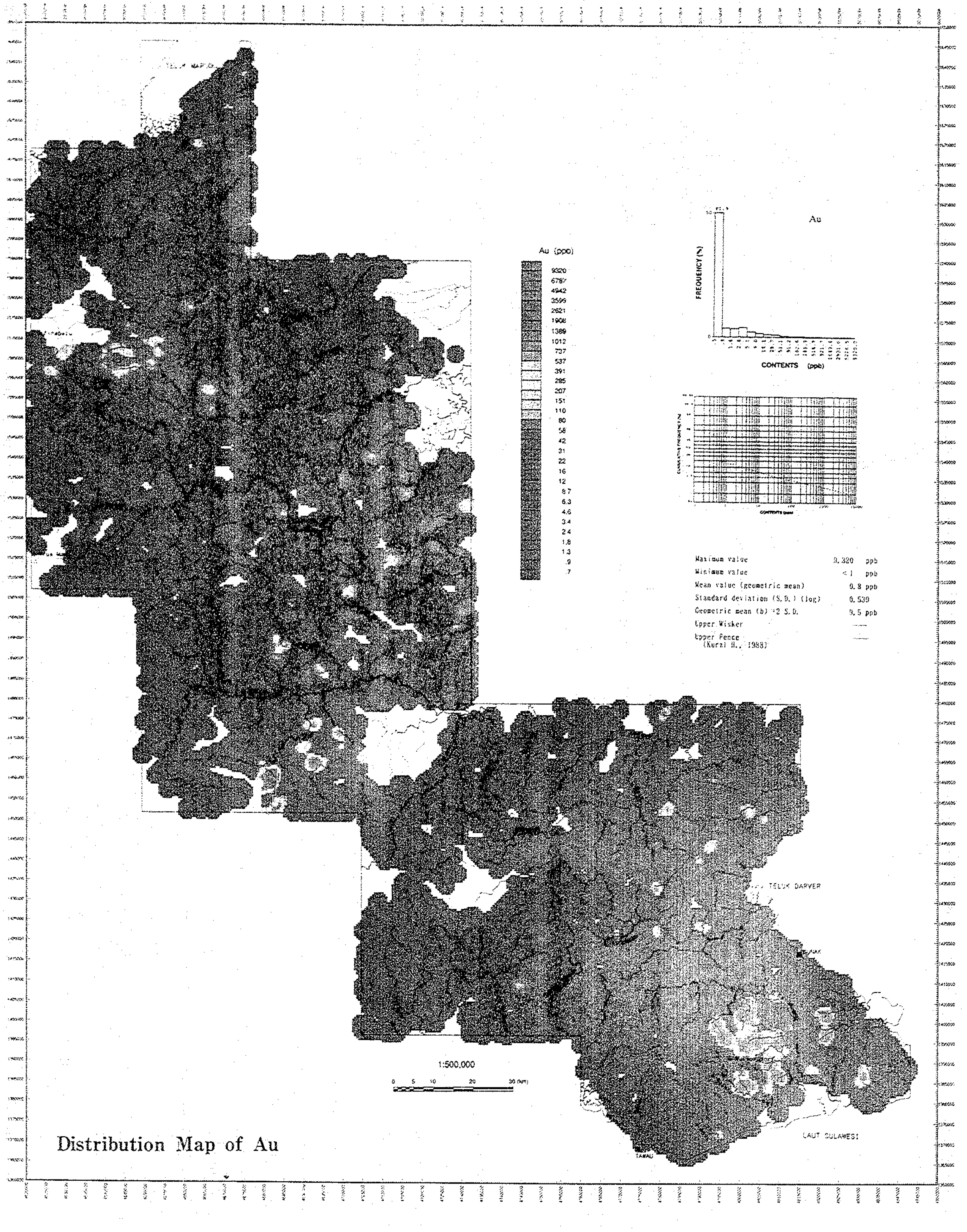
Radiometric Ternery Map



Location Map of Stream Sediment Geochemical Samples



Distribution Map of As



Distribution Map of Au