PART II: DETAILED DISCUSSIONS

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Chapter 1 Existing data analysis

1-1 Collecting existing data

In order to concentrate on mineral potential area, information about geology, explorations, concessions etc., were collected and summarized from publications of organizations related to Government of the Argentine Republic and state governments, such as the Bureau of Geology and Mineral Resources (SEGEMAR), academy publications and internal materials of mining companies.

1-2 Data base

A new database of mineral deposit and mineral showings(total 512 point) was created in this analysis from compiling existing database of SSM, SEGEMAR y IGRM, (1999), database of Zappettini, (1999, CD-ROM) and geological maps published in Argentine etc., with cooperation of SEGEMAR experts.

1-3 Distribution of known mineral deposits and mineral showings.

The database includes information about metal elements such as Au, Ag, Cu, Pb, Zn, rare metals and industrial material such as rare earth, perite, limestone, borax, phosphate minerals, salt, mica, Kaolinite, and rhodochrosite, topaz etc with geo-code. In order to help better and easy understanding the relation between geology and mineral distribution, the database information are added to GIS system for visualization, and finally mineral deposits and mineral showings were grouped as 44 mineral potential area (Fig.I-4-1-1, Table I-4-1-1) .

1-4 Compilation and analysis of existing data

Through the database compilation, the following results especially regarding to distribution of minerals were summarized.

-Potential area of known porphyry copper deposit

Zone-43: Miocene porphyry copper and gold deposit in Andalgala, Catamarca states(Bajo de la Alumbrera, Agua Rica etc.)

-Potential area of porphyry copper and copper/gold deposits, epithermal gold deposits

Zone-07, Zone-09, Zone-24, Zone-26, Zone-27, Zone-28, Zone-39, Zone-42, Zone-43, Zone-46: Tertiary volcanic area in north side of survey area.

-Potential area of SEDEX lead/zinc deposits and volcanic massive sulfide

Zone-15:SEDEXtype(El Aguilar, Esperanza), Zone-01, Zone-02, Zone-08, Zone-10, Zone-11, Zone-12, Zone-15, Zone-17, Zone-22, Zone-03, Zone-05, Zone-18.

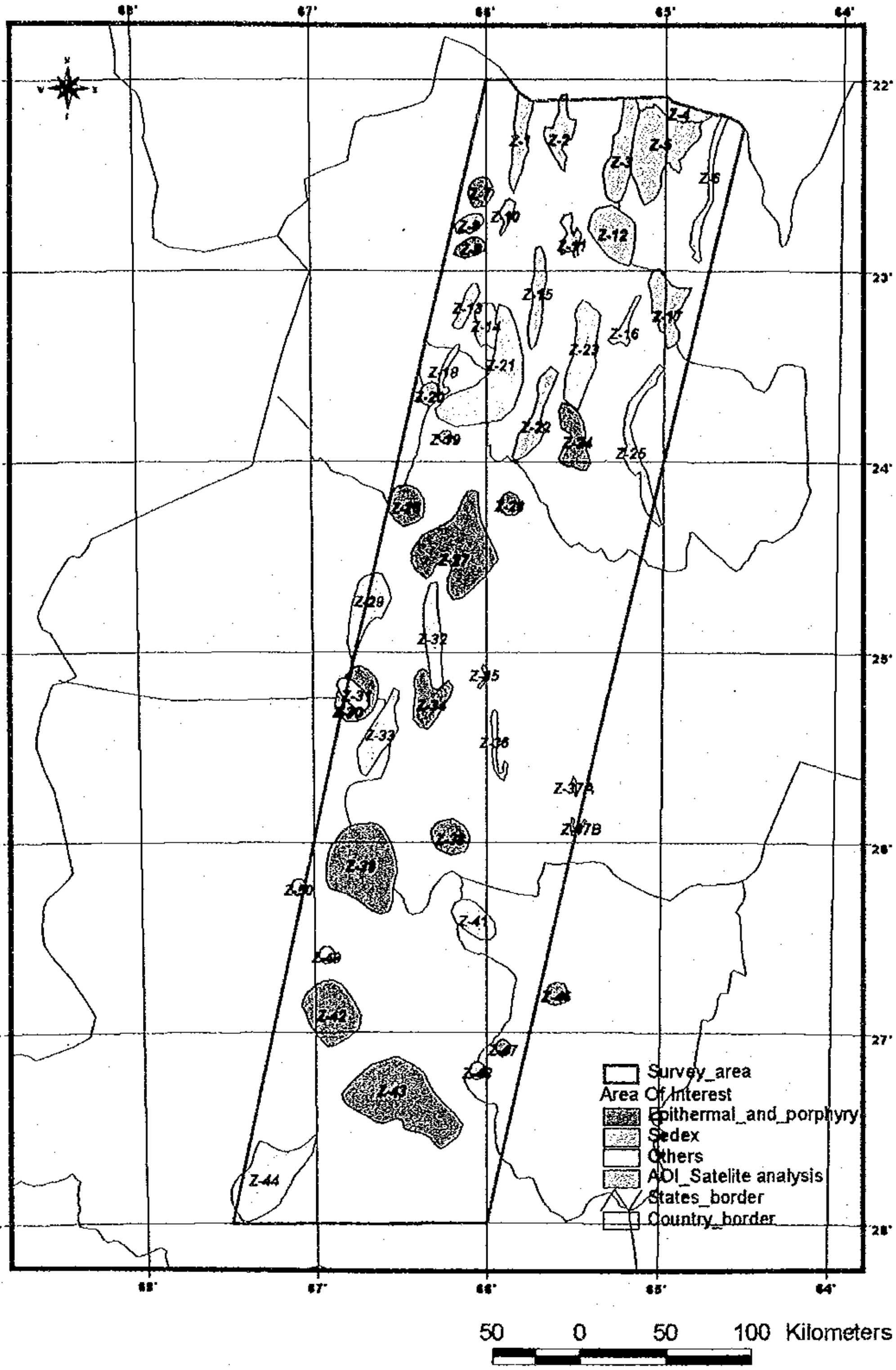

Fig.II-1-3-1 Location of Mineralized zones in the project area

Chapter 2 Airborne geophysical survey

2-1 Summary of the survey

In order to select highly potential area for mineral deposits and regional geological structures, airborne geophysical data (magnetics and radioactivity) provided by SEGEMAR are processed.

The area of the airborne geophysical data is divided into two zones. According to SEGEMAR's request, data on the north part was obtained by World Geoscience Co., Ltd. (in June 1996, about 23,000 km^2) and data on the south part was obtained by Sander Geophysics Co., Ltd. (in May 1999). The area where data was obtained spreads over Jujuy, Salta and Catamarca States, covering the west part of the survey area. The area of the north part is approximately 23,000 km^2 and that of the south part is about 44,000 km^2 (Fig. II-2-2-1-1).

2-2 Data type and analysis method

2-2-1 Data type

Air-borne magnetic data:

Total magnetic intensity (MI)

Reduce to the pole (RTP)

Air-borne radioactive data total count:

Potassium (K)

Thorium (T)

Uranium (U)

Digital topographical data: DEM

2-2-2 Analysis method

The following processing was carried out for reduced to the pole(RTP) and radiometric data.

RTP (Total magnetic intensity (reduced to the pole)):

First vertical derivative(1VD)

Second vertical derivative(2VD)

First horizontal derivative

Radiometric:

K/T

K/(K + T + U)

Color composite image(RGB=KTU)

2-2-3 Others

- Map projection: Gauss-Kruger

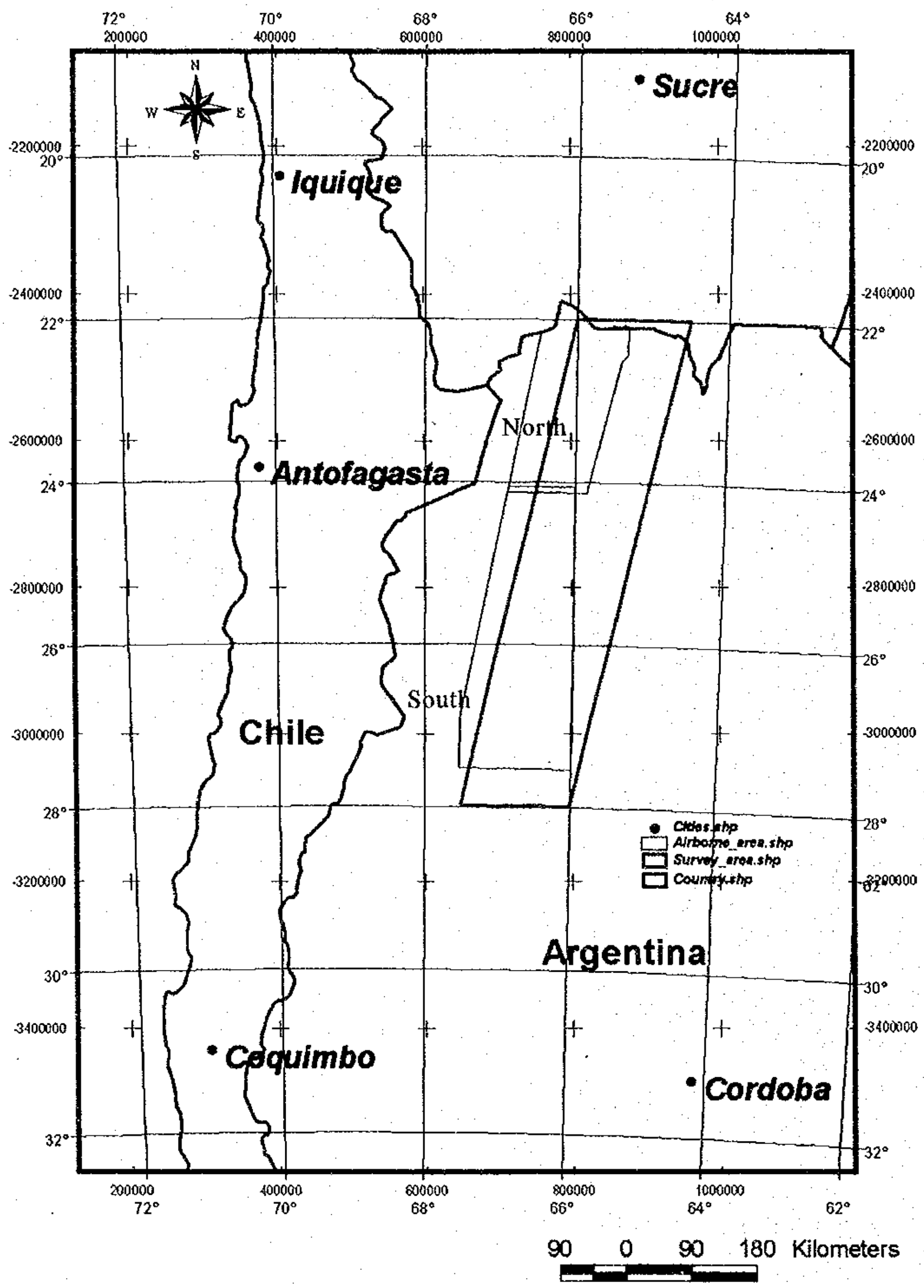

Fig.II-2-2-1-1 Location of the airborne geophysical survey

- Coordinate system (source data): Datum- Campo Inchausepe, Spheroid-International, 1924
- Analysis: Oasis Montaj S.O. (GEOSOFT) Interval of grids: 200 m
- Viewer: Arcview 3.2a (ESRI)
- Legend: In this analysis, as the range of the data differs between the north part and the south part, data cannot be expressed by absolute values. Therefore, standard deviation was used. Data of radiometric in the south part has many deficits.
- Tectonic line etc.: For the comparison with regional tectonics, caldera structure was extracted from the major tectonic line of Ulrich R. et al. (2001), and a geological map of scale 1/500,000. Then, it was overlaid on airborne physical survey data on each analysis figure.

2-3 Results of data analysis

2-3-1 Characteristics of each analyzed image

(1) Air-borne magnetic data

The aeromagnetic data is a diagram of the proportion of magnetic minerals (mainly magnetite, ilmenite and pyrrhotine) in all rock under an airplane. This can generally be considered to be the total amount of magnetite, as magnetite is the most common magnetic material.. The amount of magnetite depends on both primary process (difference in whole rock chemical composition of magma, etc.) and secondary process (metamorphism, alteration, deformation, etc.)

1) Total magnetic intensity (TMI) (Fig. II-2-2-1-2)

On the total magnetic intensity map, values are high in the west part with higher topographical elevation in the area of the airborne physical survey, while values are low on the east side with lower elevation, as a whole. It is recognized that places (Areas 1-5) where data values change in a short wave length correspond to the area with distribution of Tertiary volcanic rocks (Fig. II-2-2-1-2), as shown in Galan Caldera in the south part of the geophysical exploration area and the area around Arba Pampa in the north part of the survey area.

2) Total magnetic intensity (reduced to the pole; RTP) (Fig. II-2-2-1-3)

On a map of total magnetic intensity(RTP), consistency between the area with short-wavelength distribution, and Tertiary volcanic rocks and caldera structure, mentioned above, is clearer. It is considered that the area with long-wavelength shows structure in the deeper part, and salt lakes and new volcanic rocks are distributed in the area of long-wavelength in this survey area (Areas 6 and 7) on the existing geological map.

3) First vertical derivative (Fig. II-2-2-1-4)

First vertical derivative processing is a kind of high-pass filter. It clarifies geological borders and linear structure and emphasizes magnetic structure in the shallow part, in order to emphasize changes of response of magnetic data. In this analysis map, the structure of a long-wavelength is weakened and that of a short-wavelength is more emphasized. Distribution of Tertiary volcanic rocks is consistent with this magnetic structure with short-wavelength very well in this survey area.

4) First horizontal derivative (Fig. II-2-2-1-5)

The result of first horizontal derivative map is similar to that of first vertical derivative.

5) Second vertical derivative (Fig. II-2-2-1-6)

As Second vertical derivative further emphasizes first derivative, tectonic borders and linear structure are even clearer. On this analysis map, although noise components are amplified, the results are not largely different from those of first horizontal differential.

