REPORT
ON
THE GEOLOGICAL SURVEY
IN THE URUBAMBA RIVER INFERIOR AREA
OF
THE REPUBLIC OF PERU

FINAL REPORT

MARCH 2000

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

PREFACE

In response to the request of the Government of the Republic of Peru, the Japanese Government determined to conduct a series of survey related to exploration of ore deposits including analysis of the existing data and satellite image analysis, for the purpose of examining the potentialities of mineral resources in the inferior areas of the Urubamba River of the Republic of Peru, and entrusted the survey to the Japan International Cooperation agency (JICA). In view of the geological and mineralogical nature of the intended survey, the JICA commissioned the Metal Mining Agency of Japan (MMAJ) to implement the survey.

The survey was commenced in FY1998 (Phase I), which was followed by the Phase II (FY1999) or the second year's survey. During Phase II, the MMAJ organized and sent a two-man survey team to the Republic of Peru for the period from February 12 to 18, 2000. The field survey was completed as scheduled, in close collaboration with the Peruvian government agency, the Institute of Geology, Mineralogy and Metallurgy (INGEMMET) under the Ministry of Energy and Mines. This is the final report incorporating the results of surveys in Phases I and II.

We should like to take this opportunity to express our sincere gratitude to the Peruvian government agencies and persons concerned for their valuable cooperation. We are also thankful to the Japanese Ministry of Foreign Affairs, the Ministry of International Trade and Industry, the Embassy of Japan in Lima and persons concerned who have rendered assistance and support for the survey.

March, 2000

Kimio Fujita

Kimio Fujita
President
Japan International Cooperation Agency

Naohiro Tashiro

Naohiro Tashiro
President
Metal Mining Agency of Japan

THE GEOLOGICAL SURVEY
IN THE URUBAMBA RIVER INFERIOR AREA,
THE REPUBLIC OF PERU

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Summary

This report describes results of the first year's survey in FY1998(Phase I) and the second year's survey in FY1999(Phase II), implemented in the Urubamba river inferior area of the Republic of Peru, under the technical cooperation for the mineral exploration. The survey was conducted with an aim to effectively select promising zones from the extensive survey area in a short period of time, by means of satellite image analysis, existing data analysis and integrated studies of survey findings of an area upstream of the Amazon in eastern Peru, which covers the Ucayali River Basin and its upper streams, the Urubamba and the Tambo, where the metallogenic zoning has not been clarified in detail.

The Urubamba river inferior area covers an area of about 65,500 km^2, spreading over the 27 quadrangles of the 1:100,000-scale topographic map issued by the National Geographical Institute of Peru. Topographically, the area extends from the Sub-Andes in the west to the Selva in the east.

In Phase I, the analysis of the JERS-1 SAR images was conducted of the 15 quadrangles (approx. 37,500km^2 ; 72° 30' to 75° 00' W of longitude and 9° 30' S to 11° 00' S of latitude) west of the Urubamba inferior area, while the analysis of existing Data was conducted of the whole inferior area of the Urubamba. Simultaneously, the technology transfer to the INGEMMET , the Peruvian counterpart for the survey, was implemented concerning the methods of satellite image analysis.

In Phase II, the analysis of the JERS-1 SAR images was conducted of the 12 quadrangles (approx. 28,000km2 ; 70° 30' to 72° 30' W of longitude and 9° 30' to 11° 00' S of latitude) west of the Urubamba inferior area. Besides, an integral analysis was conducted on the basis of the combined results of the satellite image analysis in Phases I and II and the analysis of the existing data, in order to evaluate potentials for occurrence of ore deposits in the entire inferior areas of the Urubamba River.

The integral analysis of the survey findings revealed the following facts:

(1) Satellite image analysis using JERS-1/SAR data

a. From the analysis of drainage patterns in the Ucayali sedimentary basin, data suggesting presence of anticlinal structures or dome structures and possible presence of intrusive rocks were obtained. In the Selva zone in eastern Peru as represented by the Ucayali sedimentary basin, drainage analysis utilizing satellite images is effective for the interpretation of geology and geologic structure.

b. In the thrust zone trending NNW-SSE located in the east of the Sira range, many parallel lineaments to the thrusts, considered to reflect small faults accompanying the thrusts, and many intersecting lineaments to the thrust trending ENE-WSW, possibly reflecting tension fractures or strike-slip faults, have been extracted and those lineaments form high density zones of lineament in this zone. Generally, tension fractures are likely to be accompanied by intrusive rocks and hydrothermal activity having the intrusive rocks as the thermal source. At Agua Caliente in the northeast of the study area, there are thermal springs accompanying faults with the NE-SW trend. Therefore, the high concentration zone of lineaments in the thrust fault zone east of the Sira range is considered to be important for metallic mineral resources exploration.

(2) Analysis of the existing data

a. It was ascertained by recent geological survey conducted by INGEMMET that an intrusive rock accompanied by gold and copper ore showings is present 13 km east of Puerto Inca in the quadrangle 19-n of the 1:100,000-scale topographic map. This indication is similar with the placer gold deposit in the Negro river (located in Quad. 20-n) in structural setting, whereas the indication is considered to be a source (primary deposit) of placer gold. It may be said that to discover both primary and secondary (placer) types of ore deposit might be possible, depending on a systematic prospecting in future.

b. In the Ucayali sedimentary basin, gold and tin concentration have been reported in heavy minerals in stream sediments along the Urubamba river near Atalaya (Quad. 22-o) and Sepa (Quad. 22-p). Especially, near Sepa, panning samples of heavy minerals is reported to assay Au: 1.6 g/t, which suggests high possibility of occurrence of alluvial gold deposits.

In the light of the integral analysis referred to above, it is considered desirable that field survey aimed for discovering new ore deposits, including geochemical survey, ore showings survey and confirmation of lithofacies along the survey route, should be undertaken in the promising ore-bearing areas which follow:

- The surrounding areas of the Negro River where the known alluvial gold deposits are located.

