4-2 Results of image analyses

4-2-1 Band selection

(1) Soamanonga area

Topographic map and geologic map of Soamanonga area are shown in Fig.4-3 and Fig.4-4 respectively. This area is located in the middle reaches of the Onilahy river and vegetation could be dense in the northern part where density of drainage is high. In the southern part of this area, granite intrusion is distributed and gold-silver bearing copper deposits occur in Precambrian and Permian rocks around granite intrusion. Relationship between geological setting and distribution of copper mineralization is not represented clearly in existing geologic map.

LANDSAT TM bands 145, 157 and 457 false color images are shown in Fig.4-5, 4-6 and 4-7. Dense part of vegetation cover is displayed in green and contrast with sparse part of vegetation is very clear in bands 145 false color image. Lithologic boundaries in this image, however, are not clear except boundary between granite and surrounding units. In bands 157 false color image, lithologic units in Precambrian are easily differentiated but those in Permian to Triassic sedimentary rocks are not so. In bands 457 false color image, lithologic units in Precambrian are clearly recognized and those in sedimentary rocks can also be delineated.

Pseudo color images of TM bands 3/2, 4/3 and 5/7 ratios are shown in Fig.4-8, 4-9 and 4-10. Most of pixels with high 3/2 ratio are distributed in granite and Precambrian. Marble in Precambrian has low value of 3/2 ratio. Ratioing by TM bands 3/2 is available to detect iron oxides. In this case, rocks including iron minerals like magnetite are probably displayed as red with high 3/2 ratio because of oxidized iron minerals in surface. Bands 4/3 ratio is available to know density of vegetation. High density zones of vegetation are observed as reddish color with high 4/3 ratio in this image. Since TM band 7 covers absorption peak of infrared by many clay minerals, 5/7 ratio is effective to detect distribution of clay minerals. In this area, 5/7 ratio shows positive correlation well with 4/3 ratio. Anomaly of 5/7 ratio might indicates surface materials contain many clay minerals.

DPCA image by ratio 4/3 and 5/7 is shown Fig.4-11. Second principal component is displayed in pseudo color in this image. DPCA method is expected to extract the distribution zones of minerals which have absorption peak of infrared in range of TM band 7 like clay minerals or carbonate minerals, reducing effects by vegetation cover. We can differentiate distribution zones of carbonate rocks in Precambrian and Permian by DPCA image of Soamanonga area but PC2 is generally low in Permian units which have originally much amount of clay minerals. DPCA image, therefore, is not available for extraction of zones where clay minerals are distributed in this case.

Geologic interpretation map of satellite images in Soamanonga area is shown in Fig.4-12. Boundaries among each geologic units are delineated accurately with respect to existing geologic map. Since many of copper deposits are located along faults or lineaments in this interpretation map, fissure controlling can be important role for mineralization. Relationship between distribution of copper deposit and possible alteration zone (positive anomaly of bands 3/2 and 5/7 ratio) is not clear but many deposits located inside or near by anomaly of bands 3/2 ratio.

(2) Tranomaro area

Topographic map and geologic map of Tranomaro area are shown in Fig.4-13 and Fig.4-14 respectively. This area is located in the upper reaches of the Mandrare river and eastern part shows mountainous topography with more than 1,000m in elevation. Granitic complex is distributed in eastern mountainous part. Central to western part of the area mainly consists of metamorphic rocks in Precambrian age. Many uranothorianite deposits are located in topographically lower part in western front of eastern mountains made of granitic complex.

LANDSAT TM bands 145, 157 and 457 false color images of Tranomaro area are shown in Fig.4-15, 4-16 and 4-17. Boundaries between Precambrian and granitic complex are not clear in bands 145 false color image. In bands 157 false color image, to delineate boundaries between Precambrian and granitic complex is possible but Precambrian subunits are not easily recognized. In bands 457 false color image, we can easily recognize unit boundaries between Precambrian and granitic complex and subunits in Precambrian.

Pseudo color images of TM bands 3/2, 4/3 and 5/7 ratios are shown in Fig.4-18, 4-19 and 4-20. Most of pixels with high 3/2 ratio are distributed in topographically lower part. That might mean oxidation is controlled by humidity or other climatic conditions. Since reddish pixels with high 4/3 ratio are concentrated in a area where the Mandrare river meanders down to north, this ratio probably indicates density of vegetation. 5/7 ratio shows positive correlation with 4/3 ratio. Anomaly of 5/7 ratio might indicate surface materials contain many clay minerals.

DPCA image by ratio 4/3 and 5/7 is shown in Fig.4-21. Second principal component is displayed in pseudo color in this image. Granitic complex and Antsakaominary formation in Precambrian show high value of PC2 but the distribution zones of clay minerals cannot be extracted from this image.

Geologic interpretation map of satellite images in Tranomaro area is shown in Fig.4-22. Folded structures which are not indicated on existing geologic map are interpreted but distribution of lenticular granite cannot be interpreted clearly compared with existing geologic map. Uranothorianite deposits are located commonly inside of anomalous zones of bands 5/7 ratio.

Depending on the results of case study in Soamanonga area and Tranomaro area, we selected a combination of bands 457 for false color images as the best combination to make geologic interpretation and bands 5/7 ratio pseudo color images to delineate alteration zones.

4-2-2 Image interpretation

TM bands 457 false color image mosaic is shown in Fig.4-23 and bands 5/7 ratioing pseudo color image mosaic in Fig.4-24. Fig.4-25 and PL. 1 are geologic interpretation map of those images. We prepared color prints of images on a scale of 1 to 500,000 and 1 to 200,000 for interpretation.

Geologic interpretation of TM images in this survey area had been already done in phase I survey by bands 234 false color images. We revised interpretation map of phase I this year. Geologic units and structures in this year's interpretation map are nearly the same as those of last year's one and descriptions about interpreted results are in a report of phase I.

We also delineated anomalous zones of bands 5/7 ratio as zones which are possibly related to alteration. Following 3 areas are extracted as areas where positive anomalies of band 5/7 ratio are concentrated:

1) Northwest end of the survey area where Lower Permian to Lower Triassic sedimentary rocks are distributed.

2) An area along circular collapse structure in the eastern area and a part of igneous complex inside of this circular structure.

3) Lower topographic area in the southwest end of the survey area.

Only northern half of the circular structure mentioned above can be recognized from false color images and southern half of that can be supposed to exist continuously from images of 5/7 rationing.

4-2-3 Consideration from interpreted results

Following considerations are possible about 3 anomalous zones mentioned above:

1) Northwest end of survey area

Lower Permian to Lower Triassic sedimentary rocks originally contain more clay minerals than Precambrian metamorphic rocks or granitic rocks surrounding those units, and also those rock types have comparatively low resistivity to weathering. On the surface of those sedimentary rocks, therefore, weathered materials which contain a great quantity of clay minerals might be exposed.

2) An area along circular collapse structure

Talus deposits which contain much clay minerals can be formed under steep scarp along circular structure. Positive anomalies of 5/7 ratio may represent a distribution of this talus deposits. But still it is possible that argillization zones caused by hydrothermal circulation were formed along circular collapse structure.

Distribution of positive anomaly of 5/7 ratio located inside of circular structure has no relation with geologic structure. This anomaly can represent alteration zone formed by unknown reason.

3) Southwest end of the area

Eocene marine facies and Quaternary beds which originally contain much clay minerals are mainly distributed in this area. Precambrian units showing high 5/7 ratio should be covered by thin layer of younger sediments like that, which is supposed from false color images.

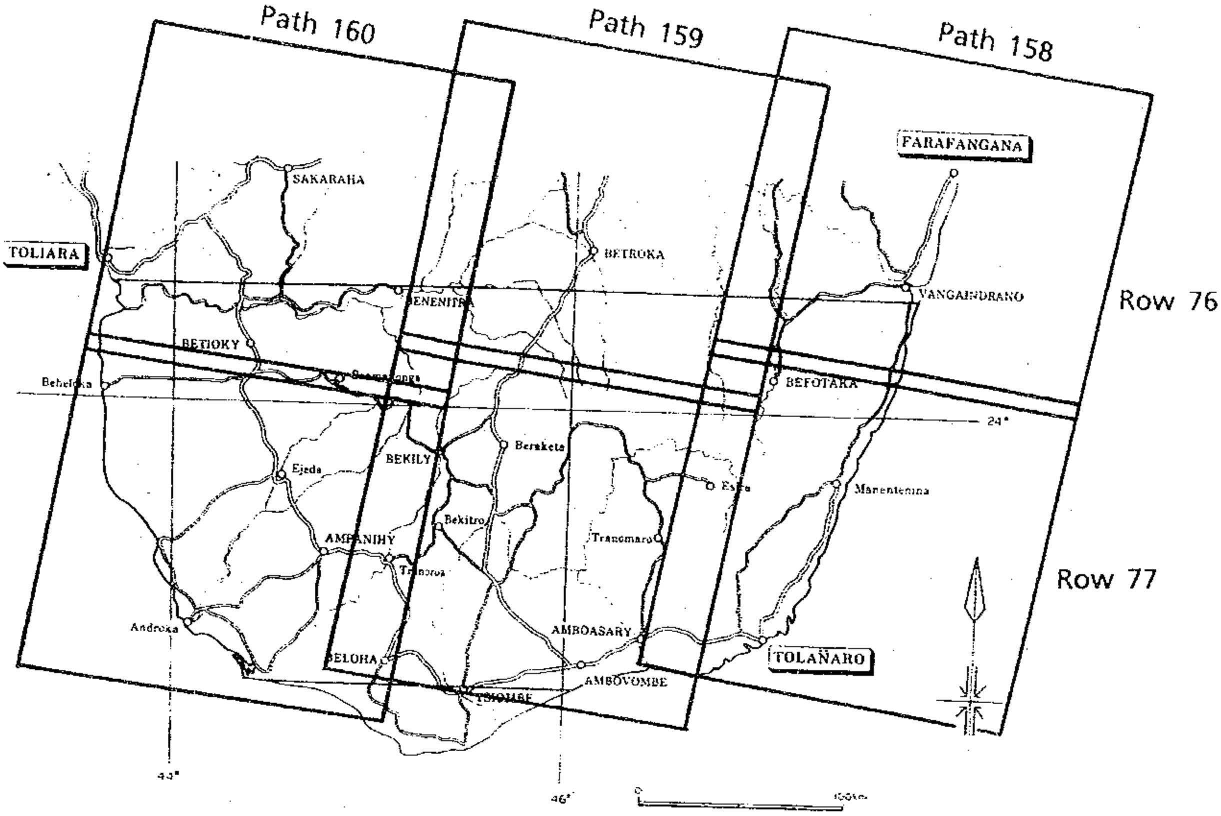


Fig.4-1 Location of LANDSAT TM data

Table 4-1 LANDSAT TM data list

	Satellite	Data Form	Sensor	Path	Row	Date	Cloud cover	Distributor
1	L5	CCT	TM	158	76	Nov.25,1984	20%	EOSAT
2	L5	CCT	TM	158	77	Nov.25,1984	20%	EOSAT
3	L5	CCT	TM	159	76	Jan.19,1985	10%	EOSAT
4	L5	CCT	TM	159	77	Jan.19,1985	10%	EOSAT
5	L5	CCT	TM	160	76	Feb.11,1985	10%	EOSAT
6	L5	CCT	TM	160	77	Feb.11,1985	10%	EOSAT