6) Upward continuation (500 m) (fig. II-2-2-1-7)

Upward continuation is a kind of low-pass filter or smoothing. It emphasizes magnetic structure in the deeper part because of emphasis on the response of long-wavelenght. In this analysis, the upward height was set at 500 m. As a result, structure with short-wavelength became more inconspicuous than that of total magnetic intensity(RTP), and major structure became clearer.

(2) Radiometric data

The airborne radiometric data is a record of natural radiometric decay of natural radioactive isotopic elements contained in rocks and minerals. The data are represented as total count of radiometric and in individual channels of potassium, thorium and uranium. It is expected that a certain kind of alteration zones, for example, a potassic alteration zone, is detected as a response of radiometric (potassium). Drainage systems also appear in radioactive data as soil and clay are accumulated in the systems.

1) Total count (Fig. II-2-2-1-8)

Structure with short wavelength in magnetic data shows good consistence with Tertiary volcanic rocks exposed on the ground surface. The area with high values in the total count resembles the shape of the area with distribution of Tertiary volcanic rocks. In the total count, however, granite rocks and gabbro also appear as high values, which is different from the distribution of magnetic structure with short wavelength.

2) Potassium (Fig. II-2-2-1-9)

Examples were reported where potassium concentrations were higher (by up to a factor of two) in porphyry-type deposits than in surrounding non-mineralized zones (Davis & Guilbert (1973)). Therefore, there is a possibility that potassium values will be one of the guides for exploration of porphyry-type deposits. In this figure, high values are distributed in the area with distribution of Tertiary volcanic rocks, similarly to total magnetic intensity(RTP) and others. It is considered that potassium in volcanic rocks responds. N-S tending distribution (Area 8) that cannot seen on the magnetic intensity map, etc. is observed from the central part to the north part on the south side of the area of the airborne geophysical survey, and NE-SW tending distribution (Area 9) is also seen on the north side of the area of the airborne geophysical survey.

3) Thorium (Fig. II-2-2-1-10)

Thorium has a tendency similar to potassium, and the distribution of volcanic rocks around Galan Caldera is particularly emphasized. Distribution of higher values in the N-S direction on the south side of the airborne geophysical survey area seen in the potassium map is unclear.

4) Uranium (Fig. II-2-2-1-11)

Although uranium shows a tendency similar to that of both potassium and thorium in a wide area, its tendency is closer to thorium than to potassium.

5) Potassium, thorium and uranium color composite (RGB = KTU) (Fig. II-2-2-1-12)

As mentioned above, potassium, thorium and uranium all show similar tendency in a wide area, and it is difficult to identify differences among them visually. For this reason, pseudo color composite was applied to images of these three radiometric data by assigned red, green and blue(RGB = potassium, thorium and uranium). Although the color tone is different between the north side and the south side of the airborne geophysical survey area, because the data quality is different, distribution of Tertiary volcanic rocks is clearly displayed in the whitish tone both on the north and south sides. In particular, volcanic rocks around Galan Caldera are clear because this distribution is characterized by thorium and uranium (Area 10).

On the other hand, it is presumed that the color tone looks dark in the areas with salt lake distribution, such as Salinas Grandes(Area 11) and Salar de Olaroz(Area 12) on the north side of the airborne geophysical survey area and Salar de la Laguna and Salar del Hombre Muerto(Area 13) on the south side, because radiometric is absorbed.

On the image of the south side of the airborne geophysical survey area, a lot of plutonic rocks of the Lower Paleozoic (the Ordovician in particular) are distributed, and are shown as area of light red in color because the intensity of potassium is relatively high (Area 14). The area shown in the blue color tone is the area where the intensity of uranium is high. On the image, many places in this color tone are found in the area where Paleozoic sedimentary rocks and Quaternary sedimentary sediments are distributed.

In comparison with distribution of the known deposits (Fig. II-2-2-1-15), more epithermal deposits are distributed in the area with distribution of volcanic rocks shown in the bright color tone from the viewpoint of regional scale, while more porphyry-type deposits are distributed in dark range shown in the slightly dark color tone.

6) Ratio of potassium to thorium (Fig. II-2-2-1-13)

In radiometric exploration of epithermal deposits, there are examples where the potassium concentration rises in alteration zones of copper deposits, etc., while that of thorium does not change (Mocham et al. (1965)). It is considered that a place with a high ratio of potassium to thorium indicates the presence of an epithermal alteration zone.

Although the result of the calculation gives an impression that values are stable from the viewpoint of the regional scale, areas with a high ratio of potassium to thorium are outlined as small spots. In comparison between these areas with distribution of the known deposits, the former is consistent with distribution of porphyry-type deposits and epithermal deposits relatively well in the area centering around Bajo de la Arumbrera (Area 15) on the south side of the airborne geophysical survey area. However, consistency with epithermal deposits in the zone containing San Antonio de Cobres (Area 16) in the central part of the survey area is not good. In La Colorada, Rachaite and Tupiza ore indications (Area 17) in the north part of the survey area, although distribution is small, there is an arrangement of areas with a high ratio of potassium to thorium.

7) Ratio of potassium to potassium + thorium + uranium K/(K + T + U) (Fig. II-2-2-1-14)

This figure shows values of potassium normalized with the total values of potassium, thorium and uranium. Values of Tertiary volcanic rocks are low, similar to those shown in the figure of the ratio of potassium to thorium. The distribution area of epithermal deposits in the central part (Area 18), in particular, is shown as area with a relatively high ratio.

(3) Topography and others

The following figures are inserted for referential comparison with the airborne geophysical survey analysis:

- Digital Elevation Model (DEM) (Fig. II/-2-2-1-15)
- Geological map (Fig. II-2-2-1-16)
- Tectonic lines, alteration zones and mineral occurrences (Fig. II-2-2-1-17)

Alteration zones were outlined from the ASTER image and the TM image. Mineral occurrences are including epithermal, porphyry-type and SEDEX-type deposits. The major tectonic line is compiled by Ulrich R., et al. (2001), and calderas structures are vectorlized from geological maps of a scale of 1 to 500,000 published by each states..

- Comparison with the existing airborne geophysical analysis diagrams(Fig. II-2-2-1-18)

In studies whose data source seems the same (Chernicoff, C. J. and Zappettine, E. O. (2000)), lineament analysis was made from magnetic structure. It is pointed out that there are lineament systems in directions of NNE-SSW, NE-SW, ENE-WSW and N-S and that, particularly, the areas where WNW-ESE tending and WNW-ESE tending lineaments cross ENE-WSW tending lineament are closely related to distribution of deposits.

- Comparison with gravity data (Fig. II-2-2-1-19)

Data of global gravity is now available by using artificial satellites from Internet sites (http://topex.ucsd.edu/marine_topo/mar_topo.html). This map shows gravity structure in the survey area plotted by the use of this data. What is interesting is that distribution of the known epithermal, porphyry-type, SEDEX-type and other vein-type deposits concentrate near or around places with high regional gravity structure. Certainly, there are many Tertiary volcanic rocks in places with high gravity structure (conversely, those with low gravity form basin structure and are covered with new sedimentary rocks in many cases), and are consistent with the distribution area of epithermal deposits, etc. relatively well. It can be mentioned as another reason of this concentration that deposits were easy to find because, from the viewpoint of topography, these places are at high elevation and well exposed. However, it is anticipated that there are not only such reasons but some other casual sequence. It seems important to clarify gravity structure for consideration of places where wide-area deposits are generated.

2-4 Guides to selection of high-potential areas by analysis of the airborne geophysical survey

From the characteristics of the analysis diagrams mentioned above, two types of area have the possibility as a present guide to selection of areas with a high potential for epithermal and/or porphyry deposits; one is the area with distribution of short-wave structure found in the magnetic data, and another is the zones with a high ratio of potassium to potassium plus thorium plus uranium and those with a high ratio of potassium to thorium in the radiometric data, because these areas are consistent with distribution of the known deposits relatively well. Short-wavelength structure of magnetics directly means distribution of Tertiary volcanic rocks. Zones where, in spite of the presence of short-wavelength structure, distribution of Tertiary volcanic rocks does not exist or is not known are also interesting from the viewpoint of the possibility of prospecting. Places that have small distribution of intrusive rock on the surface layer but have gravity structure of a long cycle(vicinity of Vicuna Muerta, etc.) seem important partly because the rock body in the deep part is expected as a source supplying mineralization.

2-5 Summary

Characteristics of the whole survey area were compared from the viewpoint of magnetic and radioactive data. As a result, in the magnetic data analysis, the area with distribution of Tertiary volcanic rocks is clearly shown as an area with short wavelength in the magnetic data. In the survey area, epithermal deposits and porphyry-type deposits are consistent with the area with distribution of these volcanic rocks well. In some of zones where exposure of the intrusive rock body is small in the surface layer, distribution of magnetic structure of a long-wavelength is also recognized, which is considered to indicate the presence of the intrusive rock body in the deep part.

By radioametric data, the distribution of volcanic rocks in particular could be clearly shown, and, therefore, it seems possible to use this data for presumption of rock types. We calculated the ratio of potassium to potassium plus thorium plus uranium in order to assume the presence of epithermal deposits, etc. The results show that places where this ratio is high correspond to the area with deposits distribution from the viewpoint of the wide area. On the other hand, from the viewpoint of the local area, there is a tendency that deposits concentrate near places with a high ratio of potassium to thorium.

As a future subject, it is necessary to minutely compare geology, tectonics, radiometric data, etc. of specified areas extracted as highly potential areas in order to specify areas with deposits distribution from the more minute point of view. Besides this, improvement of data and quality is mentioned as our request. As vegetation is thin in most of the range of this airborne geophysical exploration, distribution of Tertiary volcanic rocks can be grasped easily on the satellite image. However, vegetation is thick in the zone where airborne geophysical data has not been obtained, which is located on the east side of the survey area. The importance of employing the airborne geophysical data is higher in this side. As grid-like noise is recognized on the data (particularly, linear structure in the direction of south to north has more noise component), it is necessary to improve the quality of data.

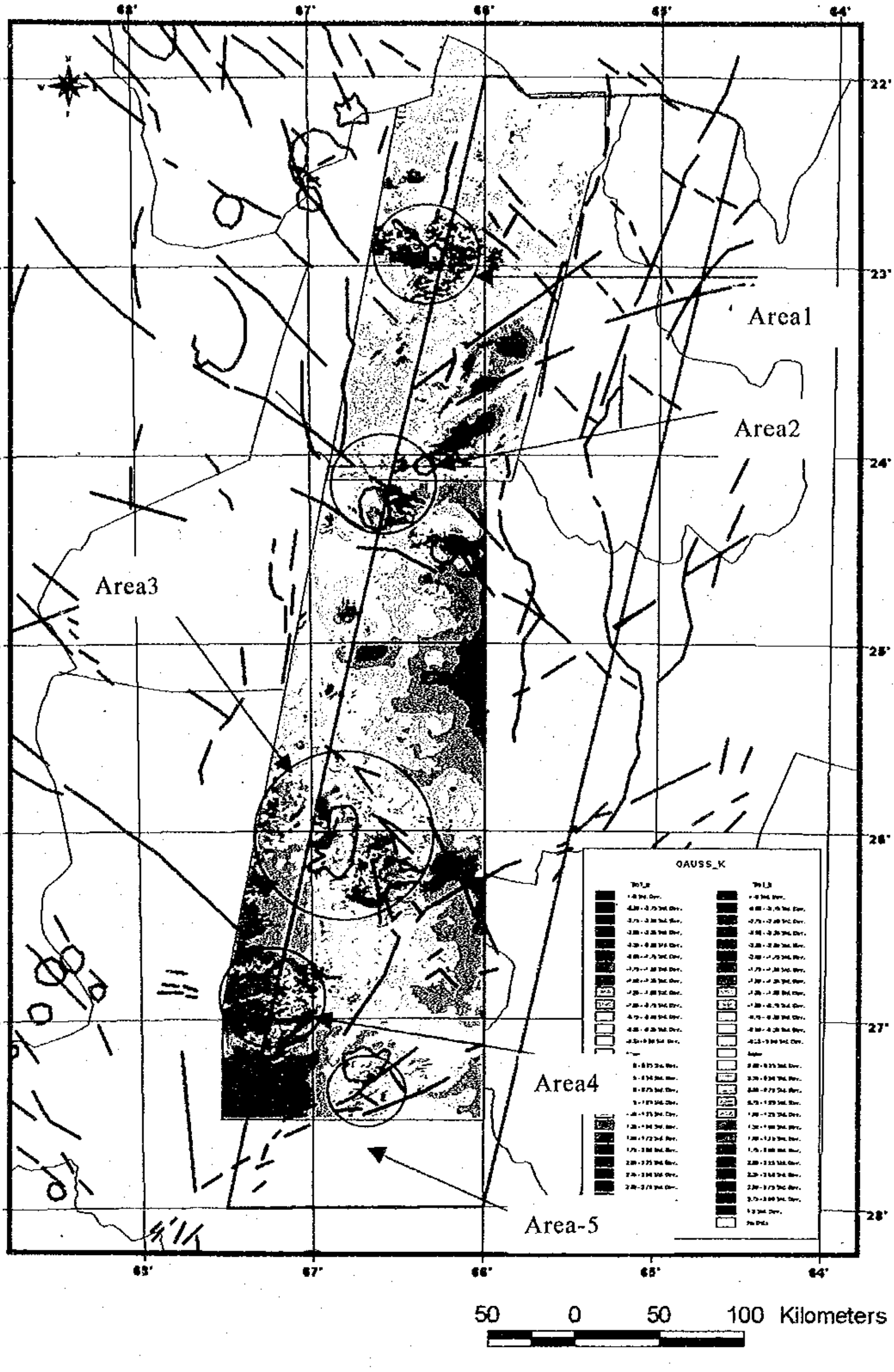

Fig.II-2-2-1-2 Total Magnetic Intensity image (TMI)