- The area stretching from the Urubamba riverbanks including the Atalaya-Sepa zone, where alluvial gold showings are located, to the eastern part of the Sira Range west of the Ucayali, where intrusive rocks occur and high density zones of lineament have been extracted.

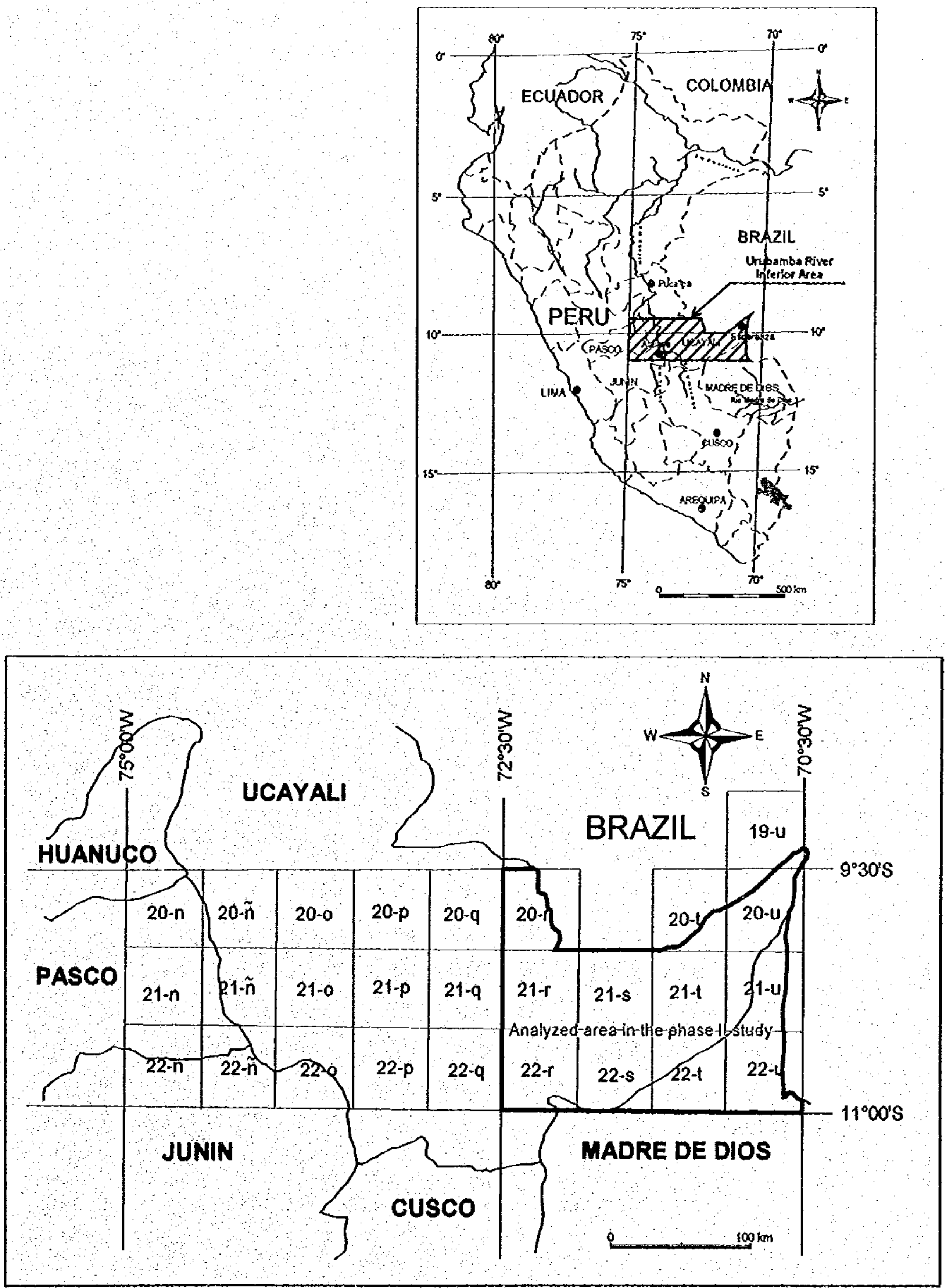


Figure 1 Location of the survey area

PART I

GENERALITIES

Chapter 1 Outline of the Survey

1-1 Antecedents and Purposes of the Survey

Peru ranks among the nations most richly endowed with underground resources. The land covers an area of 1,285,220 km^2 and its zonal distribution of the topography, geologic provinces and metallogenic provinces are nearly parallel from the Pacific coast eastward.

The metallogenic provinces in Peru consist of 1) the iron belt in the southern coastal range, 2) the copper belt in the Pacific coastal piedmont, 3) the polymetallic belt in the highlands (Sierra), 4) the polymetallic belt in the east Andes, and the zone called Selva spreading farther east of 4) in the Amazon upstream basin whose metallogenic zoning has not been fully clarified as yet. Large-scale and low-grade dissemination type gold ore deposits in massive silicified rocks have been discovered and noticed in the polymetallic belt in the northern highlands recently.

In compliance with the request of the government of Peru, the survey was conducted with an aim to effectively select promising zones from the extensive area in a short period of time, by means of satellite image analysis, existing data analysis and integrated studies of survey findings of an area upstream of the Amazon in eastern Peru, which covers the Ucayali River Basin and its upper tributaries, the Urubamba and the Tambo, where the metallogenic zoning has not been clarified in detail.

Simultaneously, it is intended to promote technology transfer to the INGEMMET - Instituto Geológico Minero y Metalúrgico, the Peruvian counterpart, concerning the methods of survey and analysis.

The survey was executed in accordance with the Scope of Work signed by the both governments on November 5, 1998.

1-2 Area and Outline of Phase I Survey

In the first fiscal year's survey, the satellite image analysis was performed on 15 quadrangles (72°30' - 75° W, 9°30' - 11° S, Figure 1) of the Urubamba river inferior area (about 65,500 km^2), designated in the Scope of Work agreed to between the JICA/MMAJ and the Ministry of Energy and Mines/INGEMMET, that consists of 27 quadrangles of 1:100,000-scale topographic maps, whilst the existing data analysis covered the whole area of the Urubamba river inferior area.