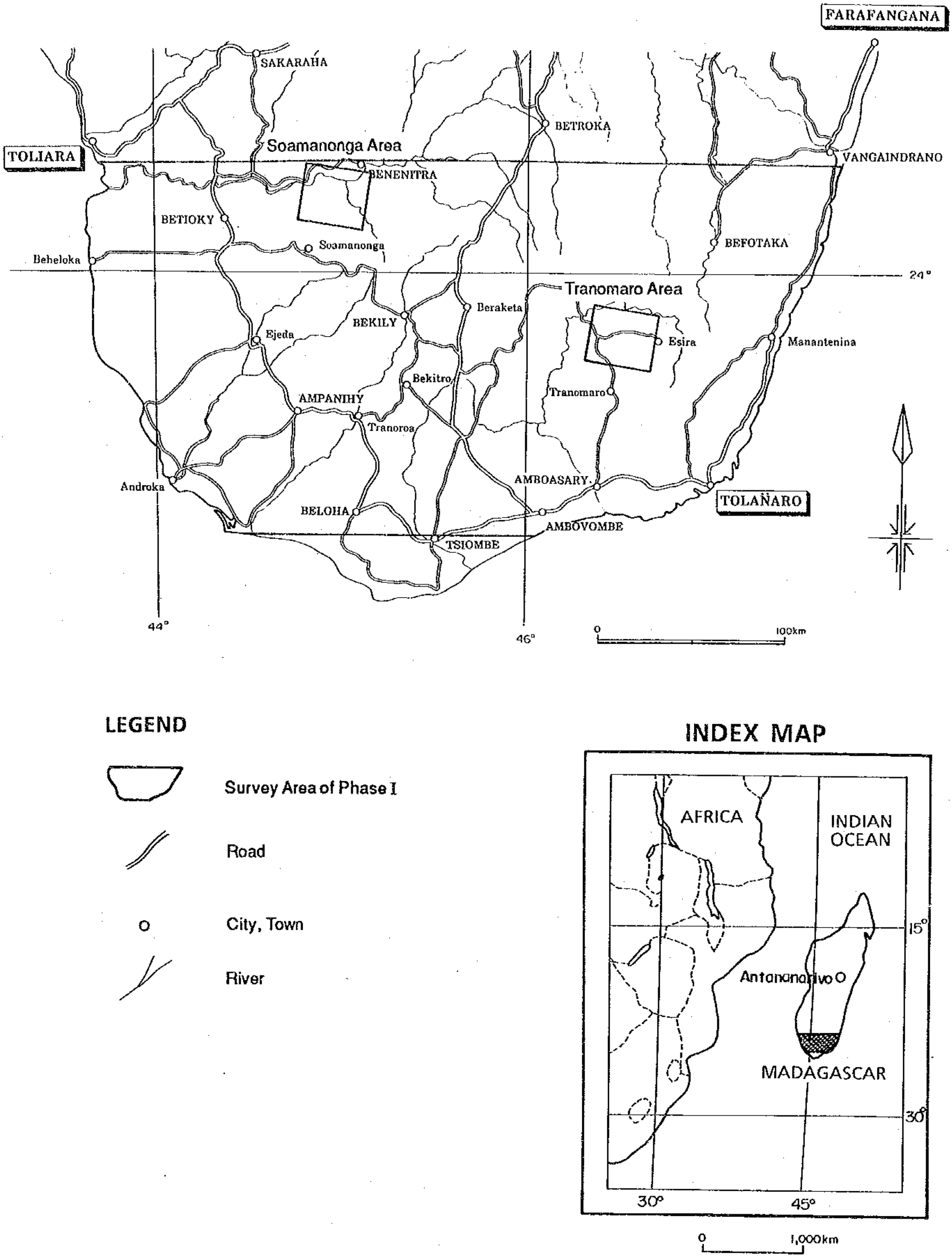


Fig.4-2 Location of Soamanonga area and Tranomaro area

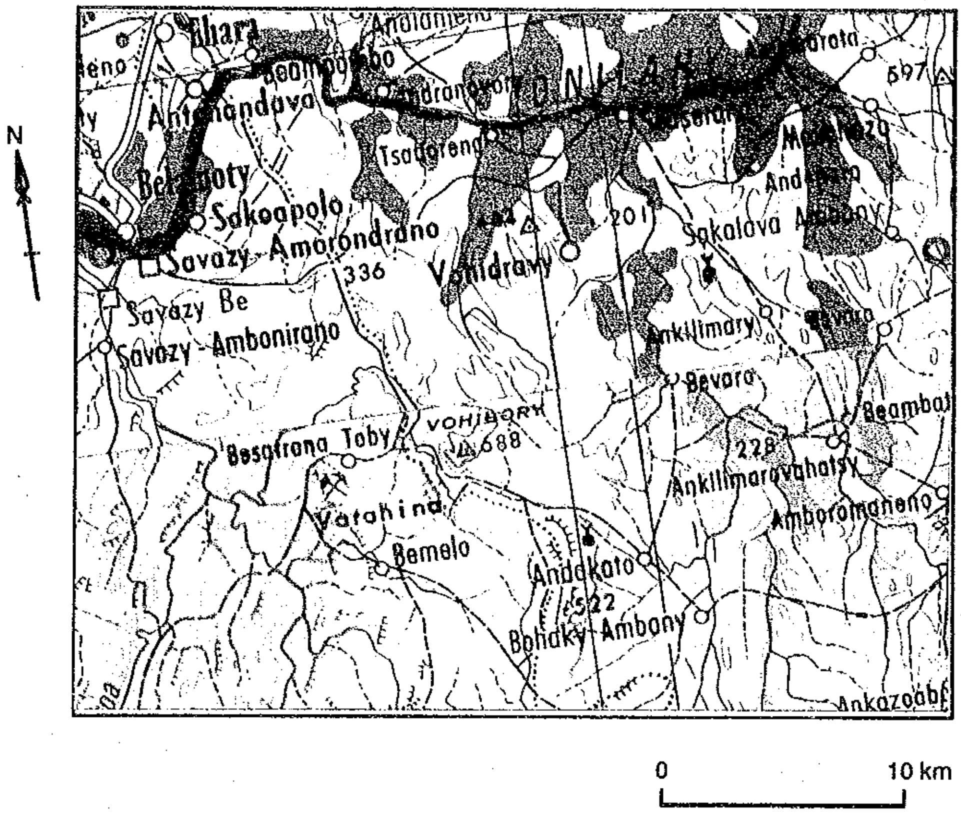
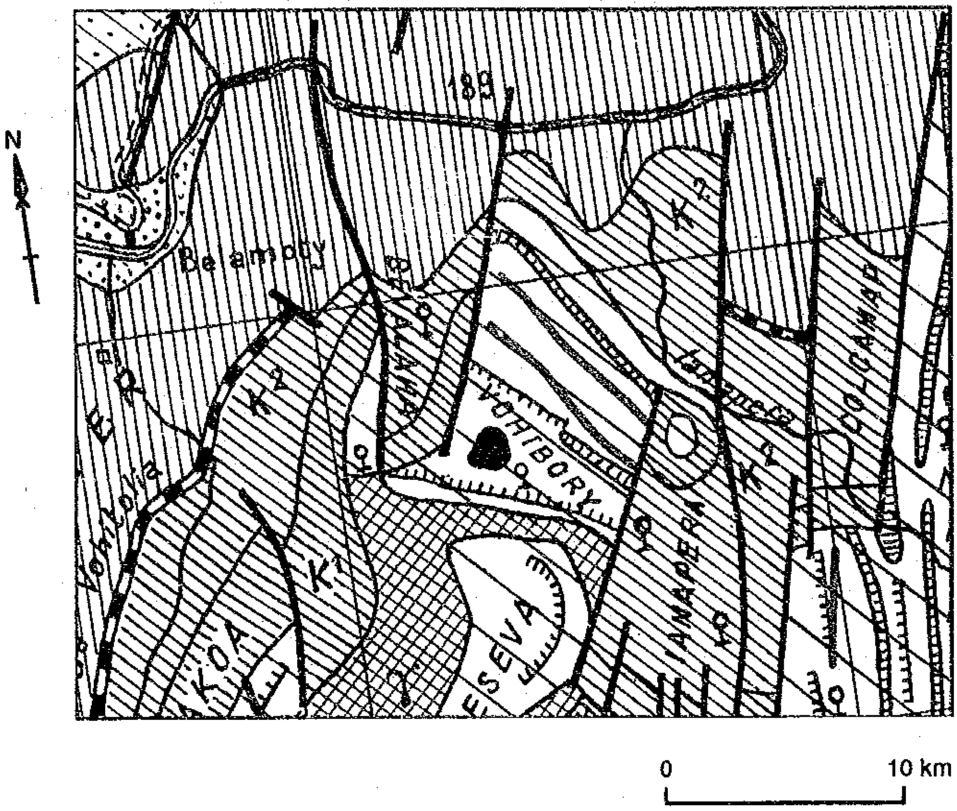