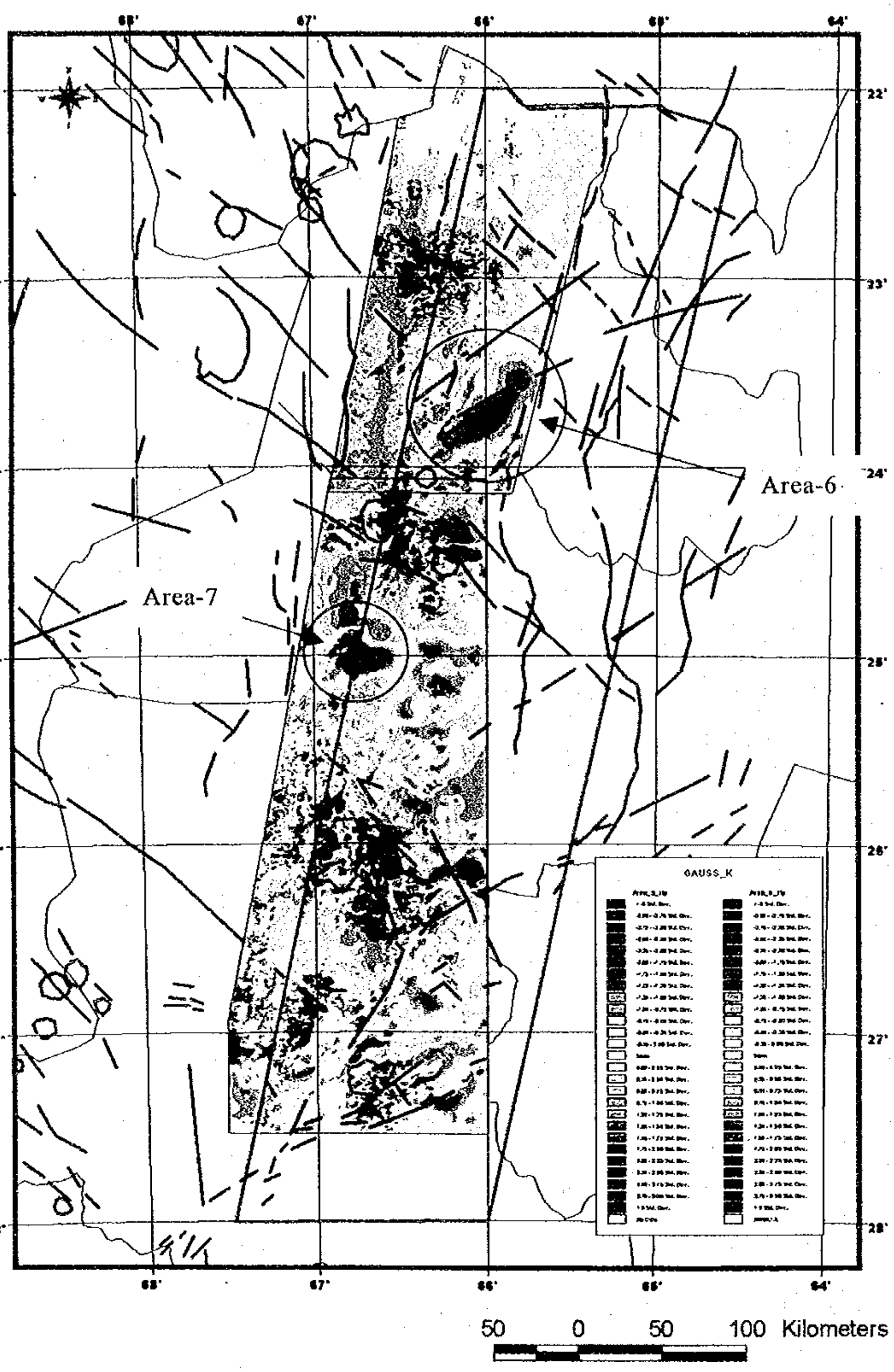

Fig.II-2-2-1-3 Total Mangnetic Intensity(Reduced to the Pole:RTP)