The survey was carried out in the following manner.

The satellite image processing and interpretation were conducted mainly in Japan after obtaining the JERS-1 SAR data and the 1:100,000-scale topographic map (partly in satellite map). The existing data analysis was conducted in Lima and Japan after the geological and mining information were obtained in Peru. During the survey, some parts of the JERS-1 SAR data processing and interpretation were conducted at the INGEMMET's head office in Lima, in collaboration with its engineers, in an effort to transfer of image analysis technique.

As the result of the satellite image analysis and the existing data analysis, the geologic interpretation maps and the lineament maps, as well as the list of ore deposits/mineral indications and the regional potential evaluation map, were elaborated.

1-3 Area and Outline of Phase II Survey

In Phase II, analysis of the JERS-1 SAR images was carried out of the 12 quadrangles (70° 30' to 72° 30'W of longitude and 9° 30' to 11° 00' S of latitude) in the 1:100 000 topographic map of the eastern side of the inferior area of the Urubamba River. In addition, an integral analysis incorporating the whole results of Phase I and II surveys was undertaken.

These surveys were conducted in the following manner:

The satellite image analysis was conducted in the same manner as in Phase I.

In the integral analysis, promising ore-bearing zones were extracted on the basis of the results of the analysis of existing data in Phase I and the image analysis in Phase II; and, evaluation of potentials for occurrence of deposits in the whole inferior area of the Urubamba River was implemented, for which the results of the Phase-I image analysis was referred to, as well.

1-4 Organization of the Survey Team

The members from the field survey team are listed in the Tables 1.

Table 1 Mission for the field survey

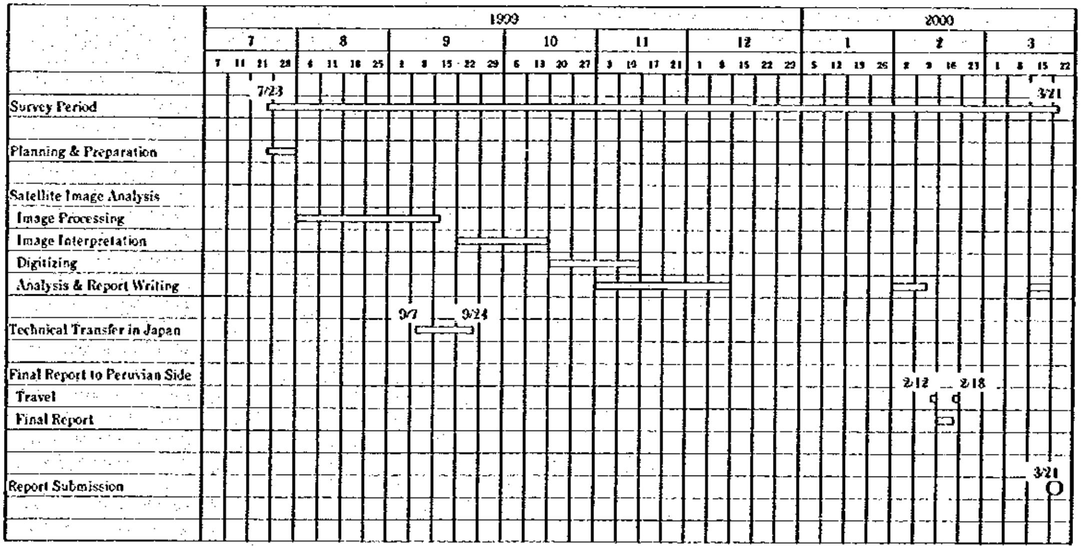
Peruvian side		*Japanese side*	
Ing. Juan Mendoza Marsano	INGEMMET	Mr. Hiroaki Kagawa	MMAJ
Ing. Hugo Rivera Mantilla	INGEMMET	Mr. Kaoru Sakogaichi	MINDECO
Ing. Oscar Palacios Moncayo	INGEMMET		
Ing. Manual Paz Maidana	INGEMMET		
Ing. José León Aparicio	INGEMMET		
Ing. Marco A. Lara Moreno	INGEMMET		

INGEMMET: Instituto Geológico Minero y Metalúrgico
MMMJ: Metal Mining Agency of Japan
MINDECO: Mitsui Mineral Development Engineering Co., Ltd.

1-5 Period and Quantity of the Survey

The survey period is indicated in Table 2.

Table 2 Study period



The quantities of the survey are indicated in Table 3.

Table 3 Quantity of the study

Survey items	*Quantities*
Satellite image analysis	12 quadrangles (the eastern potion of survey area)
Integrated analysis	The entire Urubamba river inferior area

Chapter 2 Geography of the Survey Area

2-1 Location and Transportation

The survey area expands 750 km in E-W direction, from 250 km ENE (75°W) of Lima, a capital of Peru, to the Brazilian border (70°30'W) and 170 km in N-S direction from the down stream of Urubamba river towards north, and it covers about 65,500 km^2 (Figure 1).

The main administrative divisions covered by the area are the Departments of Pasco, Ucayali and Madre de Dios, as well as the Cities of Atalaya and Esperanza, the former falling on the south end while the latter on the east end of the area. Atalaya, population 15,200, is the seat of the Atalaya District government and has the police and military stations, hotels and restaurants, etc.

Atalaya is accessible by air from Lima, via Pucallpa. It takes 1:15 hours from Lima to Pucallpa and one hour from there to Atalaya.

The transportation in the survey area is limited to either chartered small planes or small vessels. Major towns and villages have runways in nearby areas for landing of small planes.

2-2 Topography and Drainage System

The western part of the survey area topographically included in the Sub-Andes mountains adjacent east to the Cordillera Oriental of the Andes, and the eastern part included in the Selva, or the lowlands embracing the Amazon's upstream.