Fig.4-3 Topographic map of Soamanonga area



LEGEND

Alluvium

Permian - L. Triassic

K4 upper Sakamena group

K3 middle and lower Sakamena group

marine limestone

K2 upper Sakoa group

K1 lower Sakoa group

granite

stratiform granite

marble

amphibolite

copper

Precambrian

Vohibory system
gneiss, leptinite, amphiboleite

Fig.4-4 Geologic map of Soamanonga area

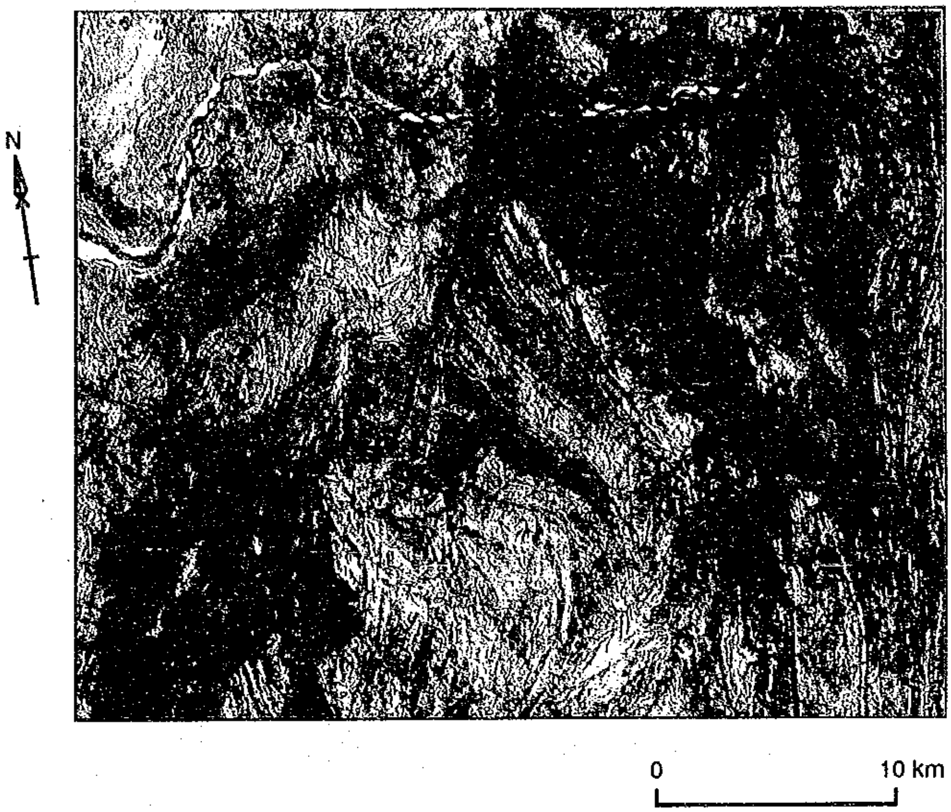


Fig.4-5 False color image of band145=BGR of Soamanonga area

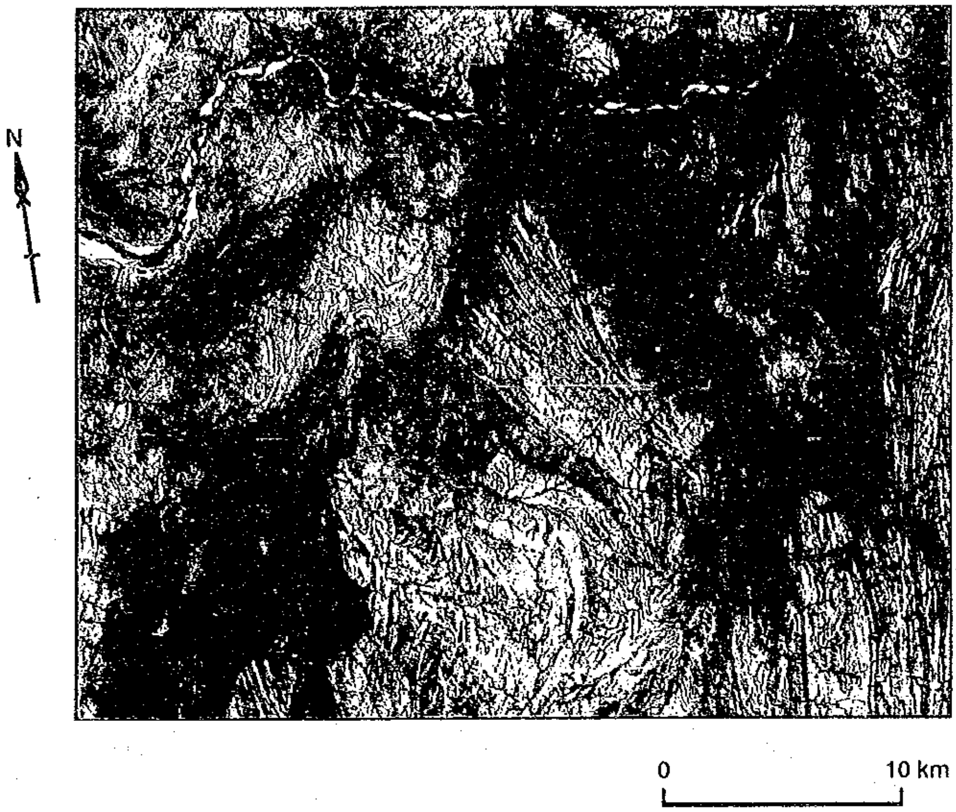


Fig.4-6 False color image of band157=BGR of Soamanonga area

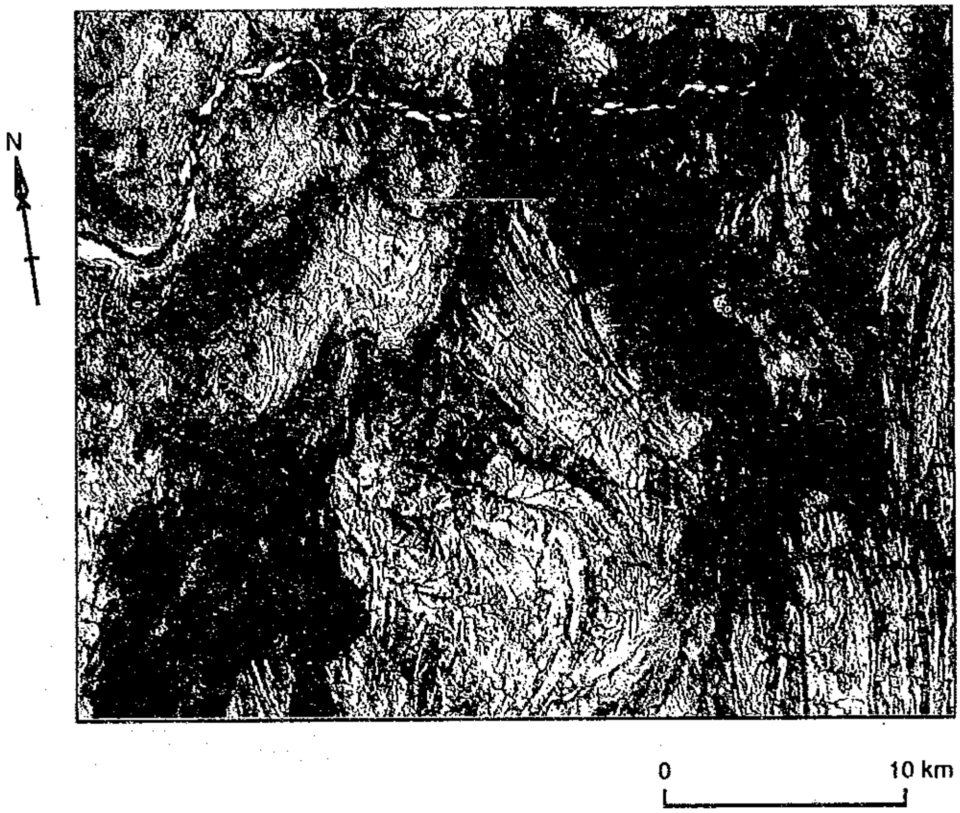


Fig.4-7 False color image of band457=BGR of Soamanonga area

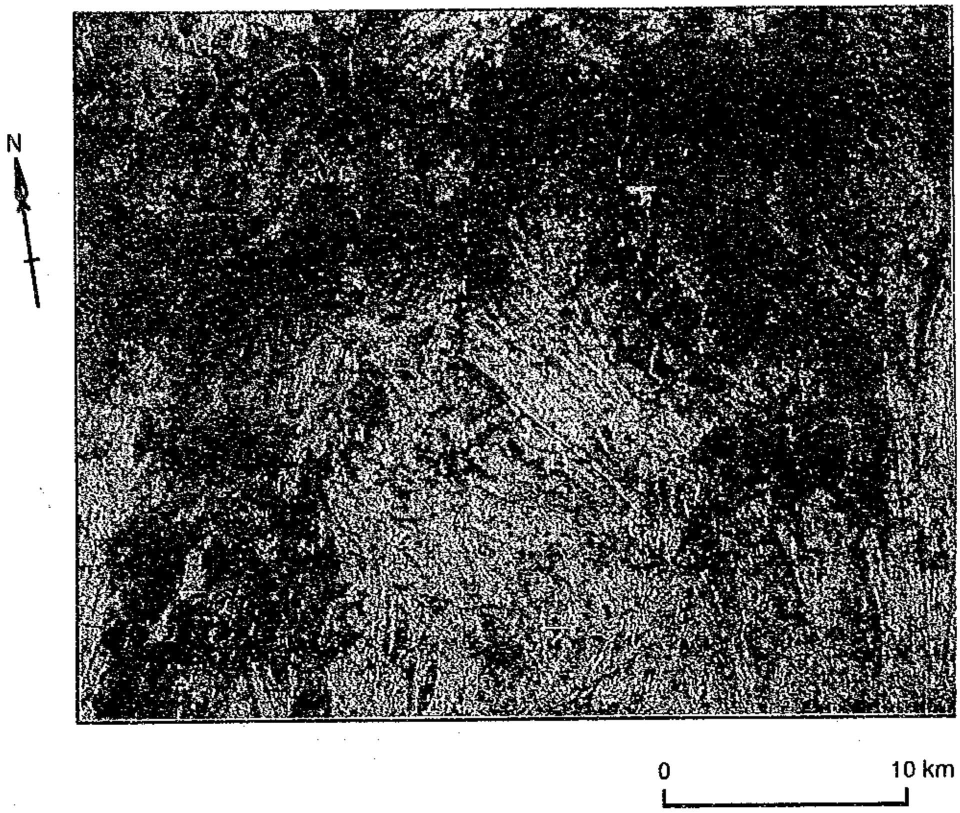


Fig.4-8 Pseudo color image of band3/band2 ratio of Soamanonga area