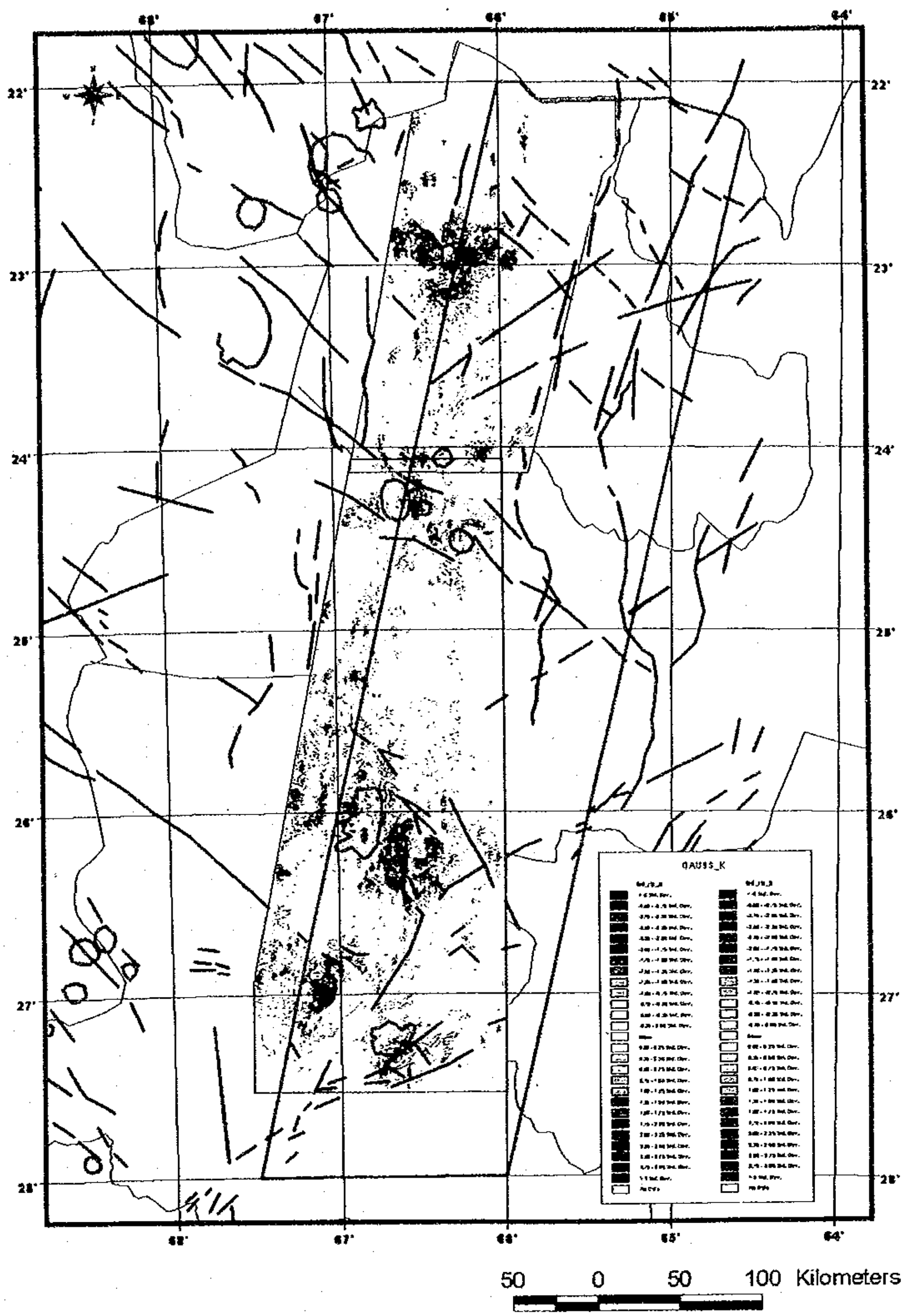

Fig.II-2-2-1-4 First vertical derivative image of RTP

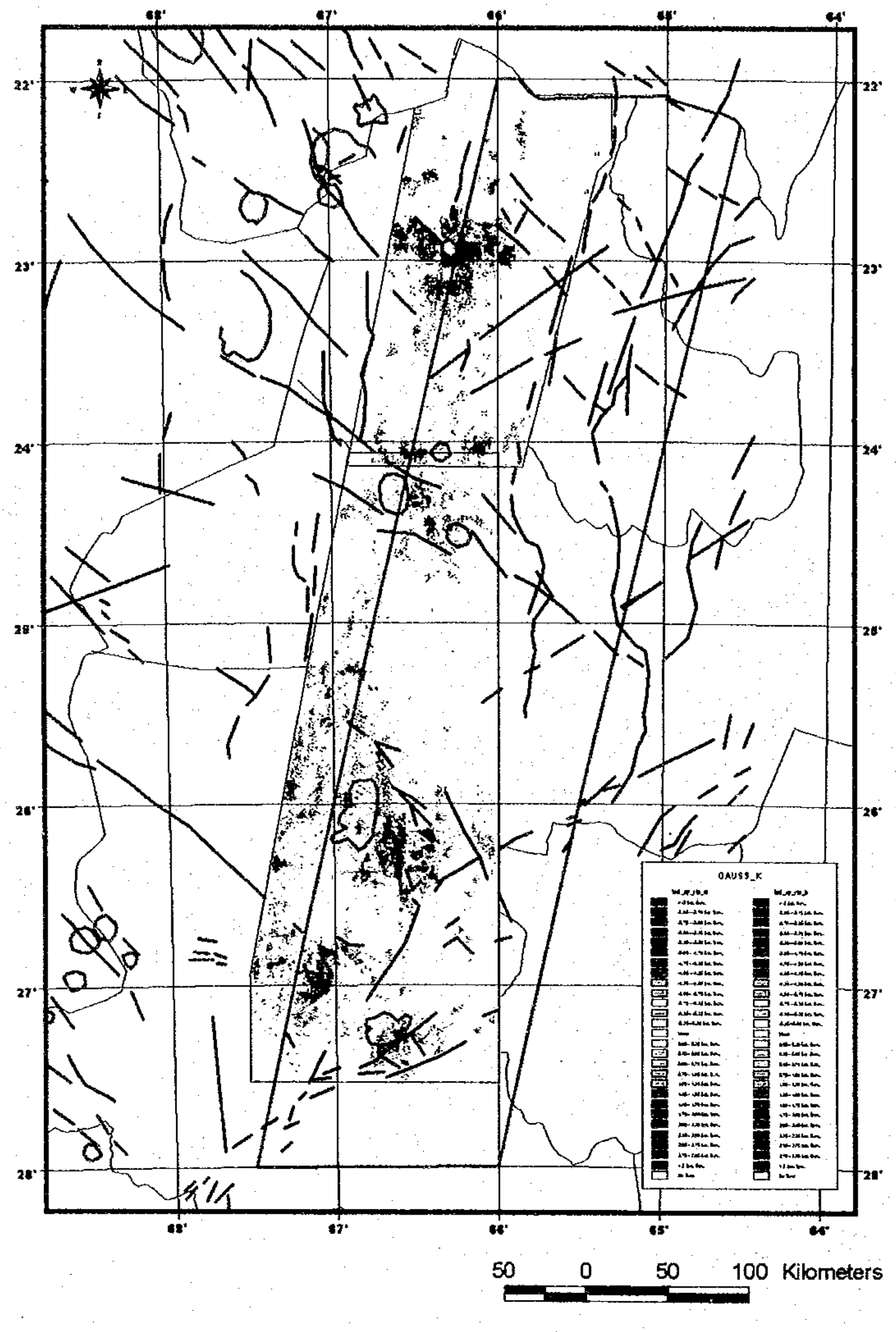

Fig.II-2-2-1-5 First horizontal derivative image of RTP

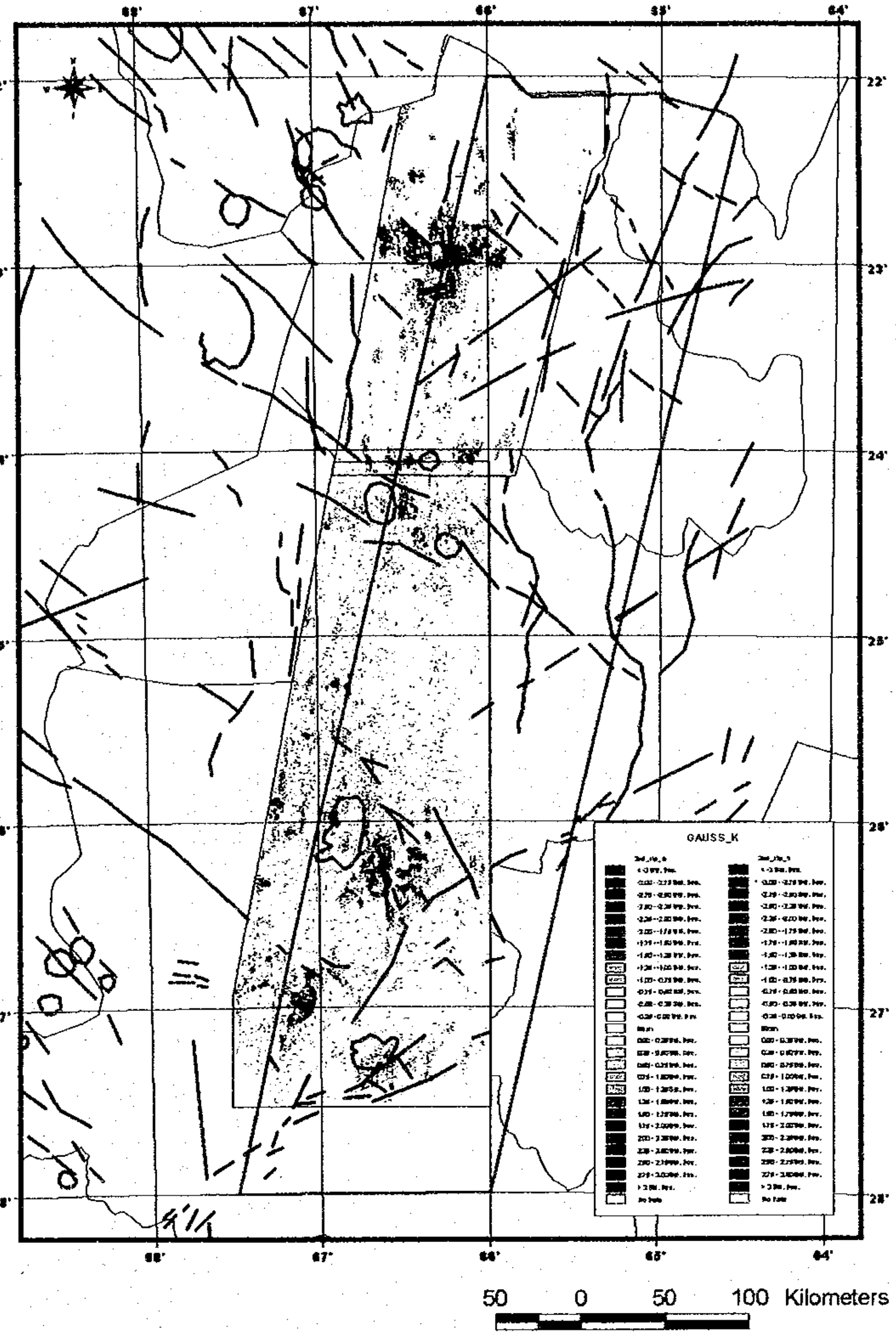

Fig.II-2-2-1-6 Second vertical derivative image of RTP

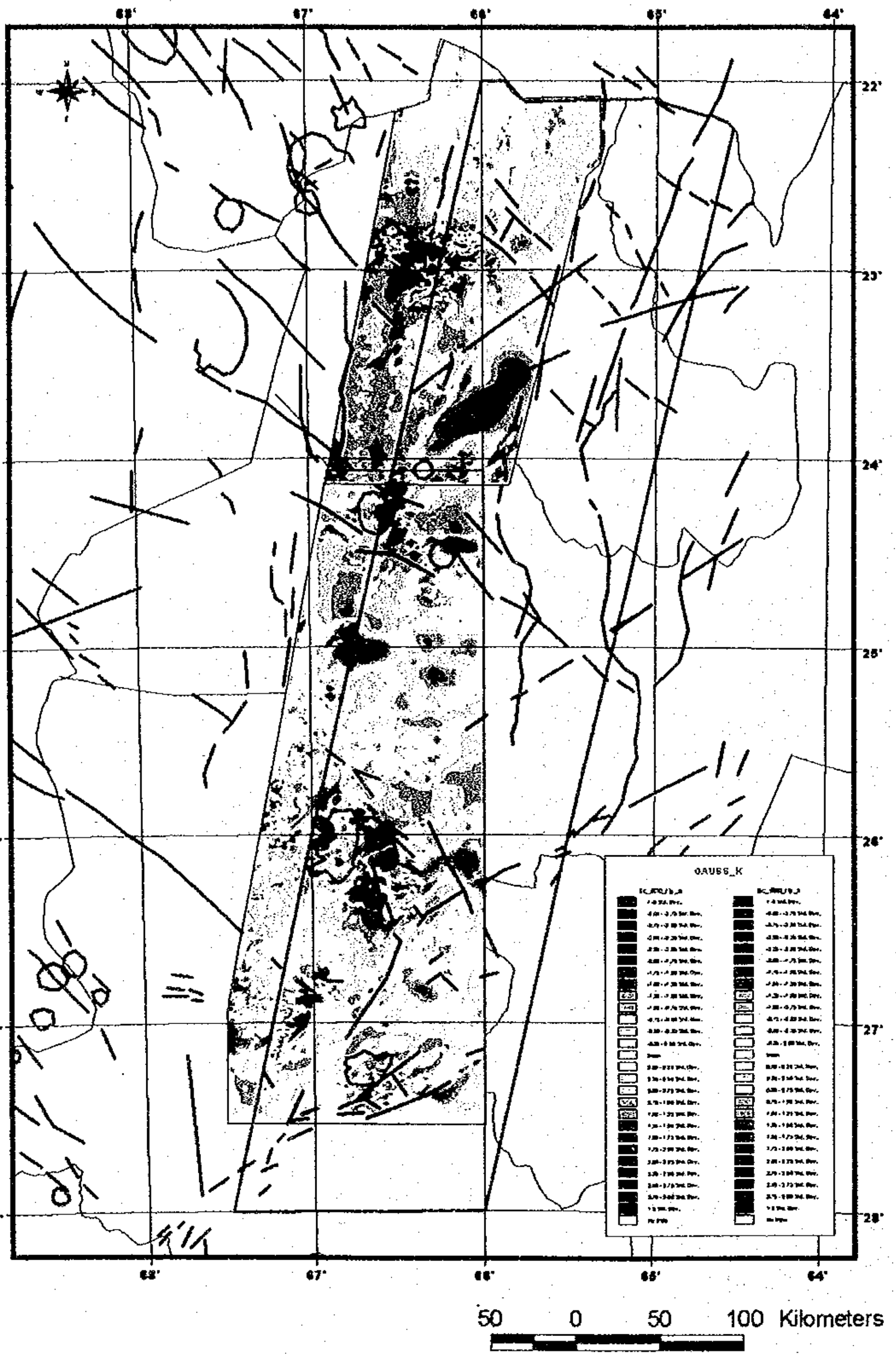

Fig.II-2-2-1-7 Upward continuation (500m) of RTP

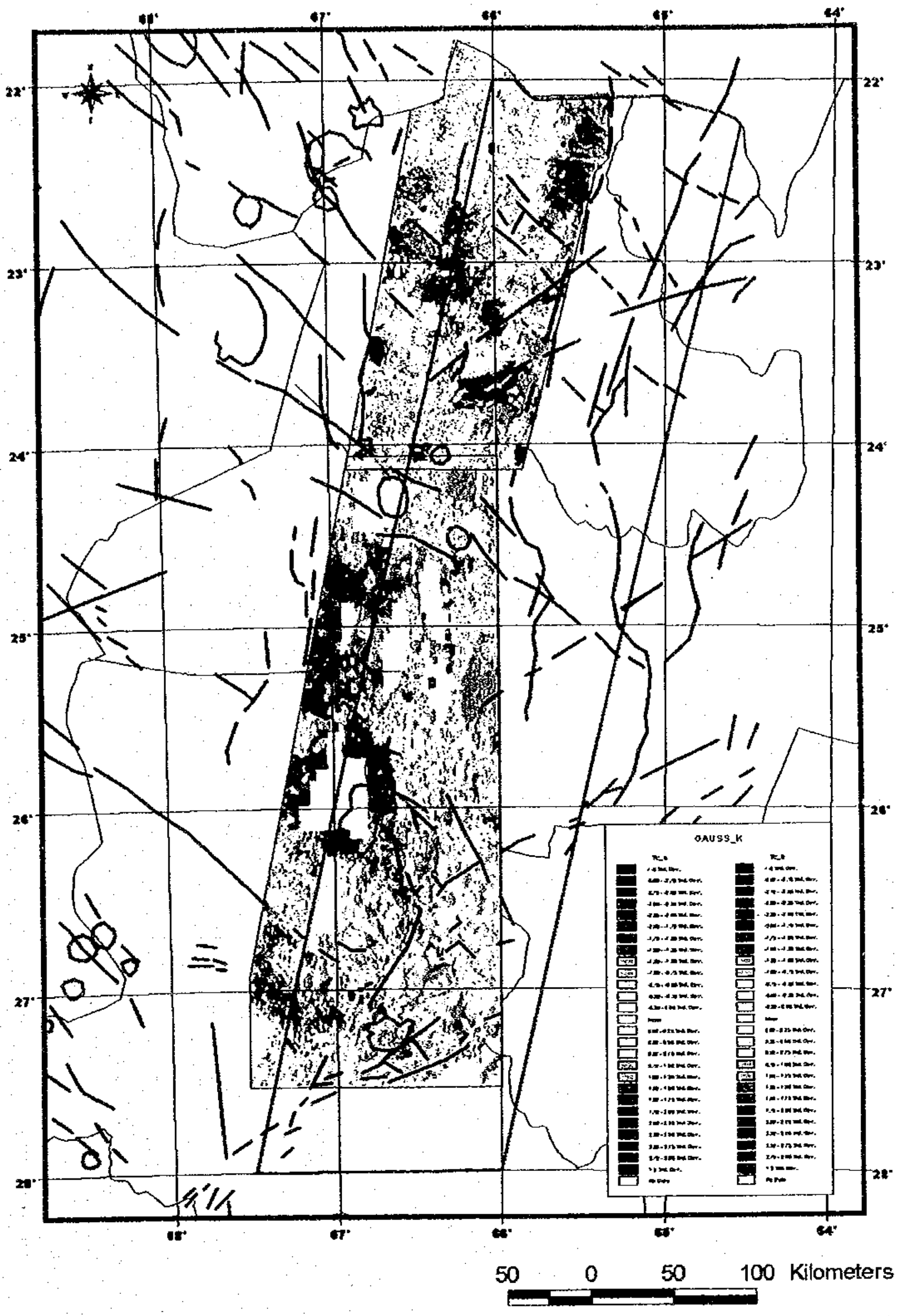

Fig.II-2-2-1-8 Total count(TC) image

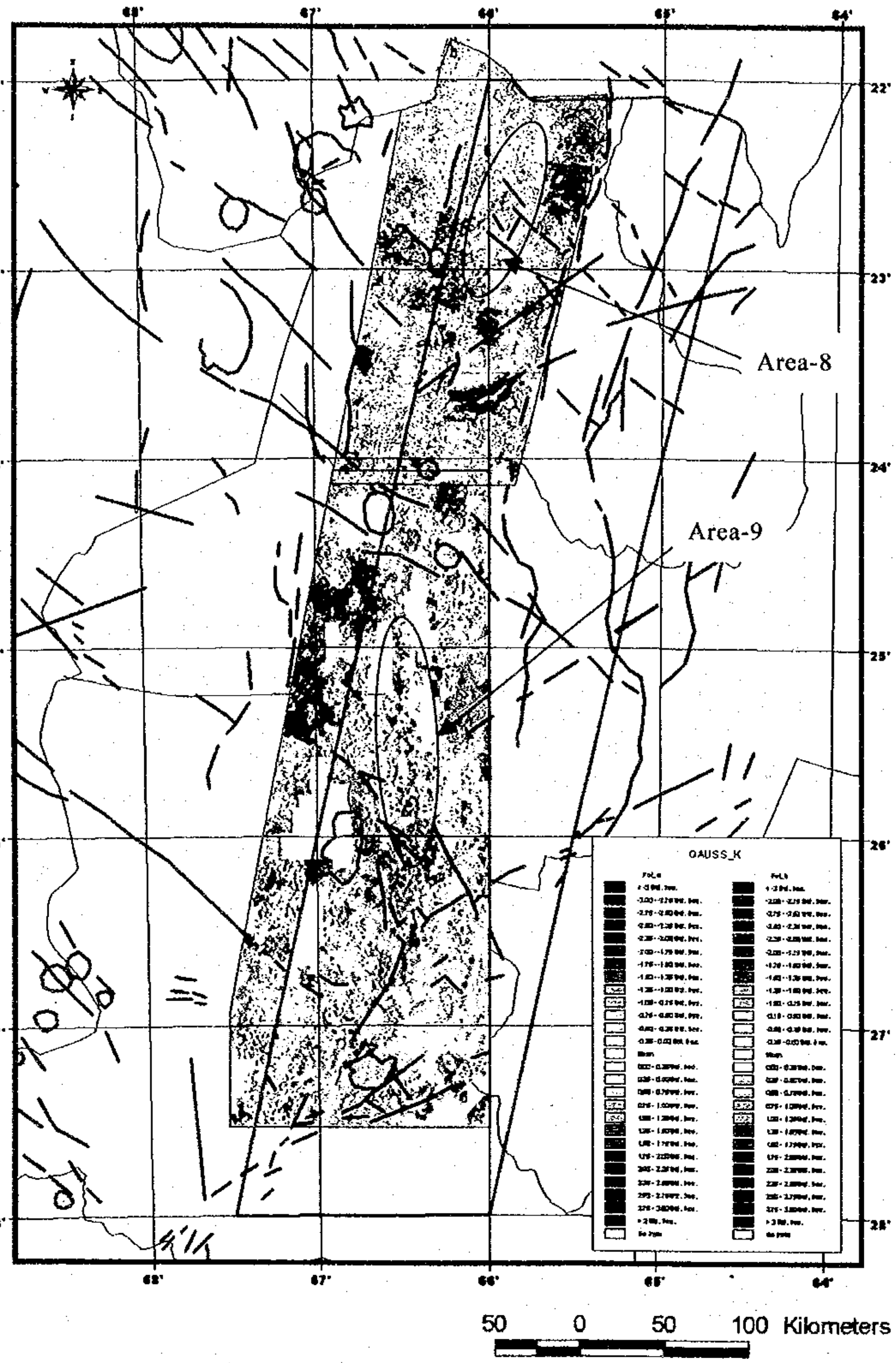

Fig.II-2-2-1-9 Radiometric image(K)