The Sira range, altitude 2,000 m, trending NNW-SSE, lies in the survey area at around long. 74°75' W within the Sub-Andes. A stretch from the Ucayali basin to the Brazilian border is the Selva, where flatlands, alt. 200 to 300 m, spreads out; the Ucayali river flows down along the east side of the Sira range in the NNE direction.

The main upper tributaries of the Ucayali river are the Urubamba and the Tambo river, which merge near Atalaya. The Urubamba river has its origin in the Lake Titicaca in southern Peru. By way of Cuzco and the Camisea gas field, it enters the survey area where it changes course from northwest to west to join the Ucayali. Within the survey area, tributaries such as the Inuya (from the right bank) and the Sepa (from the left bank) flow into the Urubamba river.

The northeast side of the line connecting lat. 11°S - long. 72°30' W and lat. 9°30' S - long. 75°30' W in the survey area pertains to the basin of the Purús and the Yurúa, both of which enter Brazil and run into the Amazon. Within the survey area, the Purús runs down northeastward whereas the Yurúa meanders but generally runs northward.

2-3 Climate and Vegetation

Both the Sub-Andes including the Sira range and the Selva have the rainy season roughly from November to April and the dry season from May to October. The climate in the Selva is generally hot and humid, with certain fluctuations of the atmospheric temperature in a day. The average annual temperature and precipitation in Atalaya (1934 - 1935) are 15.7℃ and 3,029.5 mm, respectively. The average monthly temperatures and precipitation are tabulated below.

Table 4 Monthly average temperature and precipitation in Atalaya (1934-1935)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Temp. (℃)	26.2	26.4	25.9	25.6	26.1	25.6	24.4	24.3	25.0	25.7	26.4	26.0
Precip. (mm)	294.0	291.4	423.4	364.4	121.2	156.2	100.0	137.4	208.9	211.1	421.1	300.0

The zonal distribution of flora in the survey area is as follows:

a) Tropical jungles (Selva)
   The flora comprises trees parasitized by orchids, vines, etc., and the lichens. As thick forests block off the sunlight, plants in the Selva tend to have leaves of gigantic sizes.
b) Evergreen trees in highlands
   Compared with the Selva, the density of trees is low due to strong wind, forest fires, fall of old trees, etc.
c) Ferns in marshlands
d) Ranges of reeds
   Reeds range along rivers and grow up to 10 m tall.
e) Forest zones on river terraces outside of floodplains
f) Forests of trees and shrubs on fords and playas of large rivers such as the Ucayali.

The greater part of the survey area falls within either the a) or the b) categories.

Chapter 3 Existing Geological Information of the Survey Area

3-1 Outline of Existing Geological Information

In the highlands of the Cordillera Oriental, precious metals, copper, etc. were mined since the Pre-Inca times. During the Colonial period, prospecting, though not systematic, was carried out so vigorously in search of precious metals that gold and silver production increased tremendously. The survey area spreads over the transitional region of the Sub-Andes toward the Selva, which has imposed enormous constraints on transportation and has retarded progress of comprehensive geological studies on the area.

Information on the Selva is very limited due to the transportation difficulties. Geological and mineral surveys were initiated in the 1950's by petroleum companies, which included interpretation of aerial photographs and satellite images and surface geological reconnaissance based on the former. Petróleos del Perú ("Petroperú"), Oficina Nacional de Evaluación de Recursos Naturales ("ONERN," presently Instituto Nacional de Recursos Naturales - "INRENA") have been involved in the survey activities. ONERN's natural resources surveys were carried out along the Urubamba, the Tambo and the Alta Yurna upstream, situated in the central part of the survey area.

As regards surveys of placer deposits undertaken by private firms, the Banco Minero del Perú is engaged in the systematic assessment in accordance with the Presidential Decree D.S. No. 010-74-EM/DGM, which is purported to protect small miners and also to ensure effective utilization of natural resources. Occurrence of placer gold deposits in the survey area is not clearly defined.

As for geologic maps of the survey area, INGEMMET has elaborated 1:100,000 and 1: 200,000-scale maps, while a geologic map at 1: 2,000,000-scale was also compiled by the same Institute in 1995.

3-2 Outline of Geology

According to the geologic map of Peru(INGEMMET, 1995, Figure 2), the highlands in the survey area is underlain by Precambrian metamorphic rocks as the basement; sedimentary rocks of the Ordovician Contaya Formation and of the Carboniferous to early Permian Ambo, Tarma and Copacabana Formations; sandstone of Permian to Triassic Ene Formation; limestone of the Triassic Pucara Formation; sandstone of the late Jurassic Sarayaquillo Formation; sandstone of the Oriente Group; marl and limestone of the Chonta Formation, sandstone of the Vivian Formation and shale of the Cachiyaku-Huchpayacu Formation of the Cretaceous age; and, sandstone-shale-slate of the Paleogene Huayabamba Group. The intrusive rocks are granites presumably of Permian age and monzodiorite correlated with the Paleogene age. The Selva zone, stretching from the Ucayali-Urubamba basin to the Brazilian border, is underlain by sandstone-conglomerate of the Neogene Ipururo Formation, gravel of the Ucayali Formation and the Madre de Dios Formation of Pleistocene age, and the Alluvium.

3-3 Outline of Known Ore Deposits

According to the metallogenic studies of Peru, the Cordillera Oriental belongs to the East Andes metallogenic province underlain by the Paleozoic to Cenozoic units, where occurrence of gold-silver bearing copper, lead and zinc ore deposits and prospects, as well as mineral indications of rare metals such as tin, tungsten, nickel and cobalt, has been known. In the highlands of the survey area, which is contiguous with the East Andes metallogenic province, however, only some placer gold deposits are known. Small-scale placer gold mining is still ongoing in the Negro river, a tributary of the Pachitea river at the western piedmont of the Sira range in the west of the survey area.