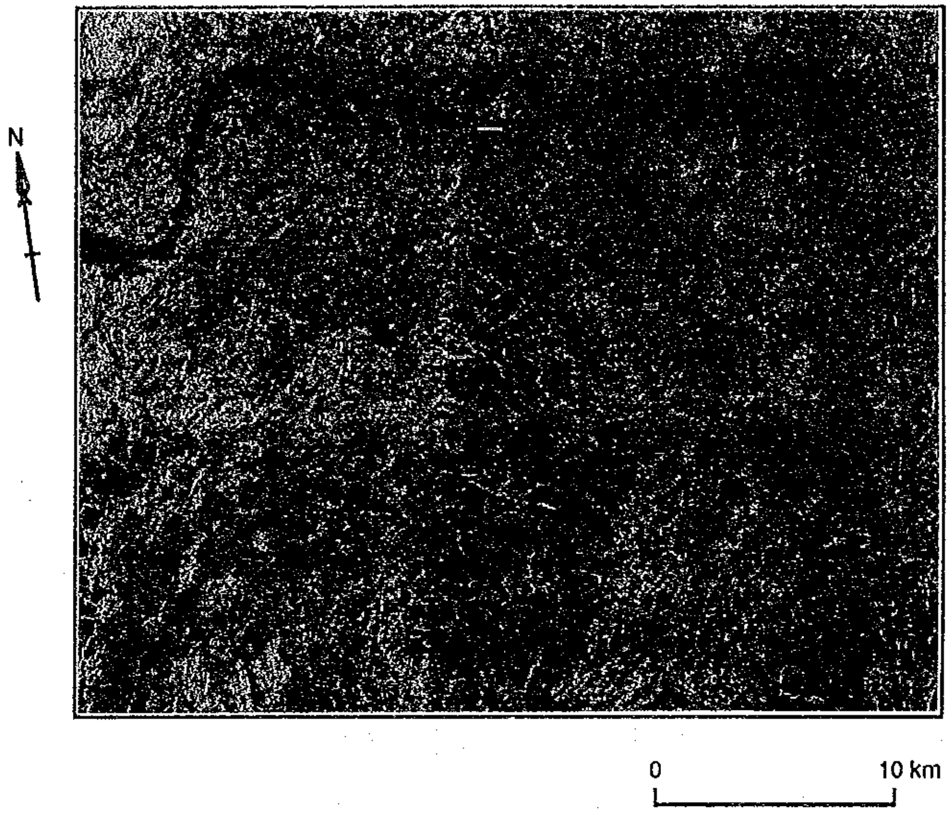


Fig.4-9 Pseudo color image of band4/band3 ratio of Soamanonga area

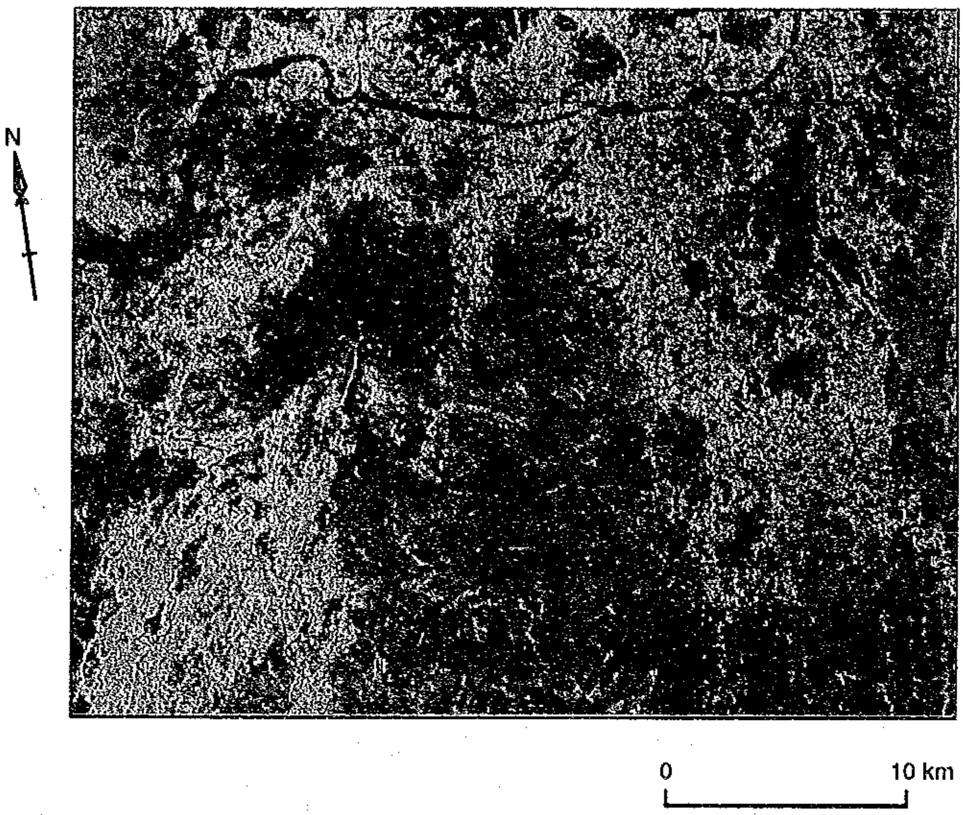


Fig.4-10 Pseudo color image of band5/band7 ratio of Soamanonga area

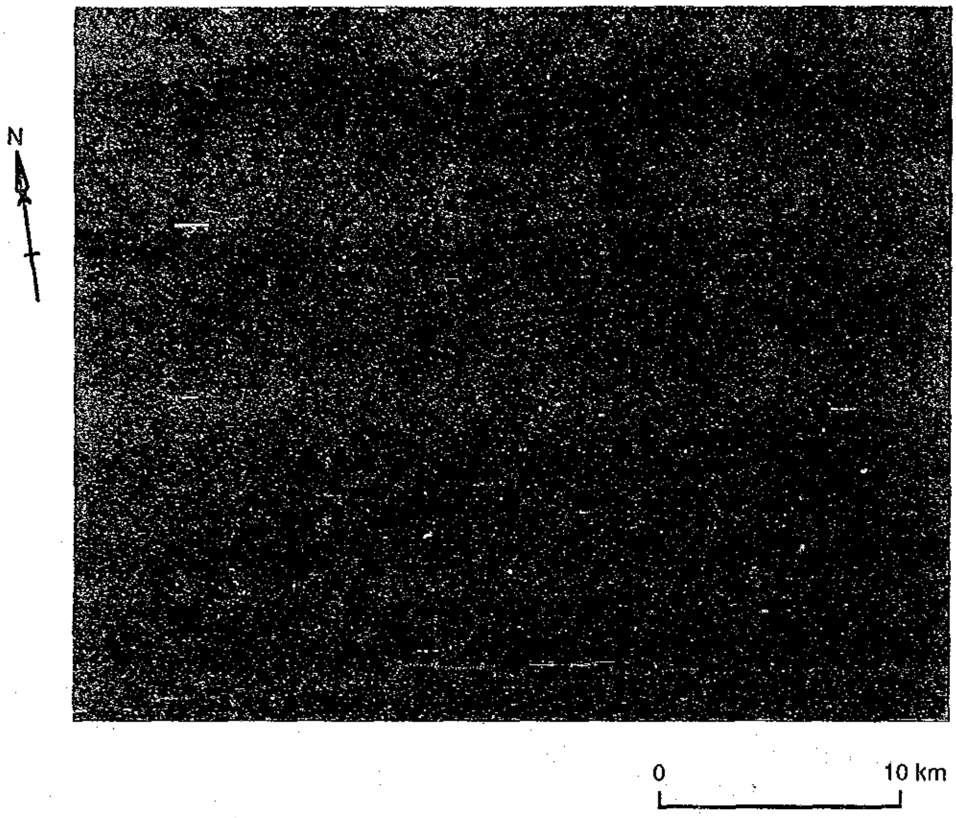
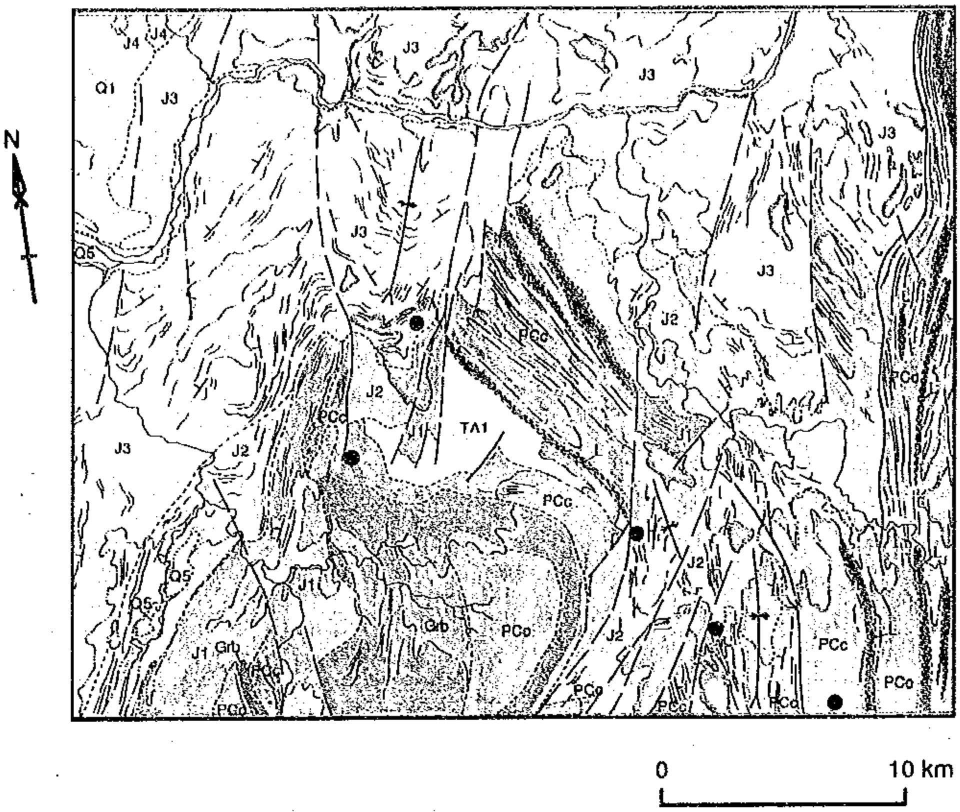


Fig.4-11 DPCA image of Soamanonga area



LEGEND

Quaternary
- Q5 alluvium
- Q1 Carapace sand

U. Permian - L. Triassic
- J4 upper Sakamena group
- J3 middle and lower Sakamena group

L. Permian
- J2 upper Sakoa group
- J1 lower Sakoa group

Precambrian
- PCc Vohibory system
- L marble
- Grb granite
- TA1 tonal anomaly

———	fault
— — —	inferred fault
—✱—	syncline
┬	dip direction
~	bedding trace
(shaded outline)	anomaly of TM band3/band2 ratio
(dotted outline)	anomaly of TM band5/band7 ratio
●	copper minaralization