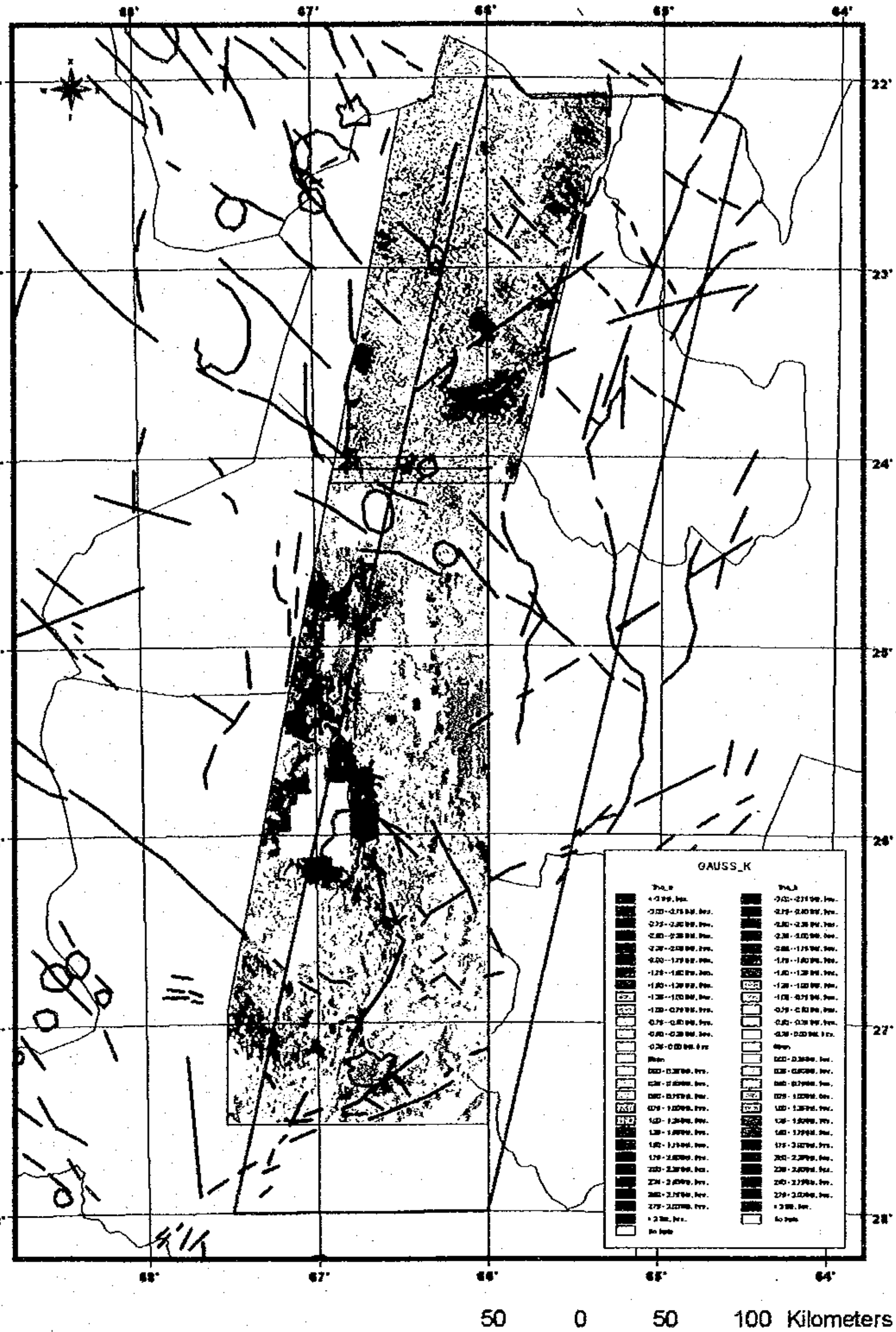

Fig.II-2-2-1-10 Radiometric image(T)

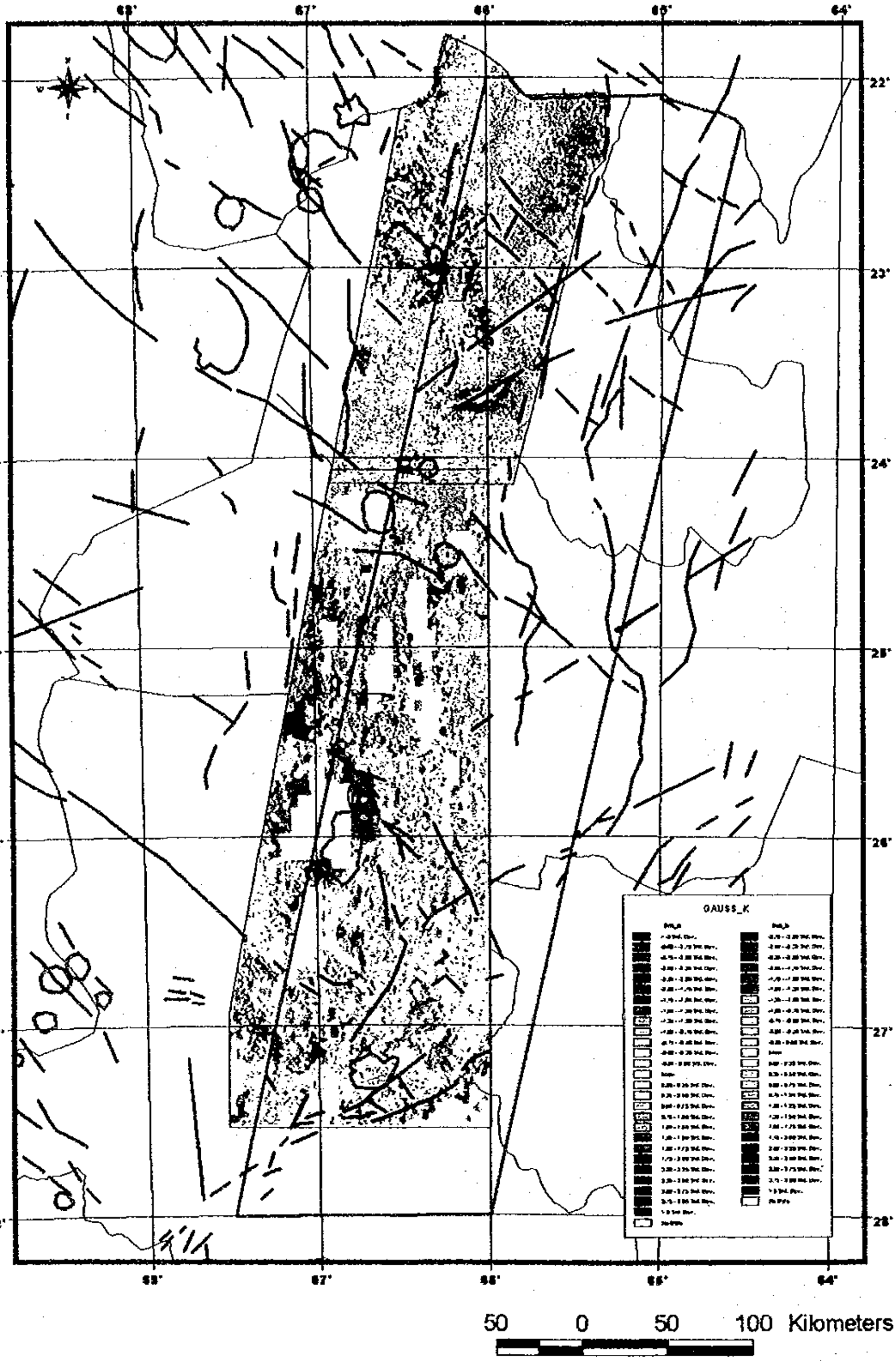

Fig.II-2-2-1-11 Radiometric image(U)

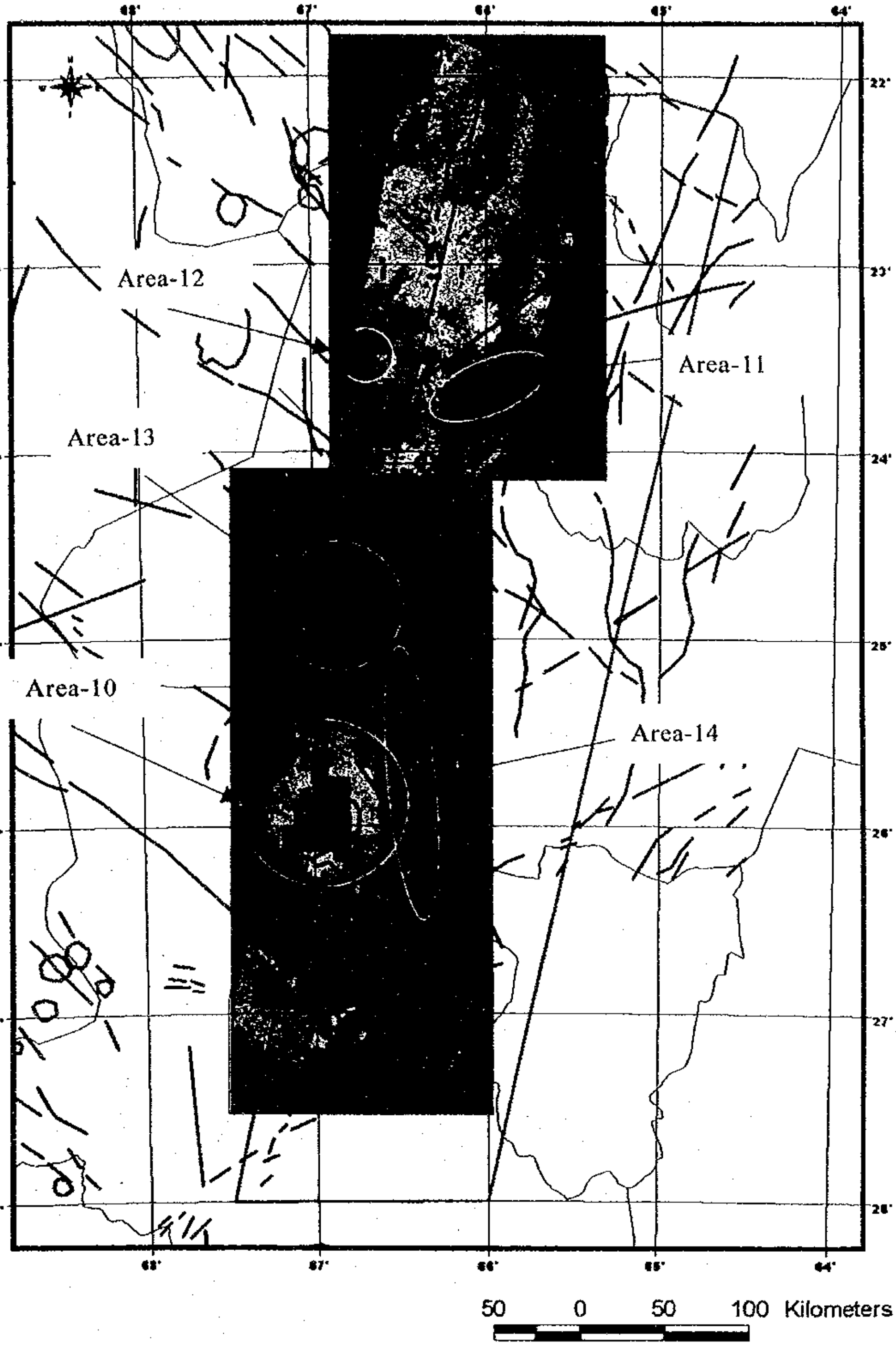

Fig.II-2-2-1-12 Color composite image of K,T,U(RGB=KTU)