In the Selva region, whose geologic-metallogenic provinces are not yet clearly defined, Tertiary to Quaternary sedimentary rocks are widespread on the west margin of the Brazilian shield. Ore deposits in the Selva are petroleum, gas and placer gold deposits. Petroleum and gas deposits were investigated by Petroperu and oil companies from 1950's to 70's but the activities have since declined. In March, 1983, the Camisea gas field was discovered 50 km south of the survey area by oil companies including Shell. Small mining of placer gold deposits in Tertiary-Quaternary stream sediments are said to be conducted in the Ucayali and Urubamba river in the central part of the survey area.

ERA	SYSTEM	SERIES	SYMBOL
CENOZOIC	QUATERNARY	HOLOCENE	Qh
		PLEISTOCENE	Qpl
	NEOGENE	PLIOCENE	Nc
		MIOCENE	
	PALEOGENE	OLIGOCENE	
		EOCENE	P
		PALEOCENE	
MESOZOIC	CRETACEOUS	UPPER	Ks
		LOWER	
	JURASSIC	UPPER	Js
		LOWER	[illegible]
	TRIASSIC	UPPER	
PALAEOZOIC UPPER	PERMIAN	UPPER	[illegible]
		LOWER	[illegible]
	CARBONIFEROUS	UPPER	
		LOWER	
	DEVONIAN		
PALAEOZOIC LOWER	SILURIAN		[illegible]
	ORDOVICIAN		
	CAMBRIAN		

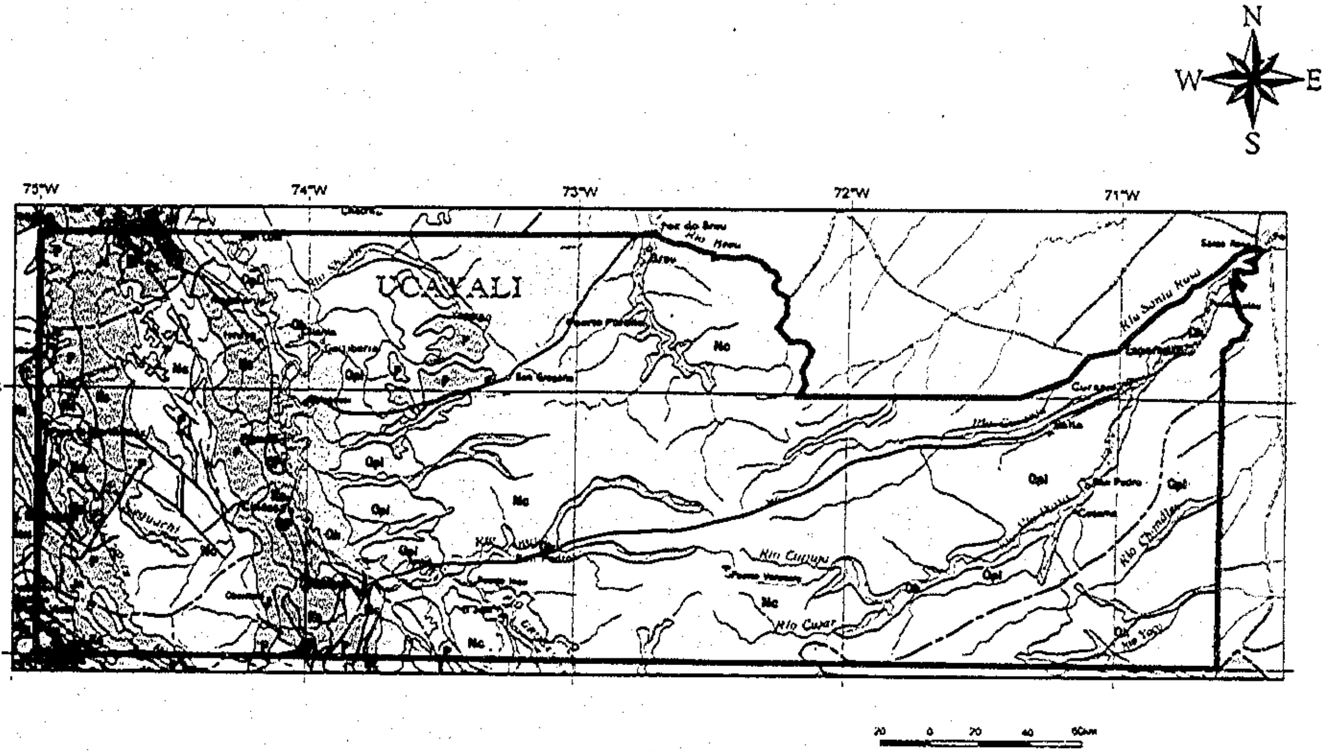


Figure 2 Geology of the survey area

ERA		SYSTEM	SERIES	SYMBOL
CENOZOIC		QUATERNARY	HOLOCENE	Qh
			PLEISTOCENE	Qpl
		NEOGENE	PLIOCENE	Nc
			MIOCENE	
		PALEOGENE	OLIGOCENE	P
			EOCENE	
			PALEOCENE	
MESOZOIC		CRETACEOUS	UPPER	Ks
			LOWER	
		JURASSIC	UPPER	Js
			LOWER	TrJi
		TRIASSIC	UPPER	
PALAEOZOIC	UPPER	PERMIAN	UPPER	Ps
			LOWER	CP
		CARBONIFEROUS	UPPER	
			LOWER	
		DEVONIAN		
	LOWER	SILURIAN		Pi
		ORDOVICIAN		
		CAMBRIAN		