Fig.4-12 Interpretation map of images of Soamanonga area

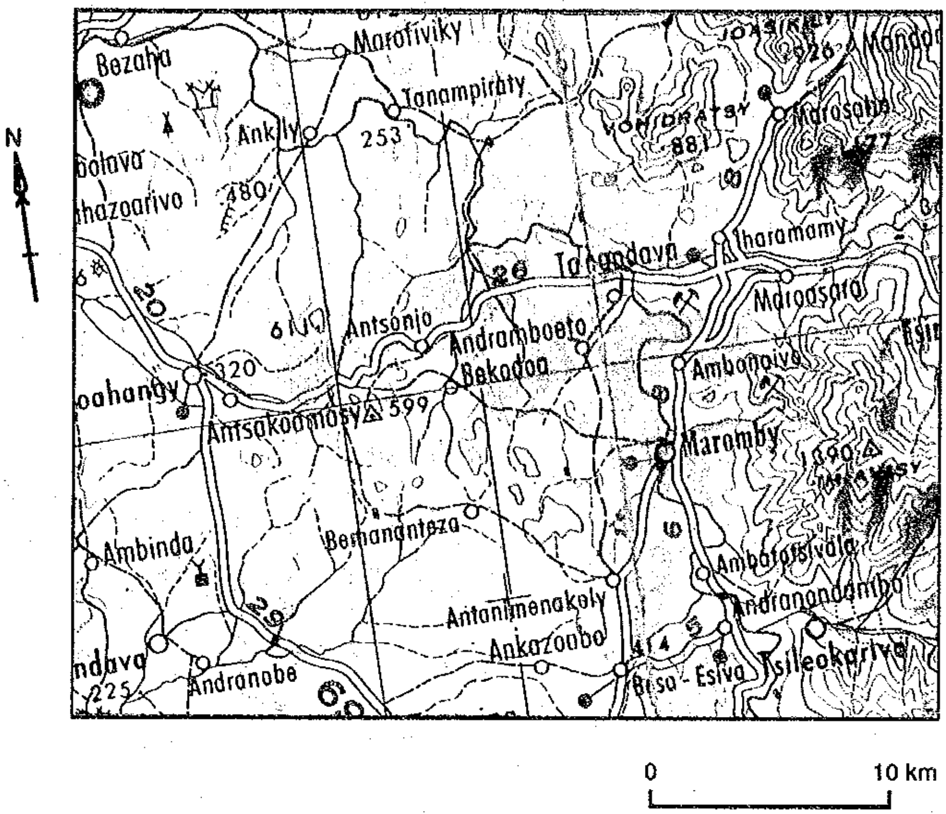


Fig.4-13 Topographic map of Tranomaro area

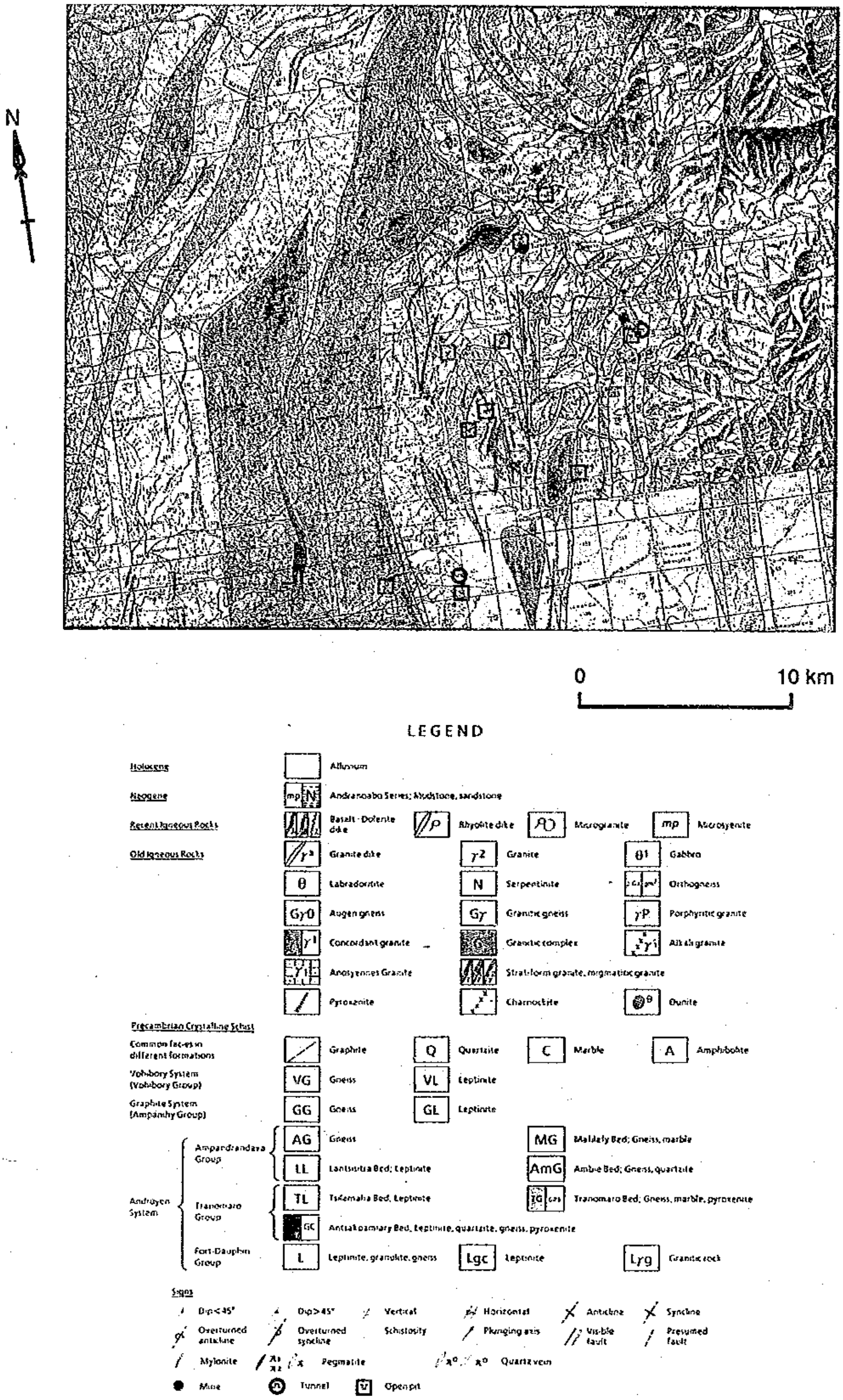


Fig.4-14 Geologic map of Tranomaro area

17-15

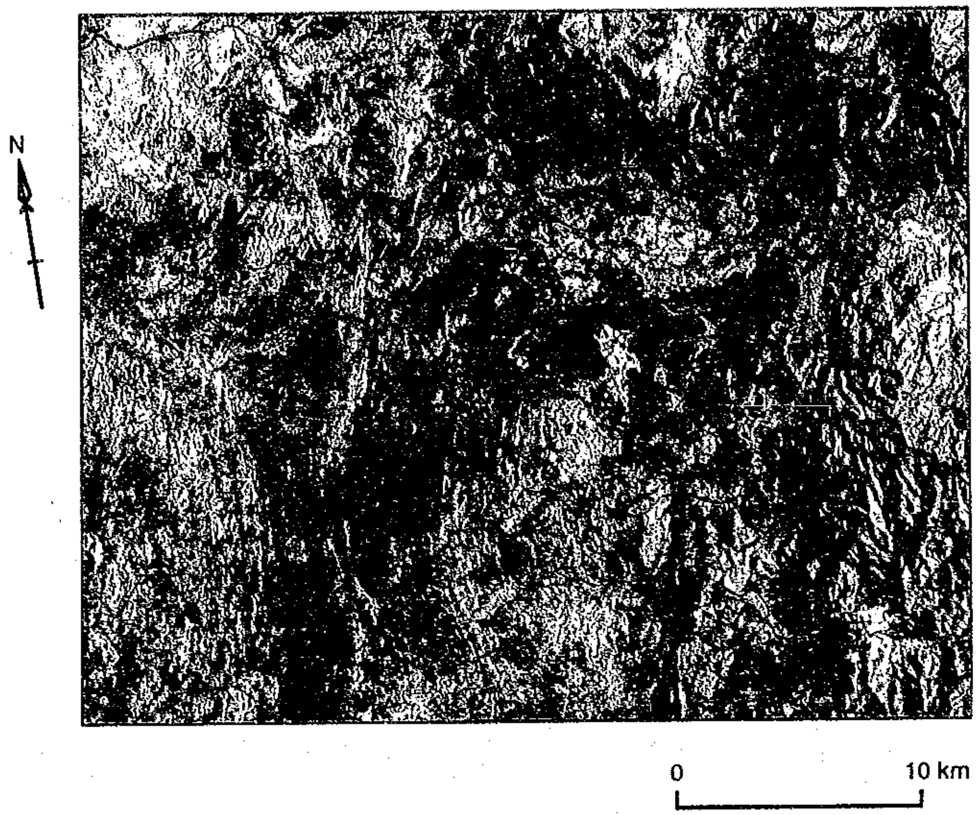


Fig.4-15 False color image of band145=BGR of Tranomaro area

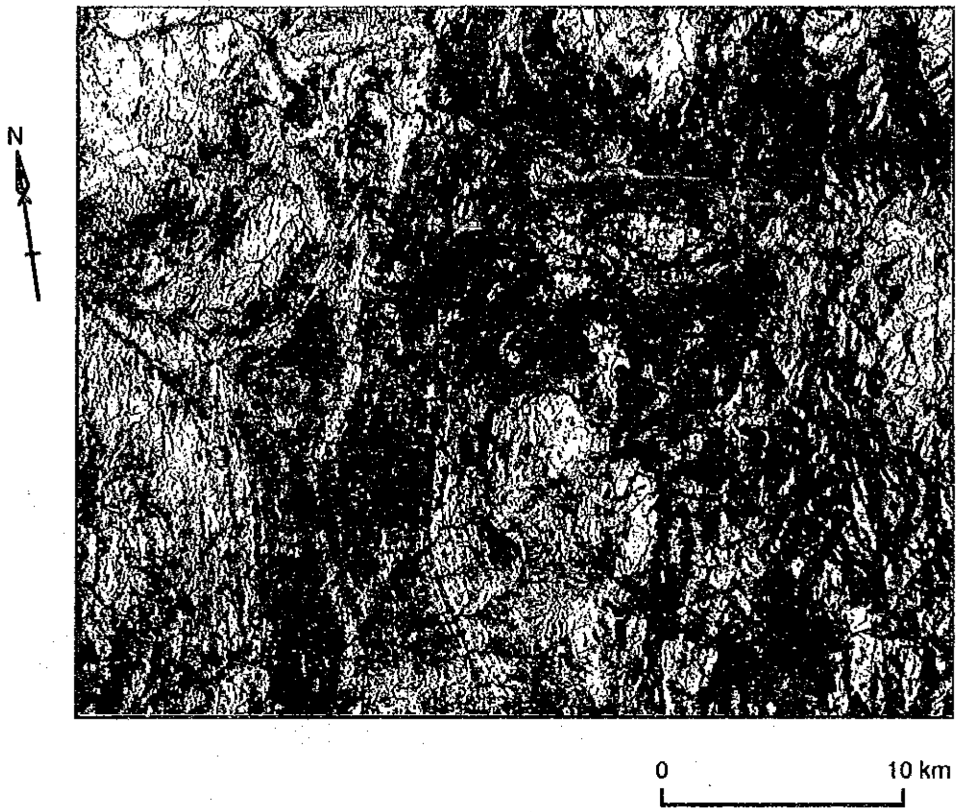


Fig.4-16 False color image of band157=BGR of Tranomaro area

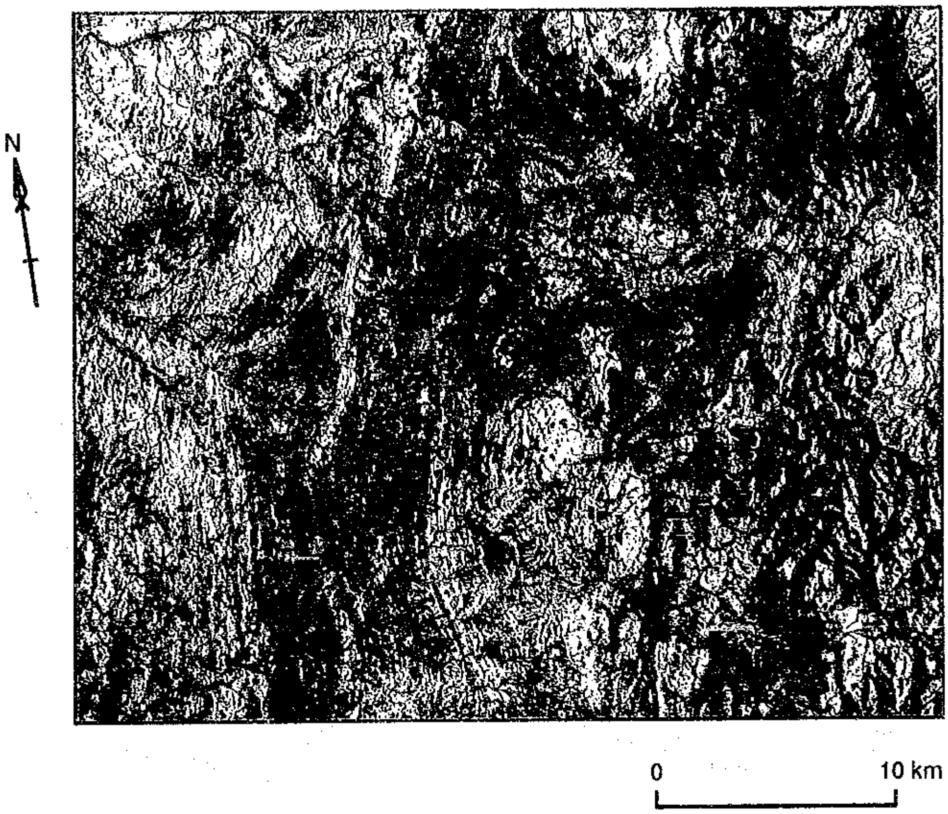


Fig.4-17 False color image of band457=BGR of Tranomaro area

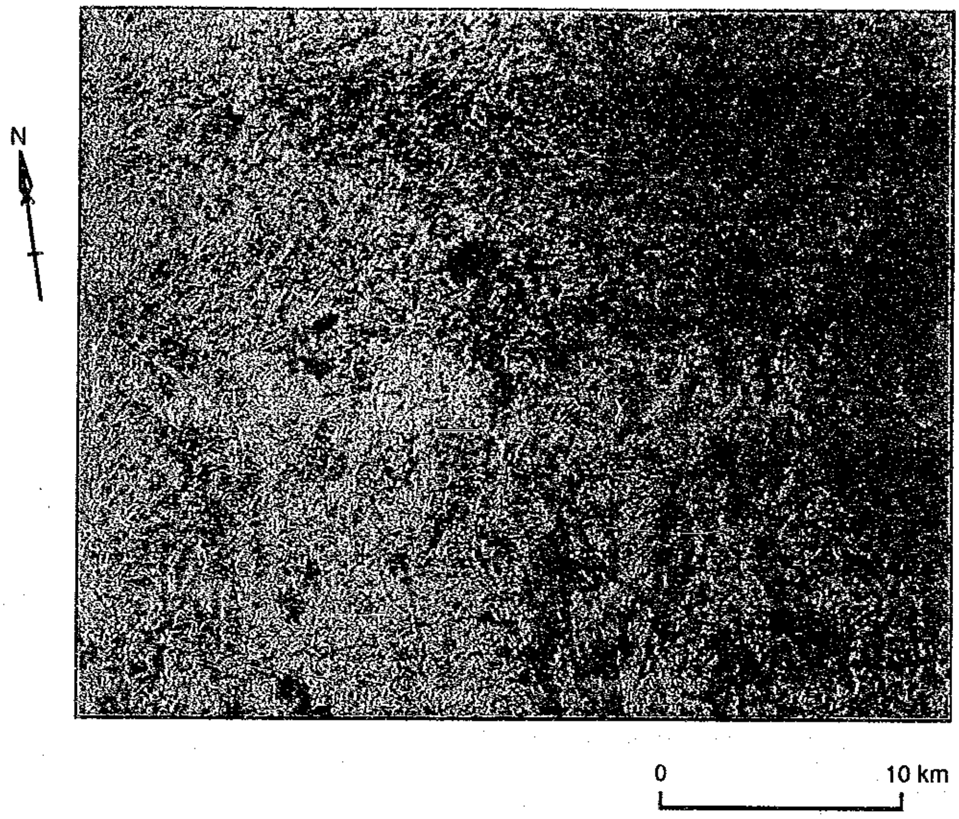


Fig.4-18 Pseudo color image of band3/band2 ratio of Tranomaro area