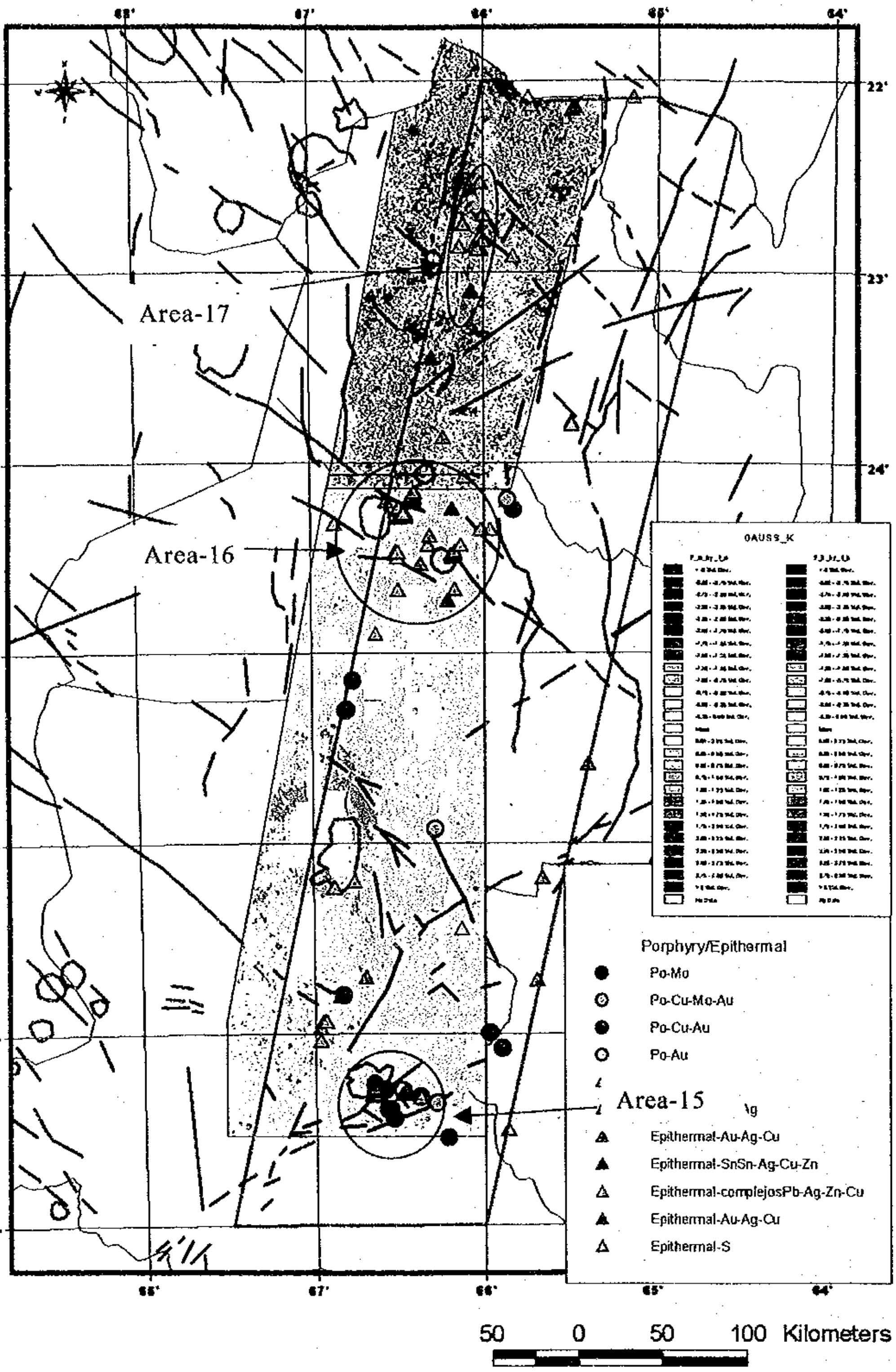

Fig.II-2-2-1-13 Ratio K/T image

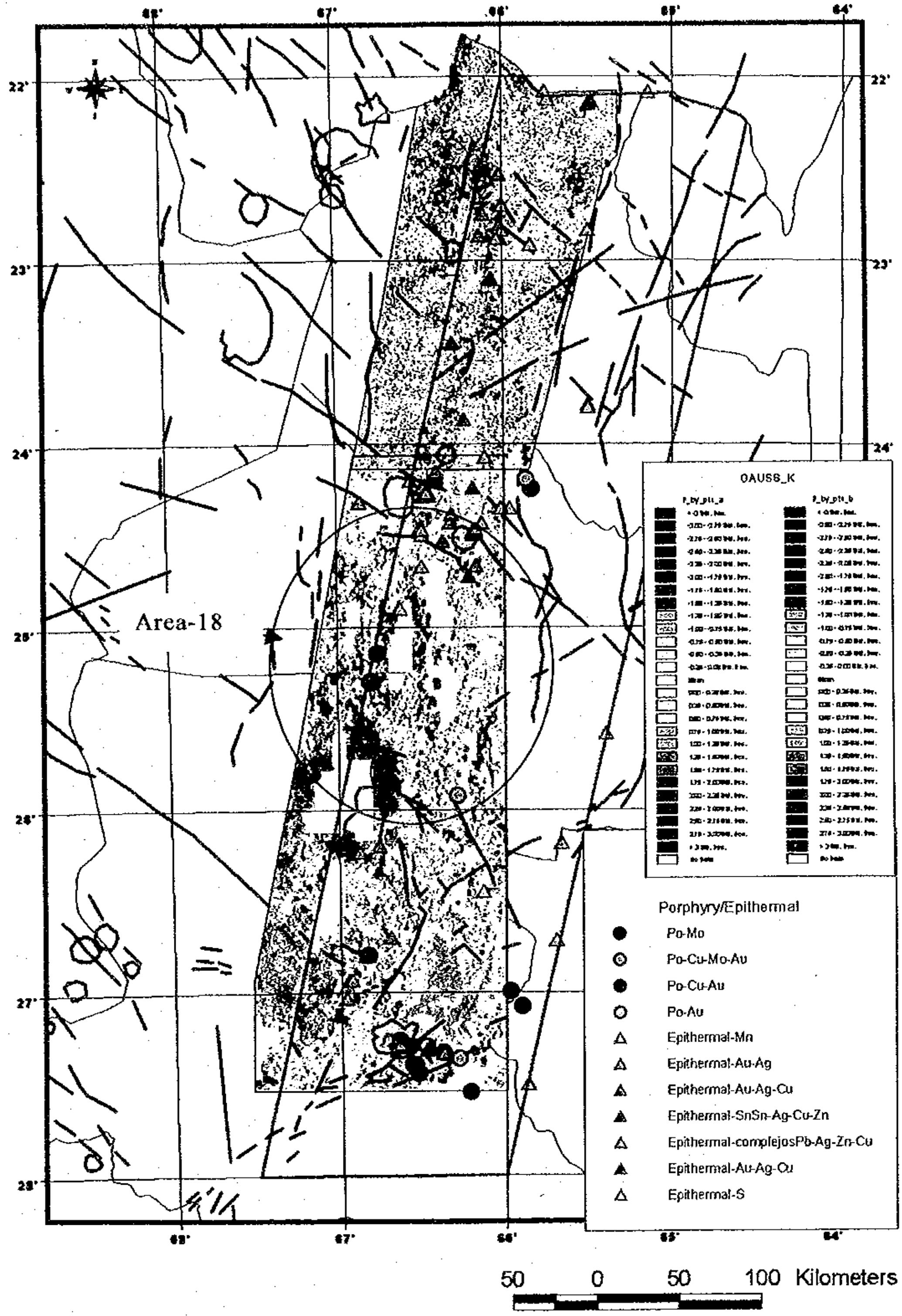

Fig.II-2-2-1-14 Ratio K/(K+T+U)image

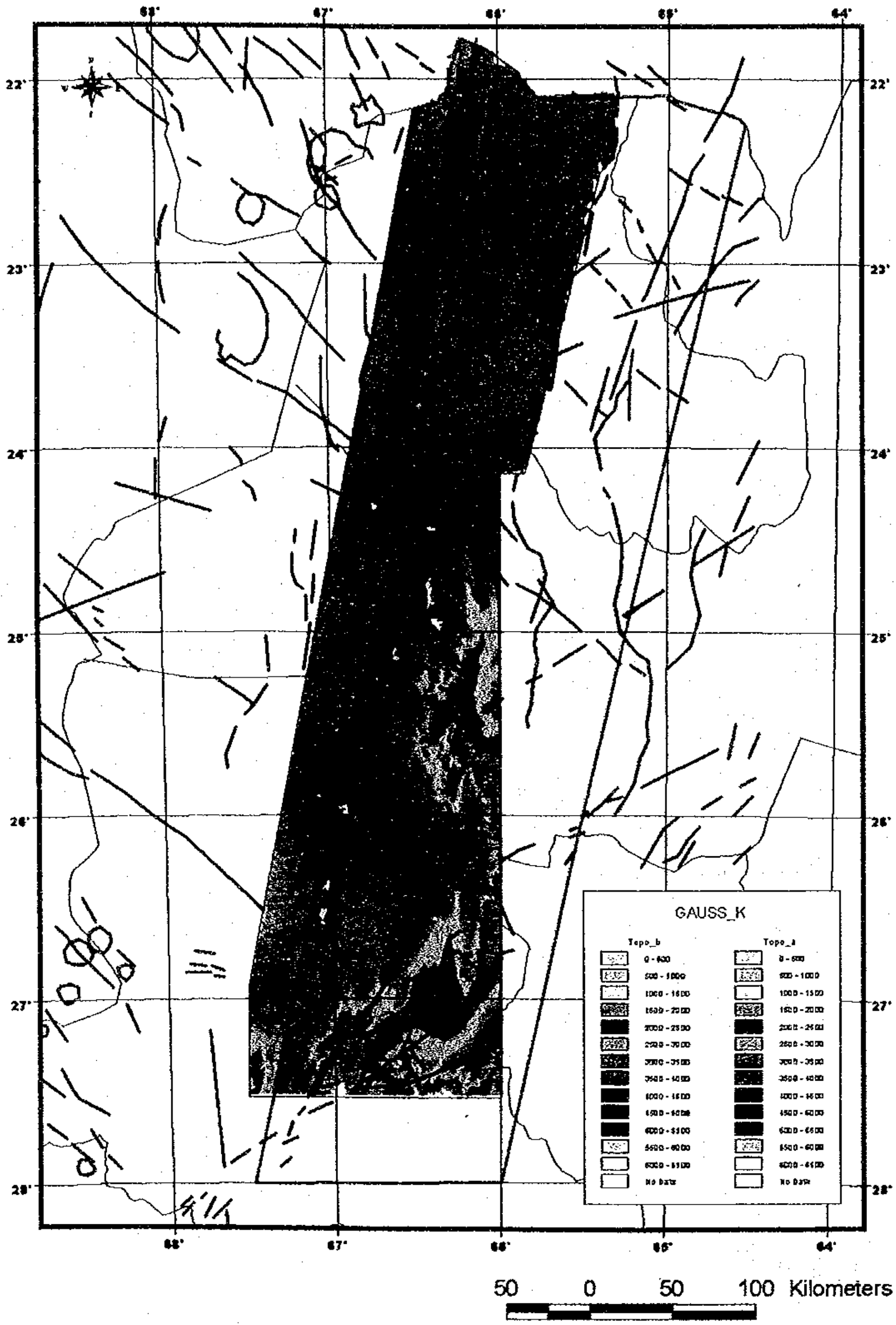

Fig.II-2-2-1-15 Digital terrain model image(DEM)