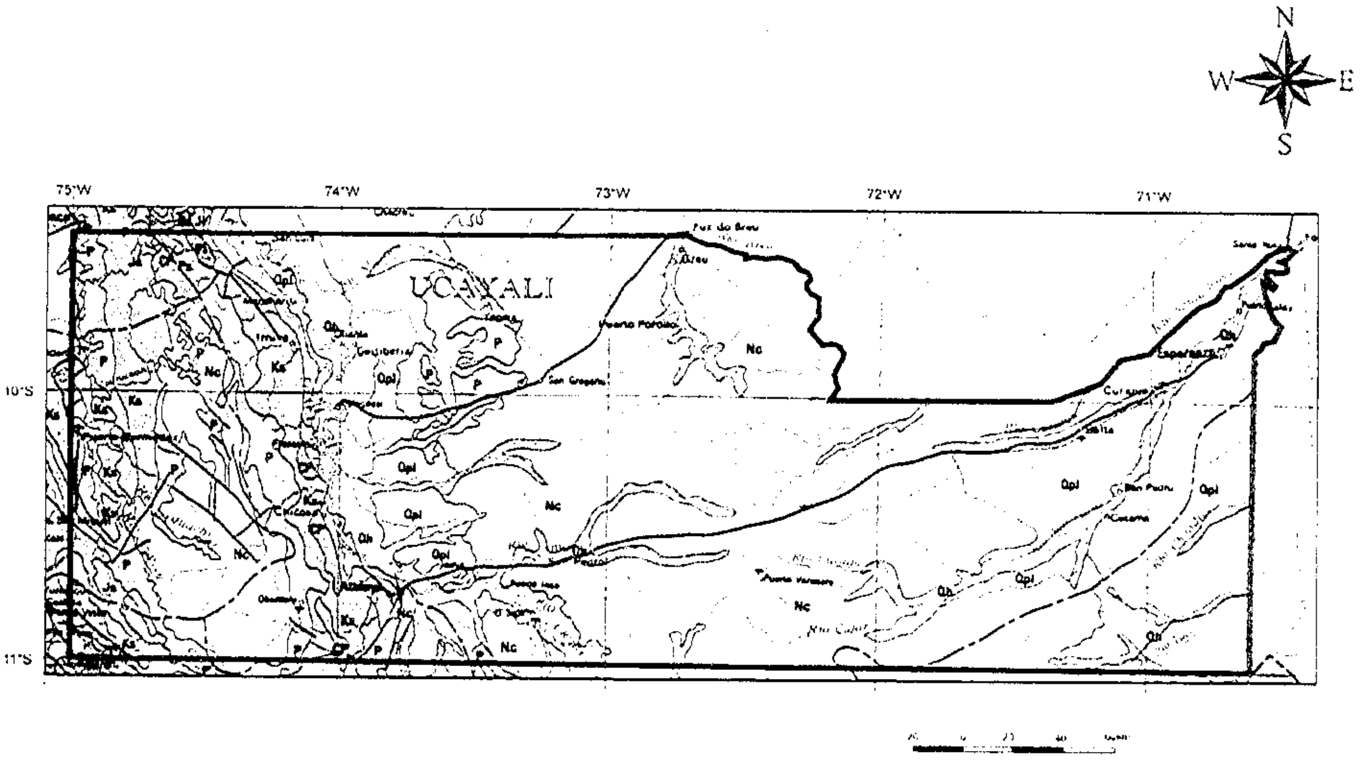


Figure 2 Geology of the survey area

PART II

PARTICULARS

Chapter 1 Satellite Image Analysis

1-1 Purpose of the Image Analysis

The image analysis is intended to produce geologic interpretation maps and lineament maps of JERS-1 SAR images, to examine the regional geologic structure of the survey area, thereby providing basic data for the evaluation of mineral resource potentials in the survey area. The geologic interpretation map elaborated in Phase II covers the 12 quadrangles, 20 to 22-r, 21 to 22-s, 20 to 22-t and 19 to 22-u -- a quadrangle represents a square with a side equivalent to 30' of the latitude and longitude -- of the 1:100,000-scale topographic map of the Instituto Geográfico Nacional (IGN).

1-2 Image processing

1-2-1 Data used

Data used for the analysis are 18 scenes(No.1 to No.18 in Table 5) of JERS-1 SAR data in PhaseII, and 24 scenes(No.14 to No.37) of JERS-1 SAR data in Phase I as indicated in Table 5 and Figure 3.

1-2-2 Procedures for image processing

12 quadrangles of image for interpretation have been processed in the following procedure.

1) Loading data: All the JERS-1 SAR data provided by ERSDAC with EXABITE tapes are copied to the hard disk (HD) connected to an engineering work station (EWS).

2) Separation of header information and image data: From transferred data files, the header files including positioning information of images are extracted and saved in text format. Image data files are converted to the standard image database format of PCI/EASI-PACE, an image processing software developed by PCI of Canada.

3) Bit number conversion: 16-bit image data is converted into 8-bit image data.

4) Histogram normalization: Simultaneously with bit conversion, histograms of digital numbers are normalized.

5) Image rotation: Images are rotated clockwise by 90 degrees.

6) Antenna pattern correction: In order to re-correct the characteristics of antenna pattern of JERS-1 SAR data that an average DN gradually decreases from far range to near range, averages in the azimuth direction of each scene are calculated, and each pixel value is divided by the average.

7) Coordinates assignment: UTM coordinates of the corners of each scene are read from header information and assigned.

8) Preparing image database for mosaicking: PCI image database file that has UTM coordinate system for making mosaic image is prepared.

9) Pasting of a center image: A scene near the center of mosaicking area is pasted to the database file for making mosaic images. The pasting position is determined by the information in header file.

10) Mosaicking: Mosaicking is starting from images adjoining the center image. Several dozens of tie-points are collected in an overlapping of images and geometric correction is applied so that the residual error may be reduced to less than 1 pixel. Simultaneously, the brightness is adjusted so that difference in DN value between two images is reduced.

11) Speckle noise reduction: The Enhanced Lee filter (7 x 7) is employed to reduce speckle noises.

12) Extraction of sub-scene images: From the prepared mosaic image, 12 sub-scene images are made so as to correspond to the quadrangles of the 1:100,000-scale topographic map. Geometric correction is again applied so that the sub-scene images may exactly be overlaid on the topographic map, for which confluence and bending points of rivers, etc. are utilized as ground control points for georeferance.