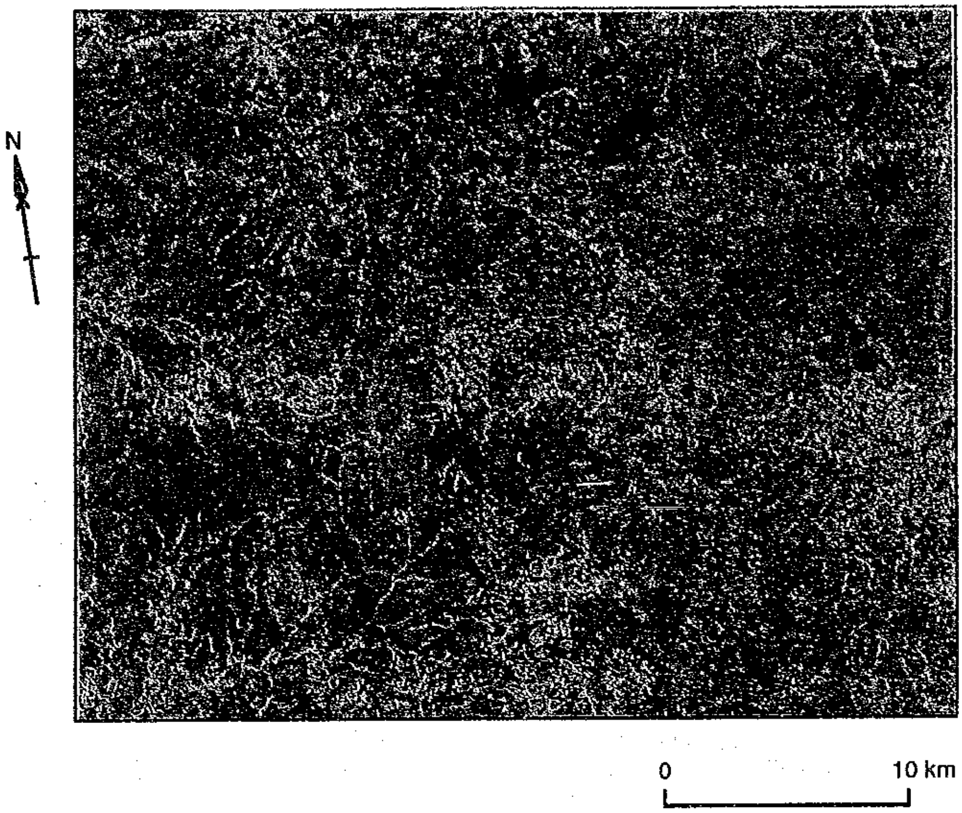


Fig.4-19　Pseudo color image of band4/band3 ratio of Tranomaro area

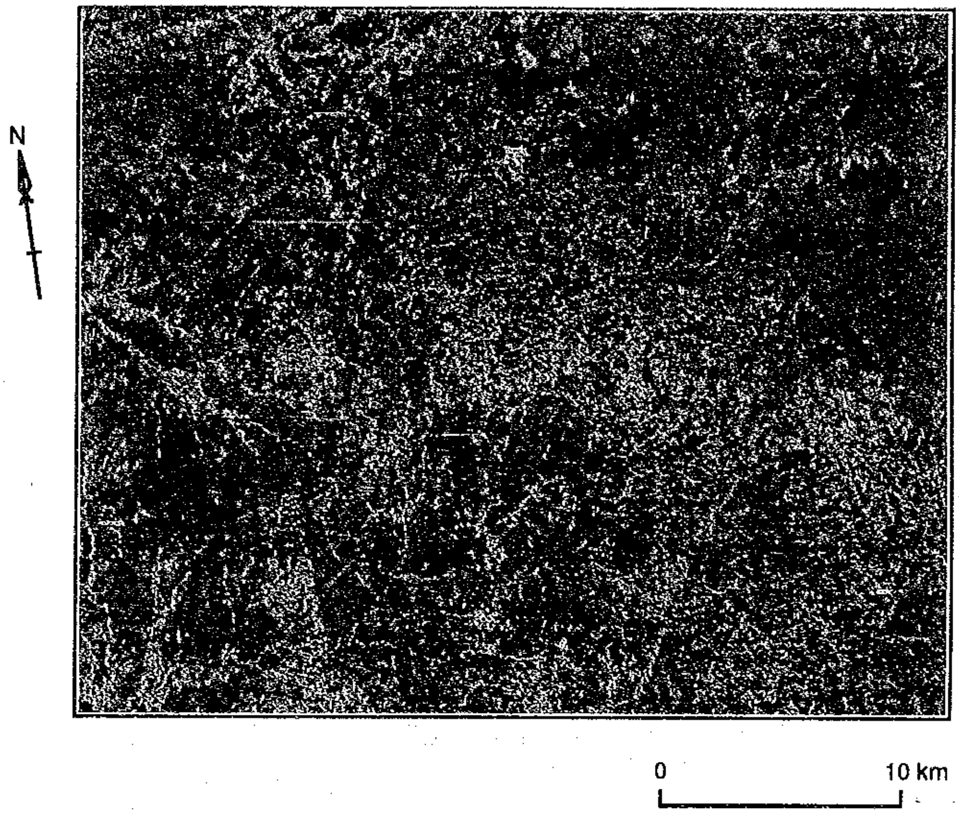


Fig.4-20 Pseudo color image of band5/band7 ratio of Tranomaro area

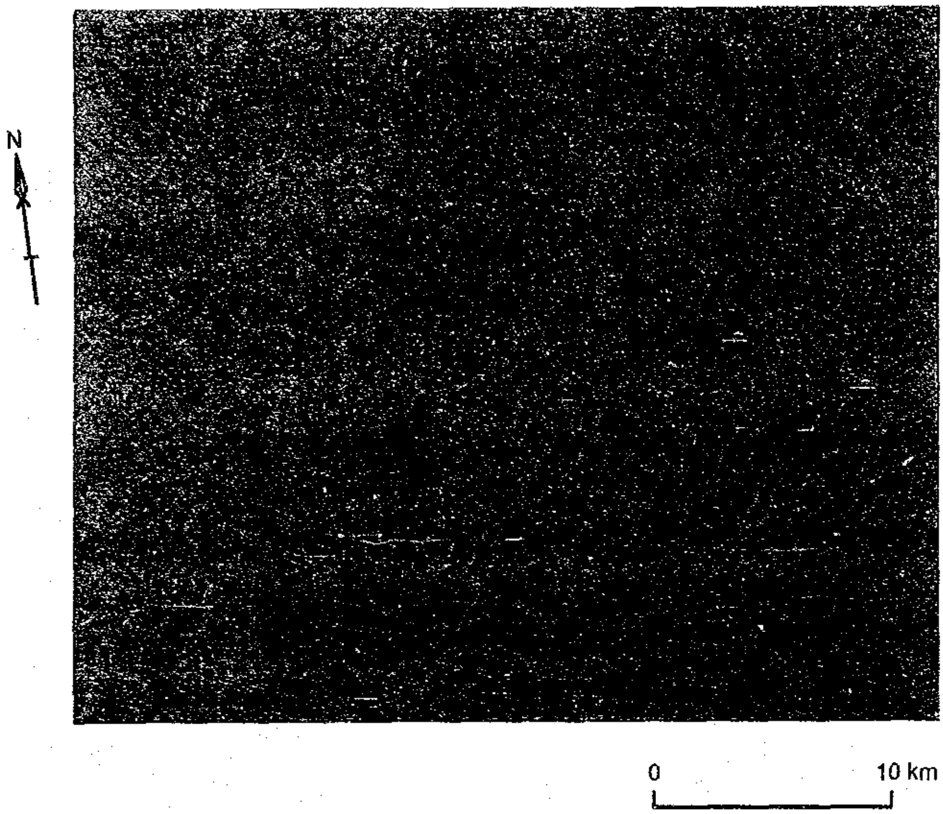
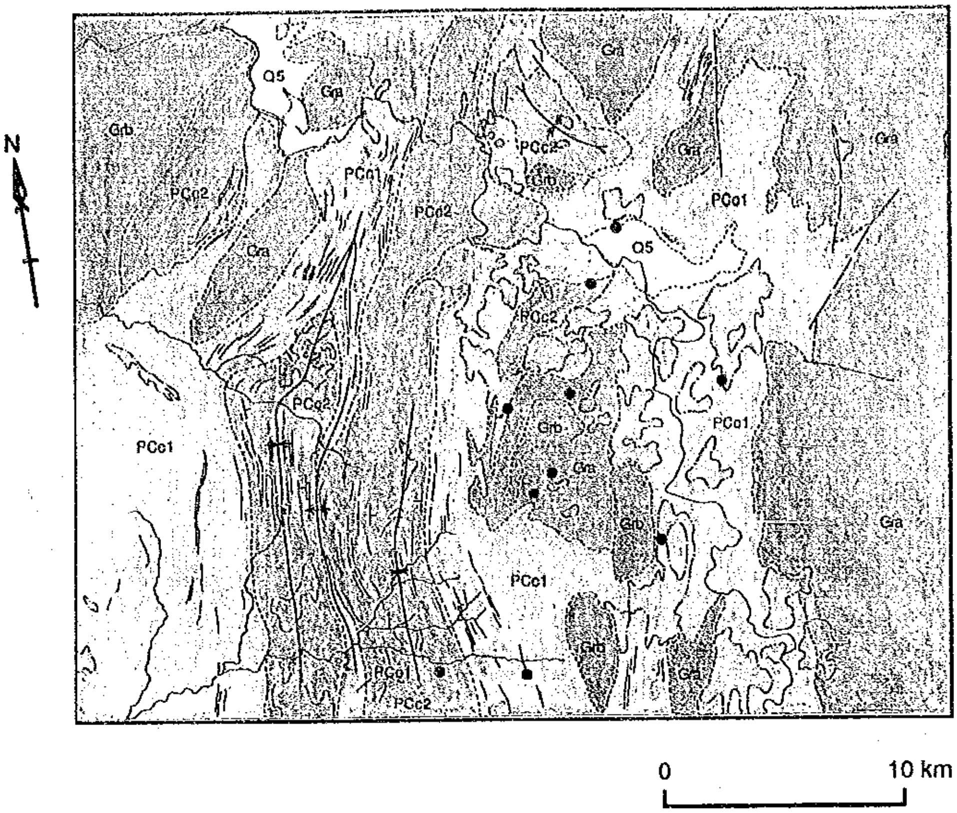


Fig.4-21 DPCA image of Tranomaro area



LEGEND

Quaternary
Q5 alluvium
Precambrian
PCc2 Antsakoaminary bed
PCc1 Tranomaro bed

Gra granitic complex
Grb concordant granite

inferred fault
syncline
anticline
dip direction
bedding trace
anomaly of TM band5/band7 ratio
uranium minaralization