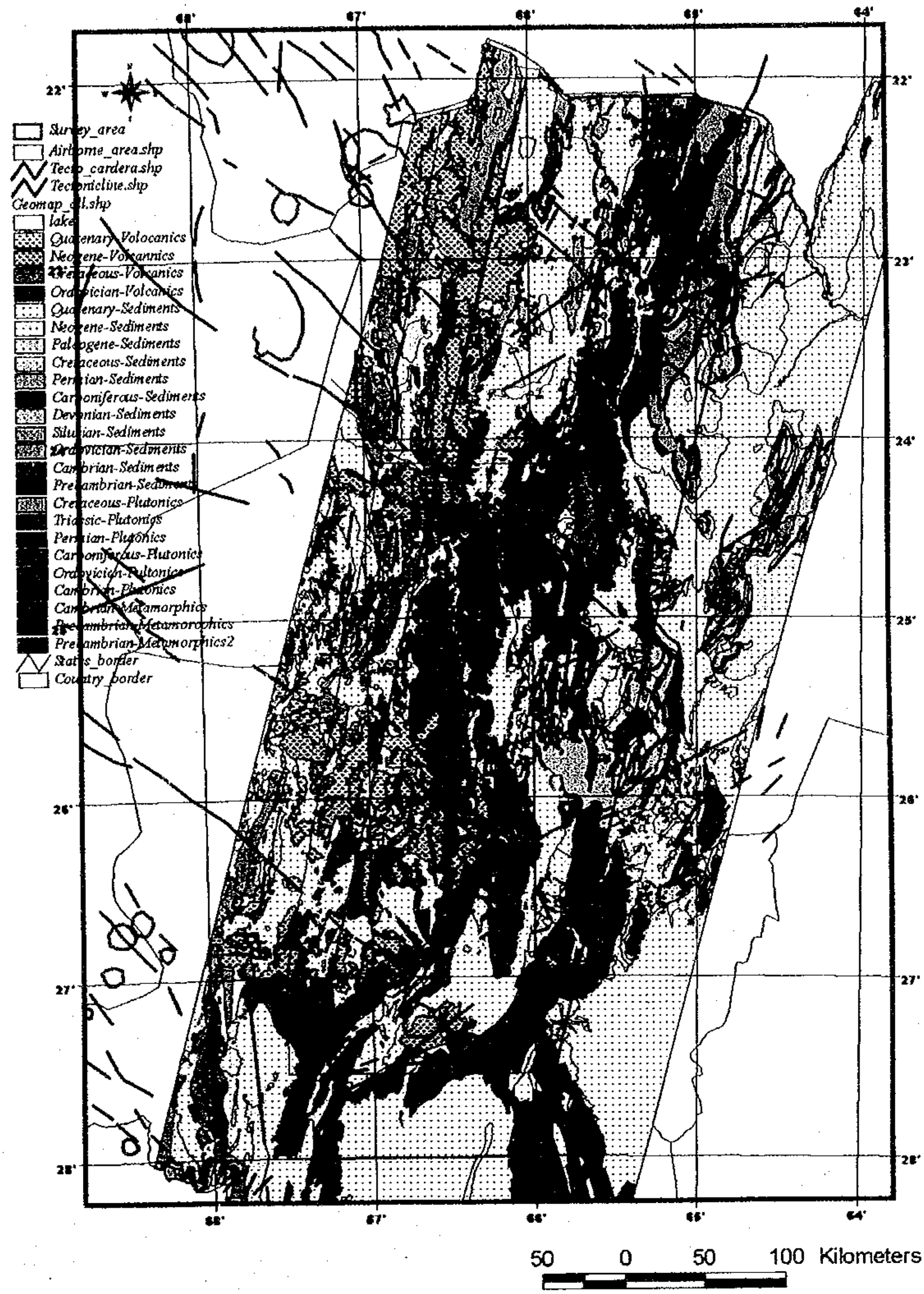

Fig.II-2-2-1-16 Geological map

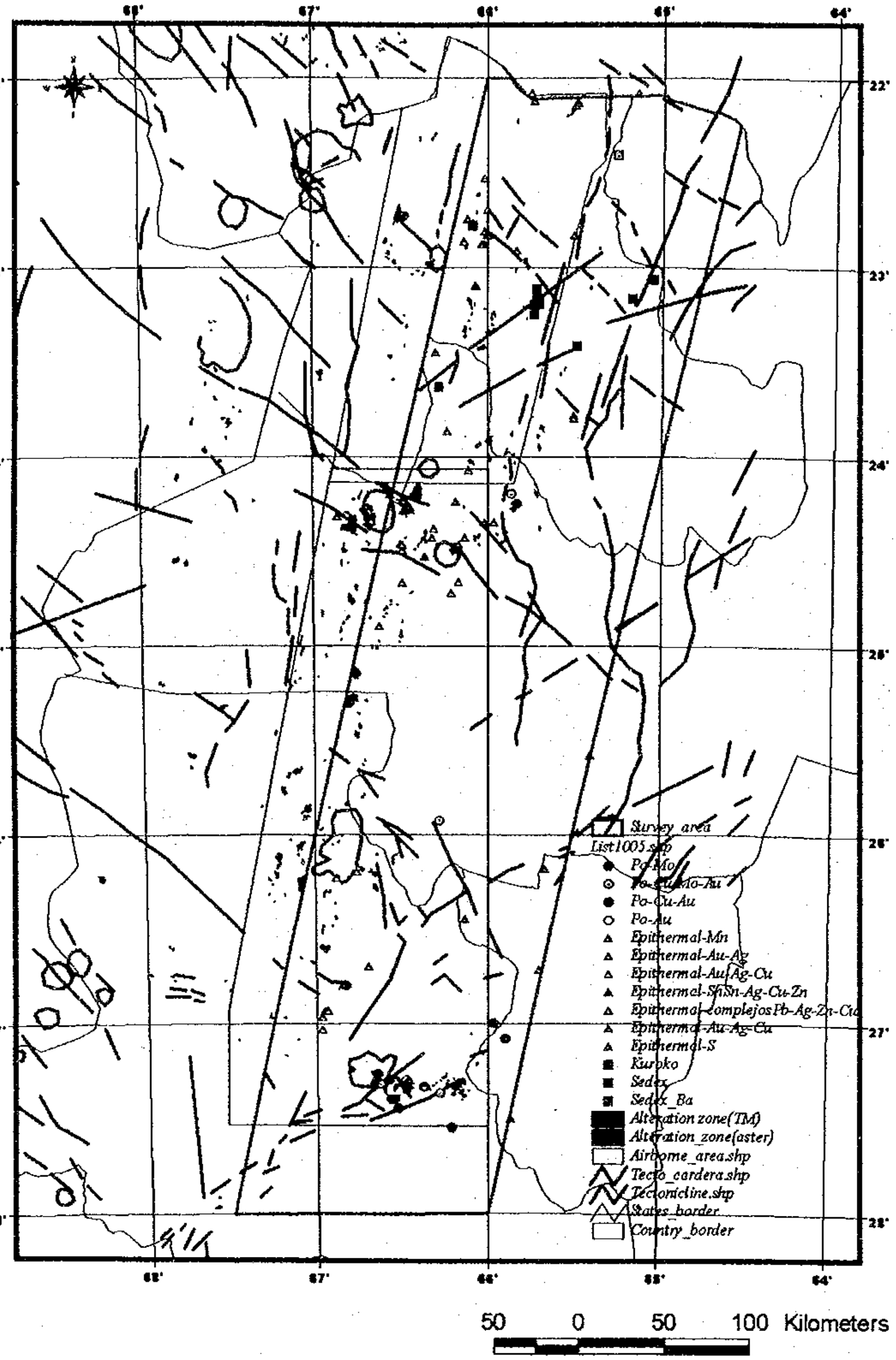

Fig.II-2-2-1-17 Tectonic line, mineral occurrences, alteration zone

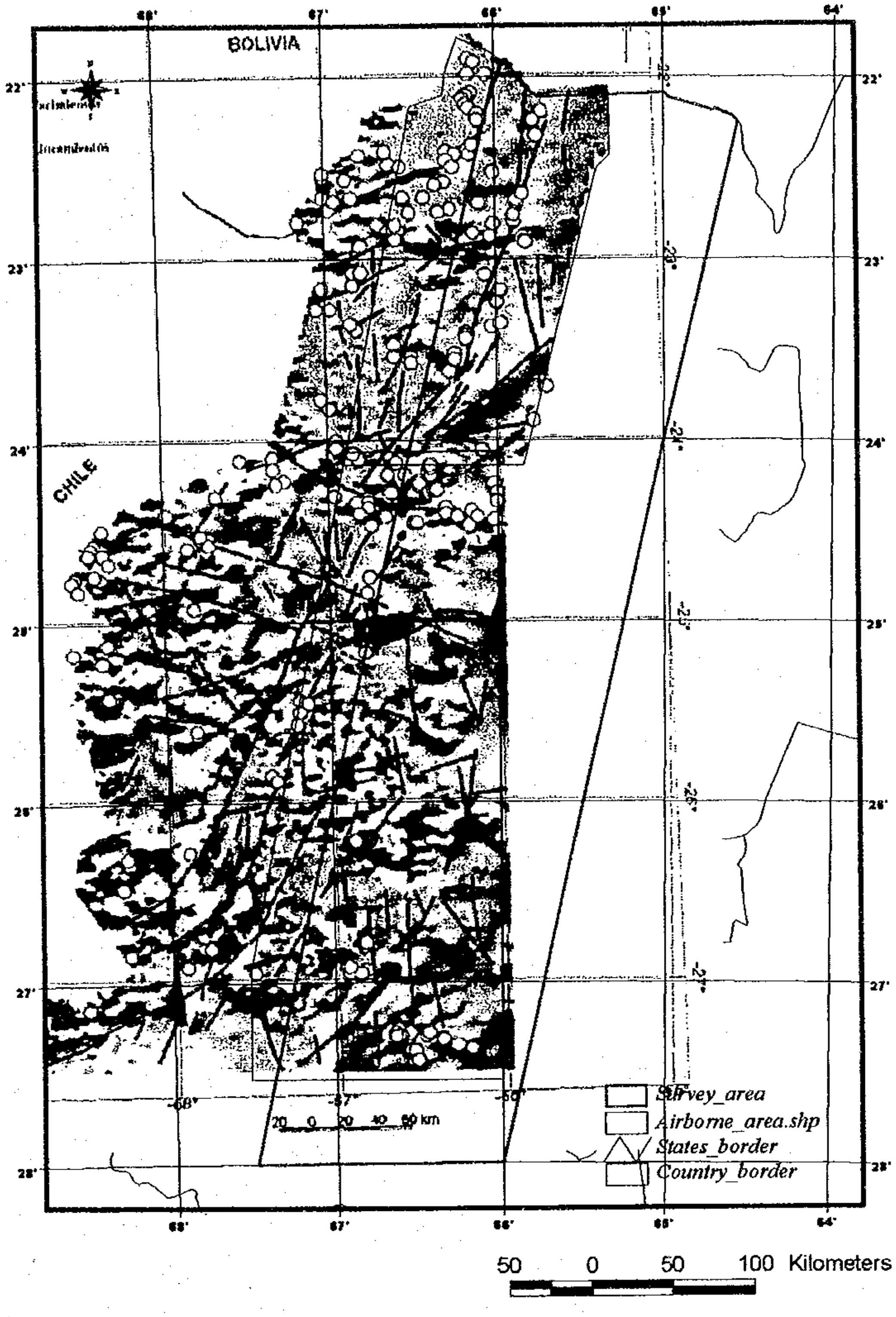

Fig.II-2-2-1-18 Airborne geophysical map from Chernicoff,C.J., Zappettine, E.O.

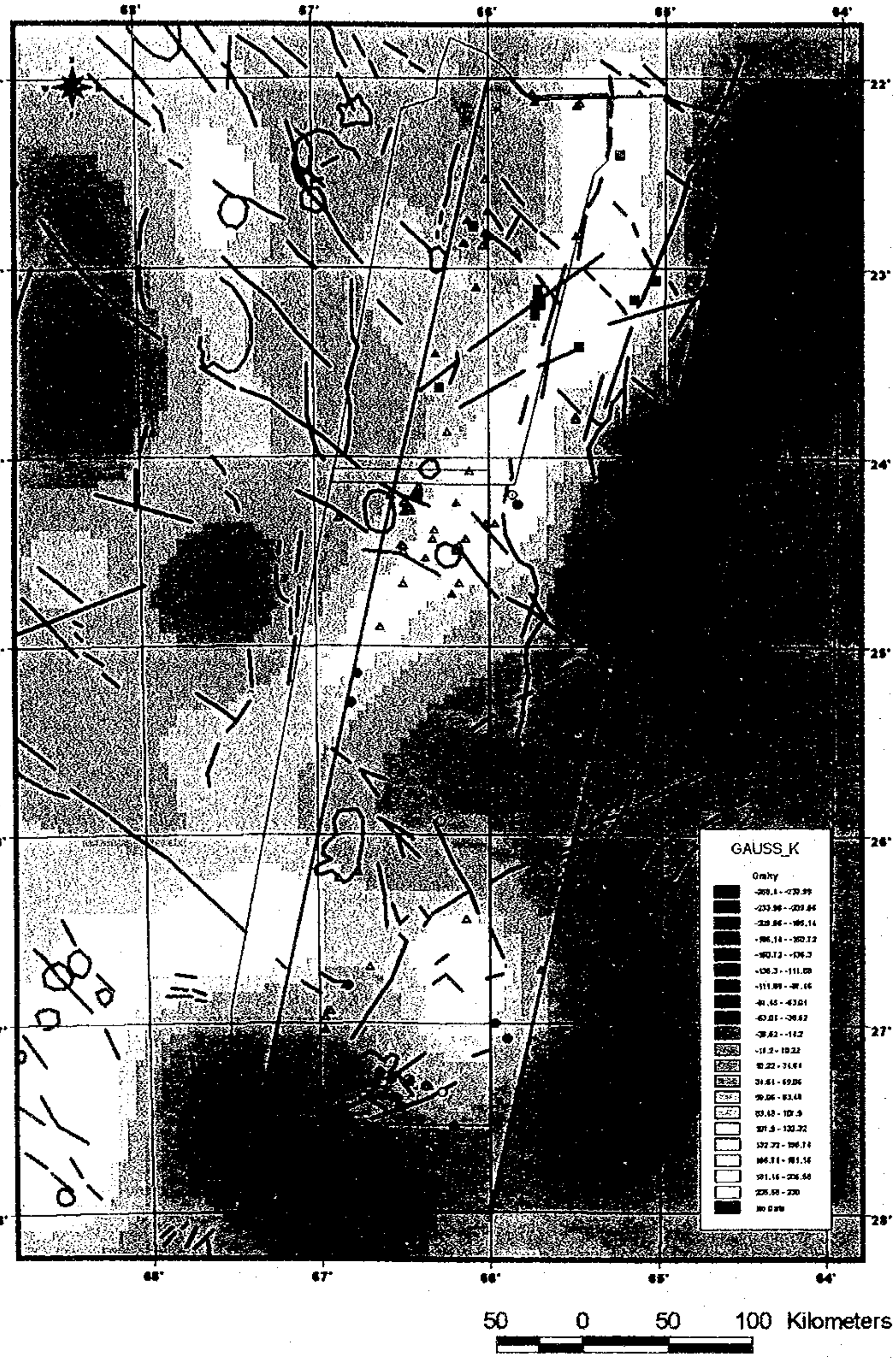

Fig.II-2-2-1-19 Gravity model image

Chapter 3 Stream sediments geochemistry

3-1 Circumstances

The regional survey of the mineral resources had carried out in the area along the Andes, in the project of Plan Cordillerano in 1960's. In the survey, stream sediment samples were collected at that time and were analyzed about major elements such as copper/lead/zinc. However, the elements as mineralization indicator such as arsenic/antimony mercury and gold/silver/molybdenum etc were not yet analyzed. Since the detection level of geochemical analysis in that time is not sufficient, SEGEMAR stored the remainder specimen for future detailed analysis.

3-2 Samples

The stream sediments samples were collected from the Northwest area of Argentina. Total number of sample analyzed is 5123 pieces in the first year survey, because of lack of sample volume and coordinate information.

3-3 Analysis

Analysis method of the package of INAA law and ICP-AES was adopted by the request of Argentina side, since the methods can applied even for small volume of sample, and has quick and low cost advantage for the analysis of the base metal, precious metals, rare earth metals. The analysis company are the XRAL Laboratories, A Division of SGS Canada Inc. which analyzed the samples of previous regional survey studies, eastern and southern area of Andes, Argentine.

Analysis result that was below a minimum detection limit value adopted the half value of the detection limit value and the result that was over a highest detection limit adopted the maximum value. Then all analytical value are visualized with standard deviation classification, ArcView GIS.

3-4 Evaluation

The analysis results are stored in CD-ROM of Appendix with geo-coordinate information as Arc View shapes and tables. Fig.II-3-3-4-1～4 show the distributions of copper, lead, zinc and silver in Northwest area. A copper anomaly corresponds to the distribution of known porphyry copper deposits, especially the high anomaly value is seen around Agua Rica mineral showings. Lead anomaly is mainly distributing over known SEDEX deposits, and partly seen around porphyry copper deposits. Zinc anomaly also distributes the SEDEX deposits. Silver anomaly is seen in the wide area in the southern part of surveyed area. The distribution corresponds well to the distribution of Ordovician granites in Southern part of the area.

Table II-3-3-1 List of elements and detection limits (upper:INAA Metod, lower:ICP-AES Method)

Element	D.L.	Element	D.L.	Element	D.L.
As	0.5ppm	Au	2ppb	Br	0.5ppm
Ce	3ppm	Cr	5ppm	Cs	1ppm
Eu	0.2ppm	Hf	1ppm	Hg	1ppm
Ir	5ppb	Lu	0.05ppm	Nd	5ppm
Rb	5ppm	Sb	0.1ppm	Se	3ppm
Sm	0.1ppm	Ta	0.5ppm	Tb	0.5ppm
Th	0.2ppm	U	0.5ppm	W	1ppm
Yb	0.2ppm				
Ag	0.2ppm	Al	0.01%	Ba	1ppm
Be	1ppm	Bi	5ppm	Ca	0.01%
Cd	0.5ppm	Co	2ppm	Cu	0.5ppm
Fe	0.02%	K	0.01%	La	2ppm
Mg	0.01%	Mn	1ppm	Mo	1ppm
Na	0.005%	Ni	1ppm	P	0.001%
Pb	2ppm	Sc	2ppm	Sn	10ppm
Sr	0.5ppm	Ti	0.01%	V	2ppm
Y	0.5ppm	Zn	0.5ppm		