13) Annotation: Each sub-scene image is annotated with the UTM coordinates, scale bars and titles.

14) File format conversion: The format of image files is converted from PCI database format to TIFF format, so as to fit to the output device used.

15) Alteration of image resolution: Resolution of each sub-scene image is adjusted so as to output at 300 dpi and at a 1:100,000-scale. As the result, the spatial resolution of images was altered to about 8.45 m per pixel.

16) Hard copy output: Two sets of the 12 sub-scene images, totaling 24 images, were output at a 1 :100,000-scale by digital photo-printer (Lightjet 5000). One set was used for the analysis in Japan while the other was prepared as the final product.

1-3 Image Interpretation, Preparation of GIS Data Set and Lineament Analysis

The output images at a scale of 1:100,000 of the respective quadrangles prepared in the above mentioned procedures were used for image interpretation, and the obtained results were digitized and output at a 1:100,000-scale. The digitized lineament map was used as the input data for computation of the lineament density, whereby the lineament densities of the entire survey area was mapped.

The work was done in the following procedures:

1) Geologic interpretation: Geologic units were classified using surface texture and topographic features on images as criteria. Correlation between the photo-geologic characteristics of each geologic unit and the existing geologic map was tabulated, using the geologic map of the INGEMMET (1995) as reference.

2) Interpretation of lineament and geologic structure: Elements of geologic structure such as faults, lineaments and folding structures were delineated, for which micro-topography was considered.

3) Digitizing: Scanned data of hand-written geologic interpretation maps and lineament maps was loaded on a computer as raster data, which, in turn, was converted to vector data. Figures such as polygons and lines included in the vector data were manually retouched on monitor screen and attributes such as names of structures were added to respective figures. For the series of processing, the TNT Mips, a GIS software developed by Micro Image Inc., USA was employed.

4) Preparation of GIS data set: Geographic data such as drainage systems, lakes, roads, villages and national borders in Arc/Info "Coverage" format provided by INGEMMET was loaded to TNT Mips database file and overlaid on the interpretation results, then annotated with legends, scale, quadrangle numbers, names, etc. and, in turn, output by a color plotter at 1:100,000-scale. The output maps were two types: a geologic interpretation map and a lineament map. From the respective vector data of geologic boundaries, faults, geologic structures and lineaments included in the database files of TNT Mips, the files in the "Export" format (E00 format) of Arc/Info were prepared as the final products.

5) Lineament density map: Lineament data prepared of each quadrangle were integrated into a MOSS (Map Overlay and Statistical System) format -- one of the GIS standard format by USGS --, and lineament densities (m/km^2) of 2 km x 2 km grids were calculated by obtaining a cumulative extension of all faults and lineaments included in each grids. For the computation, an analysis tool developed by MINDECO was employed. The lineament density distribution in the entire area of analysis was output at a 1:1,000,000-scale and rose diagrams of each quadrangle

were simultaneously produced.

Table 5 Satellite data used

No.	*Date*	*sat.*	*Sensor*	*Path*	*row*	*lati.*	*long.*	*Qual.*	*station*
1	1996/06/11	J1	SAR	430	319	-11.04	-70.21	G	FAIS
2	1996/06/12	J1	SAR	431	316	-9.17	-70.30	G	FAIS
3	1996/06/12	J1	SAR	431	317	-9.52	-70.39	G	FAIS
4	1996/06/12	J1	SAR	431	318	-10.28	-70.46	G	FAIS
5	1996/06/12	J1	SAR	431	319	-11.04	-70.54	G	FAIS
6	1996/06/13	J1	SAR	432	316	-9.17	-71.03	G	FAIS
7	1996/06/13	J1	SAR	432	317	-9.52	-71.12	G	FAIS
8	1996/06/13	J1	SAR	432	318	-10.28	-71.19	G	FAIS
9	1996/06/13	J1	SAR	432	319	-11.04	-71.27	G	FAIS
10	1996/06/14	J1	SAR	433	316	-9.17	-71.35	G	HEOC
11	1996/06/14	J1	SAR	433	317	-9.53	-71.43	G	HEOC
12	1996/06/14	J1	SAR	433	318	-10.29	-71.51	G	HEOC
13	1996/06/14	J1	SAR	433	319	-11.04	-71.59	G	HEOC
14	1996/06/15	J1	SAR	434	316	-9.17	-72.08	G	HEOC
15	1996/06/15	J1	SAR	434	317	-9.52	-72.17	G	HEOC
16	1996/06/15	J1	SAR	434	318	-10.28	-72.25	G	HEOC
17	1996/06/15	J1	SAR	434	319	-11.04	-72.33	G	HEOC
18	1996/06/16	J1	SAR	435	316	-9.17	-72.41	G	HEOC
19	1996/06/16	J1	SAR	435	317	-9.52	-72.50	G	HEOC
20	1996/06/16	J1	SAR	435	318	-10.28	-72.58	G	HEOC
21	1996/06/16	J1	SAR	435	319	-11.04	-73.06	G	HEOC
22	1996/06/17	J1	SAR	436	316	-9.17	-73.14	G	FAIS
23	1996/06/17	J1	SAR	436	317	-9.52	-73.23	G	FAIS
24	1996/06/17	J1	SAR	436	318	-10.28	-73.31	G	FAIS
25	1996/06/17	J1	SAR	436	319	-11.04	-73.39	G	FAIS
26	1993/03/18	J1	SAR	437	316	-9.17	-73.49	G	FAIS
27	1993/03/18	J1	SAR	437	317	-9.53	-73.49	G	FAIS
28	1993/03/18	J1	SAR	437	318	-10.28	-74.05	G	FAIS
29	1993/03/18	J1	SAR	437	319	-11.04	-74.12	G	FAIS
30	1996/06/19	J1	SAR	438	316	-9.15	-74.19	G	HEOC
31	1996/06/19	J1	SAR	438	317	-9.51	-74.27	G	HEOC
32	1996/06/19	J1	SAR	438	318	-10.27	-74.35	G	HEOC
33	1996/06/19	J1	SAR	438	319	-11.04	-74.43	G	HEOC
34	1994/08/30	J1	SAR	439	316	-9.16	-74.54	G	FAIS
35	1994/08/30	J1	SAR	439	317	-9.52	-75.02	G	FAIS
36	1994/08/30	J1	SAR	439	318	-10.28	-75.10	G	FAIS
37	1994/08/30	J1	SAR	439	319	-11.04	-75.18	G	FAIS