Fig.4-22 Interpretation map of images of Tranomaro area

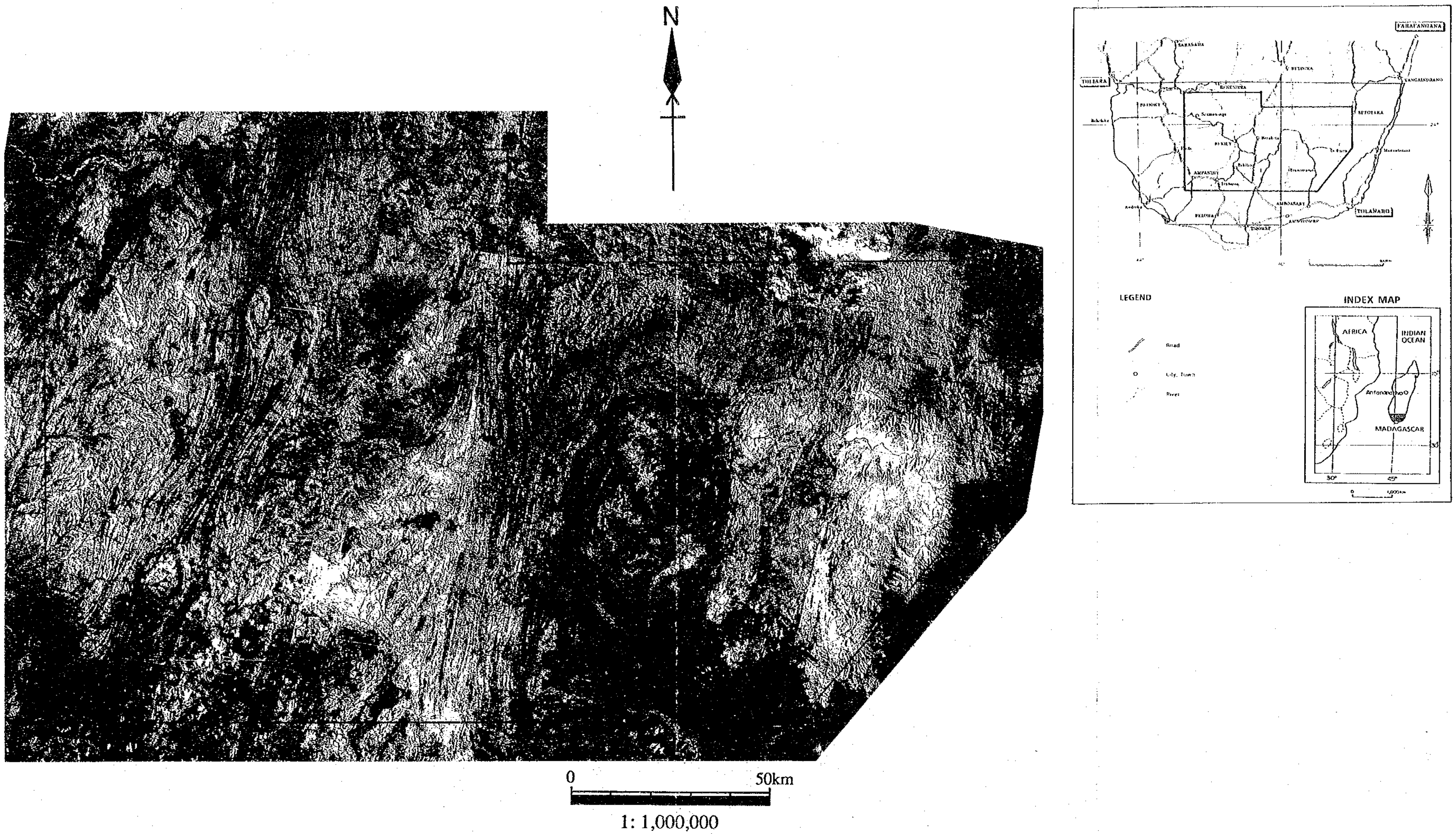


Fig.4-23 Mosaic of false color images of band 457=BGR

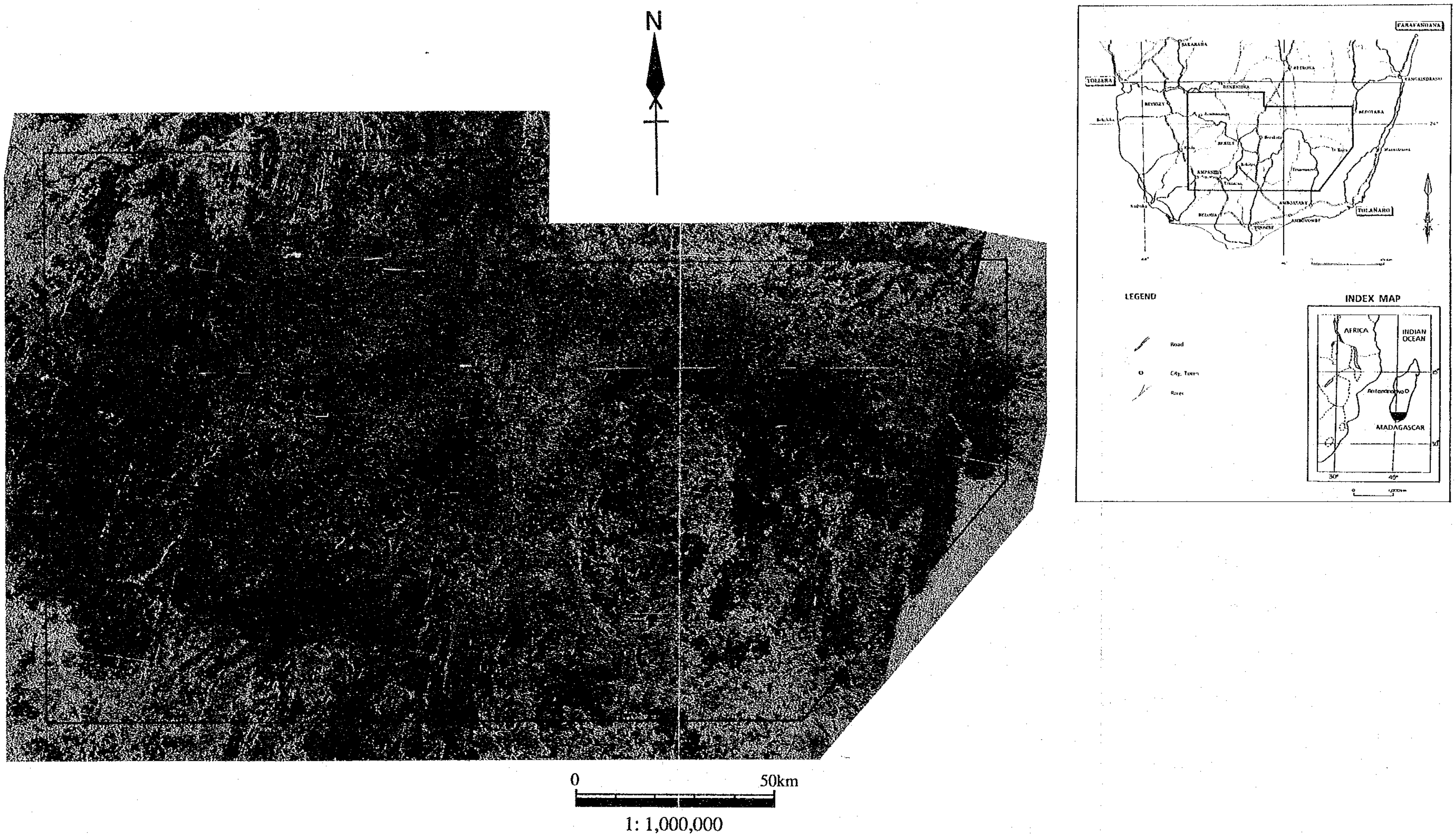
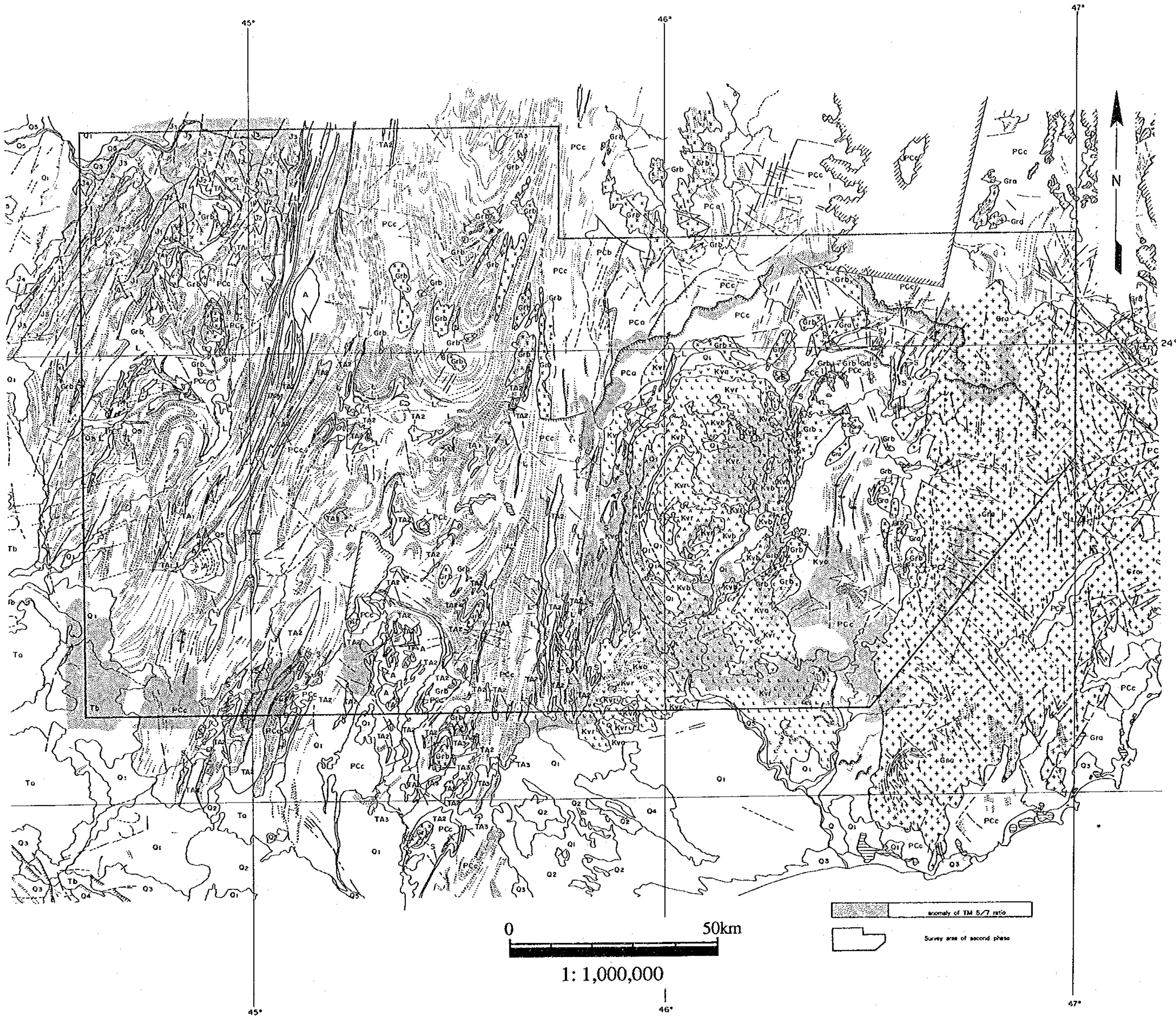
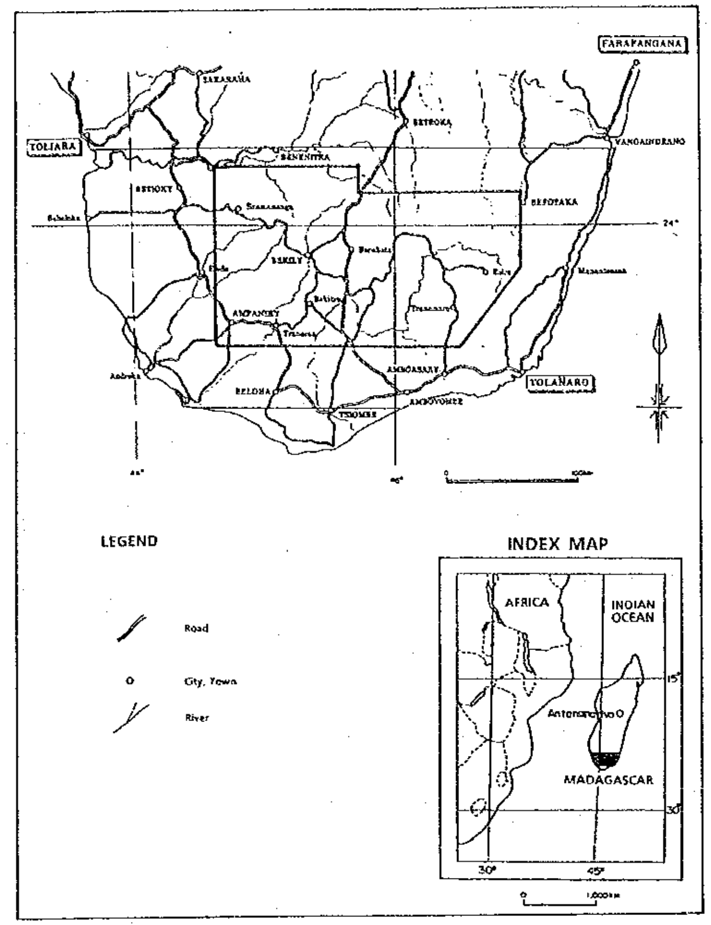


Fig.4-24　Mosaic of pseudo color images of babd5/band7 ratio





LEGEND

Interpreted units	Correlation with geologic map and rock types
Q5	alluvium
Q4	dune, alluvium
Q3	Aepyornis old dune
Q2	eluviated white sand
Q1	Carapace sand
Ta	Eocene marine facies
Tb	Eocene marine facies, Carapace sand
Tc	Eocene marine facies, Clavator Quaternary
Kvr	Cretaceous (rhyolite, dellenite, trachyte)
Kva	Cretaceous (basalt, labradorite, sakalavite)
Kvb	
Kvr	
K	Lower to Middle Cretaceous marine facies
J5	Middle to Upper Jurassic marine facies
J4	Lower Permien to Lower Triassic continental facies
J3	
J2	
J1	
PCa	Precambrian metamorphic rocks
PCb	
PCc	
Gra	Anosyennes granite
Grb	granite, migmatite
A	anorthosite
L	marble
S	quartzite
TA1	tonal anomaly
TA2	tonal anomaly
TA3	tonal anomaly
	unit boundary
	uncertain unit boundary
	bedding trace or schistosity
	strike and dip direction
	anticline with direction of plunge
	syncline with direction of plunge
	fault (barbs on downthrown side)
	inferred fault
	lineament
	drainage
	lake
	cloud cover

Fig.4-25 Geologic interpretation map of LANDSAT TM false color images

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5-1 Conclusion

Distribution of ore deposits and showings are indicated on image interpretation map in Fig.5-1 and PL.2. Following relevances between distribution of ore deposits and geological settings can be recognized from this map.