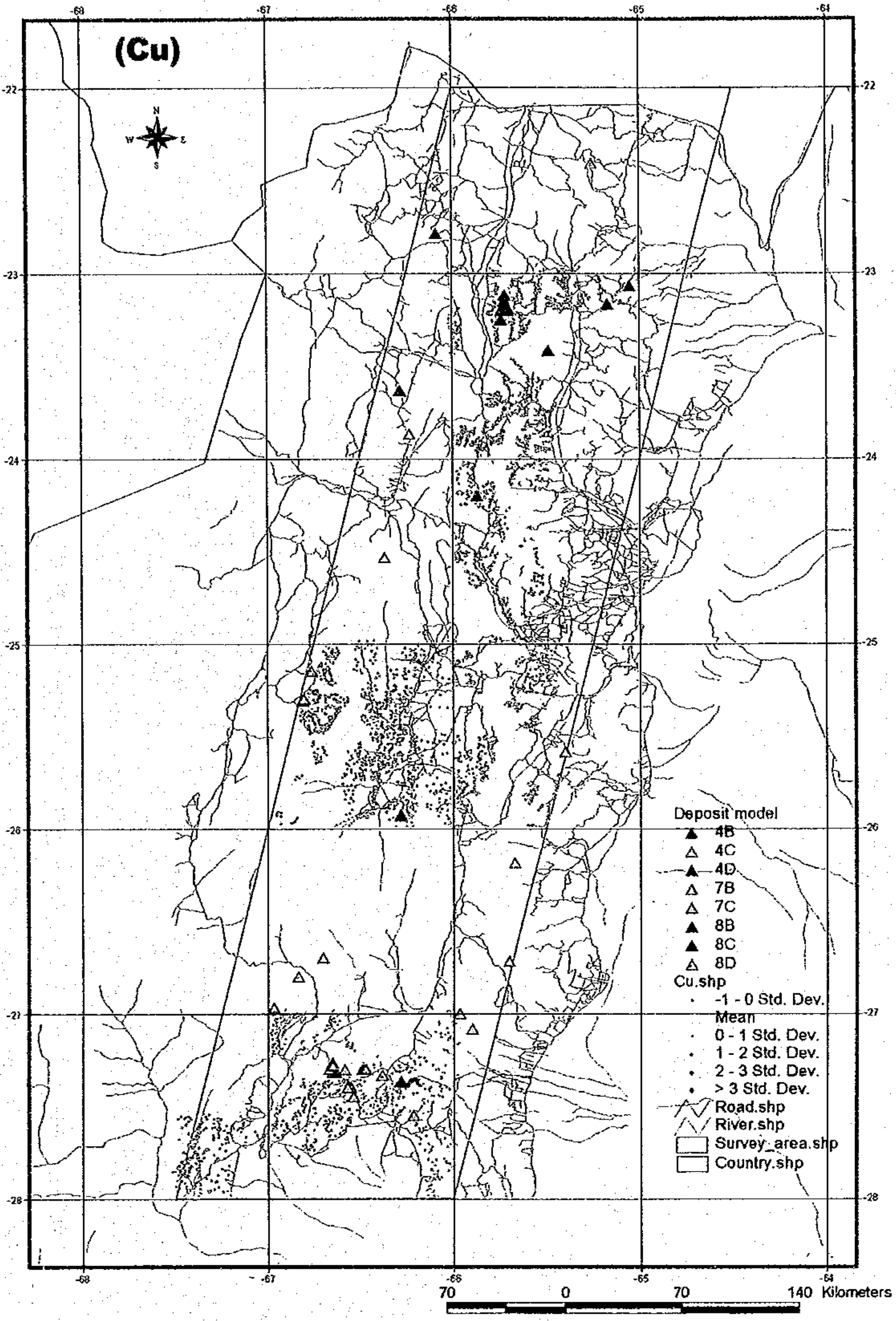

Fig.II-3-3-4-1 Geochemical anomaly map (Cu).

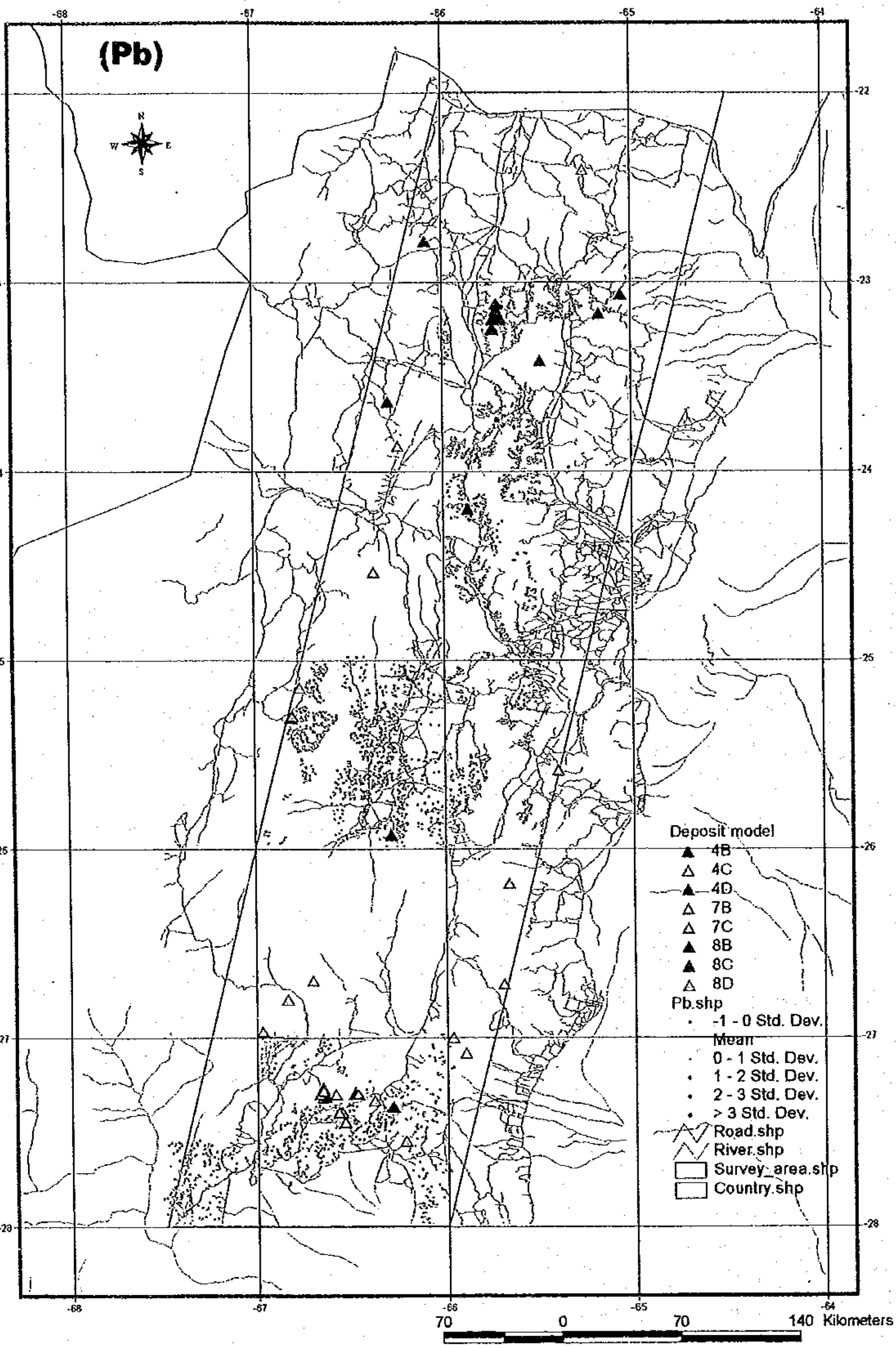

Fig.II-3-3-4-2 Geochemical anomaly map (Pb).

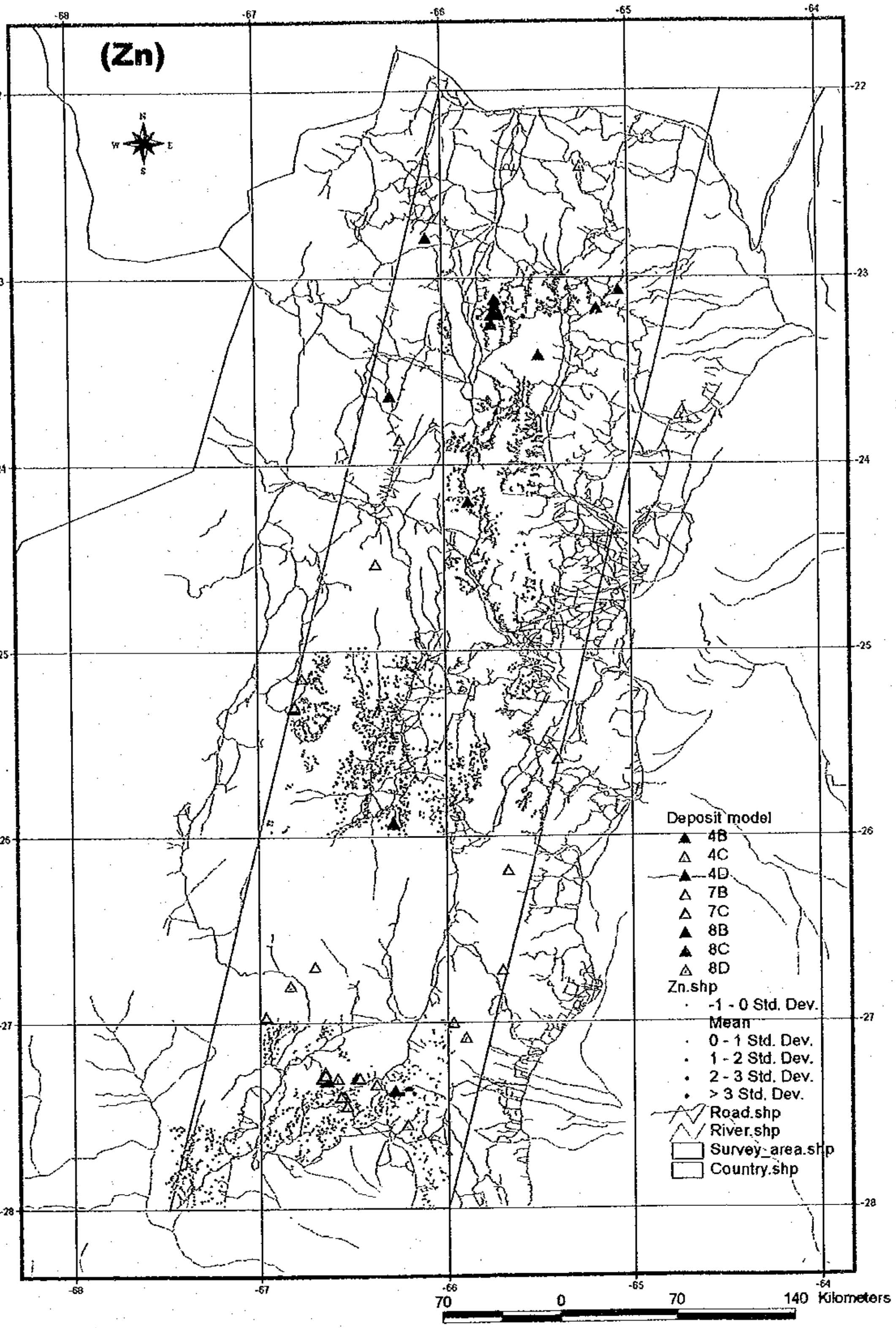

Fig.II-3-3-4-3 Geochemical anomaly map (Zn).

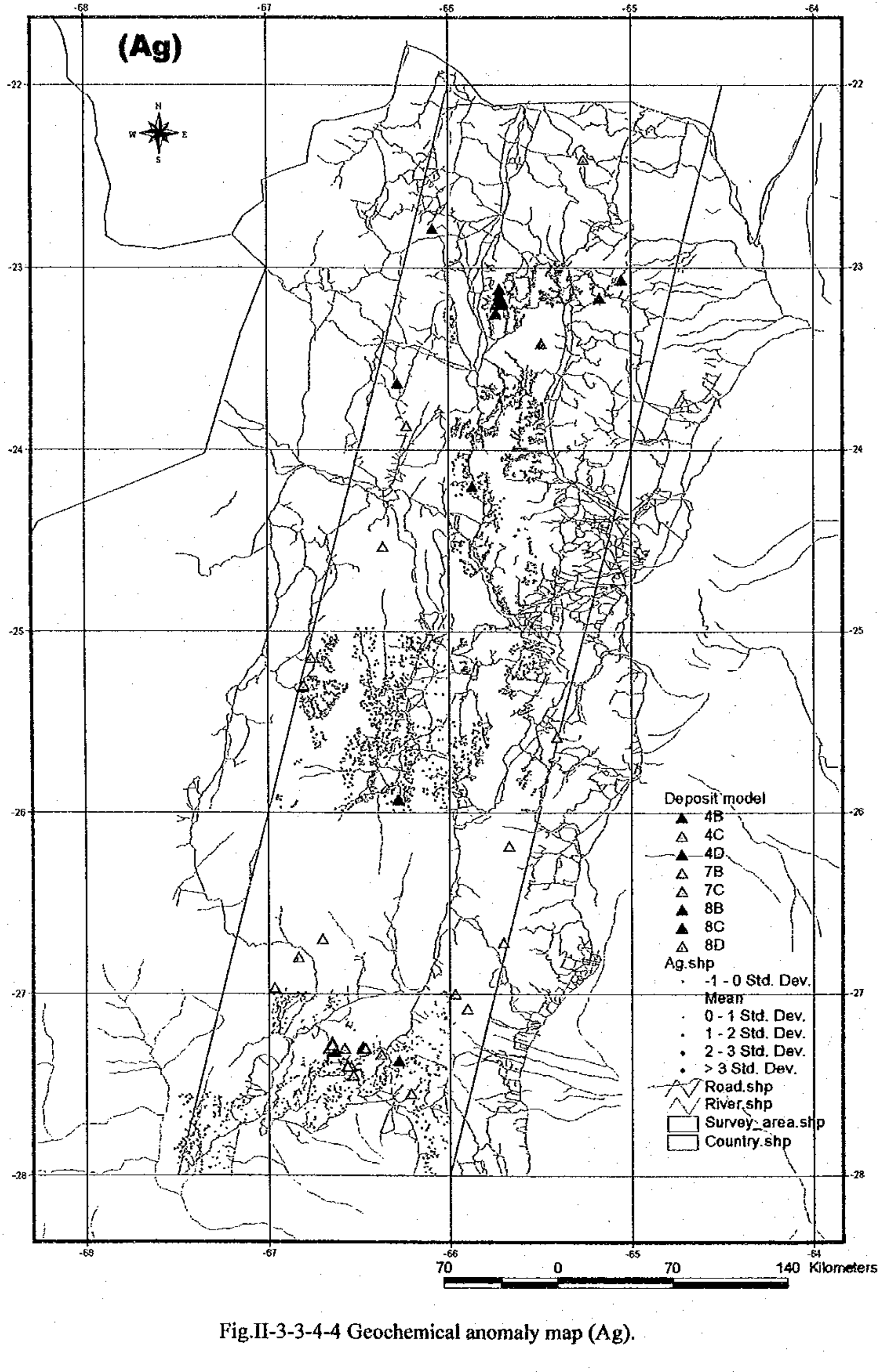

Fig.II-3-3-4-4 Geochemical anomaly map (Ag).