1) Copper

Copper deposits discovered in this area so far are distributed only around granite intrusion near a boundary between Precambrian and Permian to Lower Triassic in northwest end of the area including Soamanonga area. Distribution zones of Permian to Lower Triassic units are commonly coincide to positive anomalies of LANDSAT TM bands 5/7 ratio. Many copper ore deposits are also located near faults or lineaments interpreted from satellite images. Similar geological setting is recognized in the south of Soamanonga area where other granite intrusions are located.

2) Manganese and iron

Since most of manganese or iron ore deposits and showings are located in parallel to the structures of Precambrian, those deposits should be strata-bound type. Several manganese ore deposits are distributed near anorthosite located in southern area.

3) Uranothorianite

Uranothorianite ore deposits are distributed in Precambrian units near from the boundary between granite complex which forms mountains in eastern area and Precambrian units.

4) Ilmenite and zircon

Ilmenite and zircon ore deposits and showings are distributed in anorthosite of Precambrian.

5) Kaolinite

Kaolinite deposits are distributed in Eocene marine facies and Quaternary in southwestern area where anomalies of TM bands 5/7 ratio are also located.

5-2 Recommendation for phase III survey

The data analyses until this year show that the most of ore deposits and showings have been poorly explored, resulting in their poor development, though mineralizations of various kinds have been discovered in the area and the potentiality of mineral resources is high. But in economical point of view, to carry out reconnaissance survey in southern Madagascar area as phase III survey is not so effective. In order to obtain good results from Phase III survey, we should limit kinds of ore aimed and area on the basis of results of this year.

The most valuable mineral resources in southern Madagascar are gold and silver bearing copper deposit and uranothorianite. But mining operation of uranothorianite deposits had been already terminated and possibility to find new accessible deposit is low. We should carry out exploration in phase III, therefore, aiming on copper deposits with gold and silver.

Standing on these premise, we propose following surveys as the third year project.

1) Satellite image analysis

To carry out lineament analysis on Soamanonga area where copper deposits discovered and south area of that where granite intrusion is distributed. Synthetic aperture radar image or stereo SPOT image is most suitable for this purpose.

2) Existing data analysis

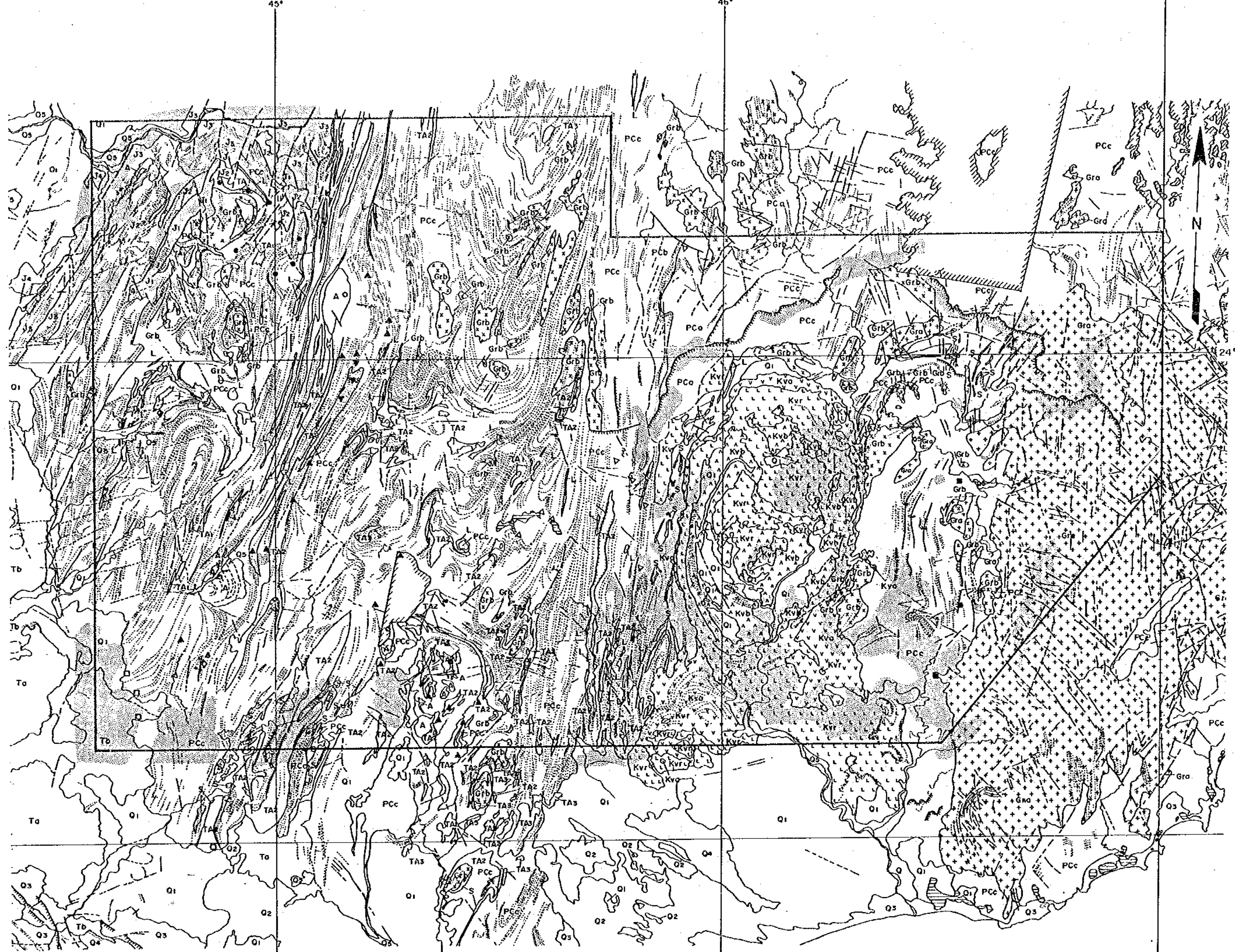
To collect and compile farther information about geology and ore deposit of Soamanonga area which can be obtained in Madagascar.

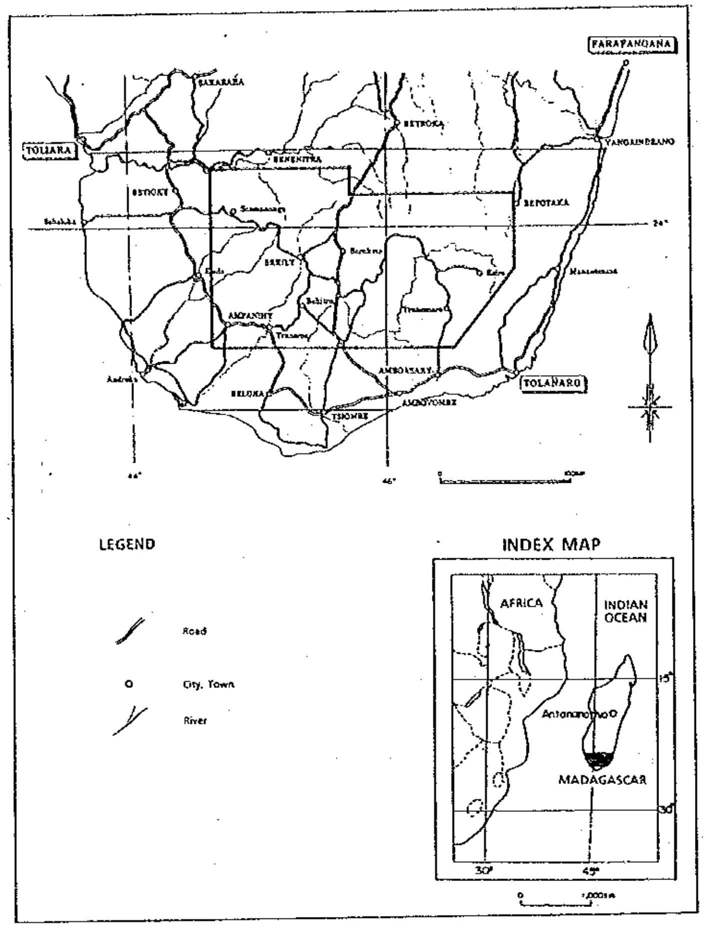
3) Geological and geochemical survey

To carry out geological and geochemical field survey to con firm the information by the satellite image analysis and existing data compilation and to extract the promising district for mineral resources.

4) Ground truth checking for anomalies of TM band5/band7 ratio

To carry out ground truth checking for anomalies of TM band5/band7 ratio which were recognized along circular collapse structure and volcanic complex in the eastern area to know how these anomalies are related with mineralizations.





Mineral Resources and Ore Showings

- ● copper
- ■ uranium
- ▲ manganese
- ▼ iron
- ○ ilmenite and zircon
- ◇ garnet
- ⊿ jasper
- ◆ corundum
- □ kaolinite
- ▽ sapphirine

0 — 50km

1: 1,000,000

LEGEND

Interpreted units	Correlation with geologic map and rock types
Q5	alluvium
Q4	dune, alluvium
Q3	Aepyornis old dune
Q2	eluviated white sand
Q1	Carapace sand
Ta	Eocene marine facies
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Tc	Eocene marine facies, Clevator Quaternery
Kvr	Cretaceous (rhyolite, dellenite, trachyte)
Kvt	Cretaceous (basalt, labradorite, sakalavite)
Kvb	
Kvc	
K	Lower to Middle Cretaceous marine facies
J5	Middle to Upper Jurassic marine facies
J4	Lower Permian to Lower Triassic continental facies
J3	
J2	
J1	
PCa	Precambrian metamorphic rocks
PCb	
PCc	
Gra	Anosyennes granite
Grb	granite, migmatite
A	anorthosite
L	marble
S	quartzite
TA1	tonal anomaly
TA2	tonal anomaly
TA3	tonal anomaly
	unit boundary
	uncertain unit boundary
	bedding trace or schistosity
	strike and dip direction
	anticline with direction of plunge
	syncline with direction of plunge
	fault (barbs on downthrown side)
	inferred fault
	lineament
	drainage
	lake
	cloud cover
	anomaly of TM 5/7 ratio
	Survey area of second phase

Fig.5-1 Integrated map of image analyses