J1: JERS-1, SAR: synthetic aperture radar, G: good, HEOC: Hatoyama, FAIS: Fairbanks

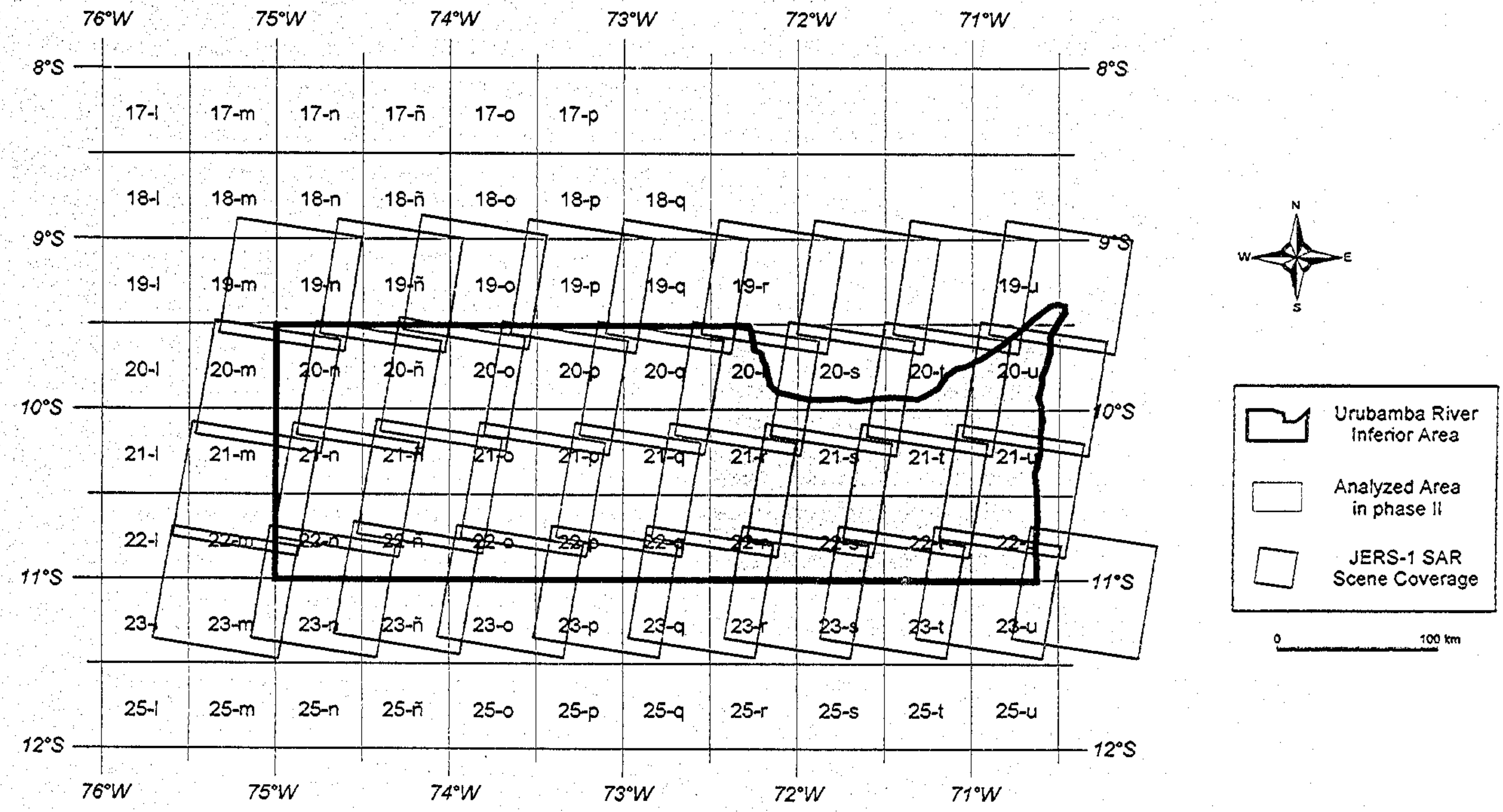


Figure 3 Coverage of Satellite Data Used

1-4 Results of the Image Analysis

1-4-1 Geologic Interpretation

For interpretation of the images, the existing 1:2,000,000-scale geologic map (INGEMMET, 1995) was used as reference. For geologic interpretation, the geologic map was referred to, while new information obtained through the image interpretation was considered as much as possible. For symbols of geologic units, the geologic ages in the map were referred to, and serial numbers were assigned, in ascending order, to the units sub-divided by the interpretation. SAR image of the entire analyzed area is shown in Figure 4, its geologic interpretation in Figure 5 and lineament map with in Figure 6. Table 6 indicates correlation between geologic units of the interpretation map and those of the existing geologic maps.

Characteristic of the respective geologic units are summarized in the following paragraphs:

(1) Unit Q4
The unit develops along main streams. Countless meandering tracks of old channels are seen. The surface texture of the unit looks smooth and flat. Tones ranging from very light to very dark (in the old channels) are mingled. (Alluvium)

(2) Unit Q3
The unit develops along main streams, forming lower terrace surfaces. Though flat, the surface plane appears to be of rough (sandy) texture. The tone is somewhat dark. (Quaternary terrace deposit)

(3) Unit Q2
The unit forms middle terrace surfaces. Sand grain-like or patch-like, light speckles are seen while the tone is somewhat light. The surface texture looks coarse. (Quaternary terrace deposit)

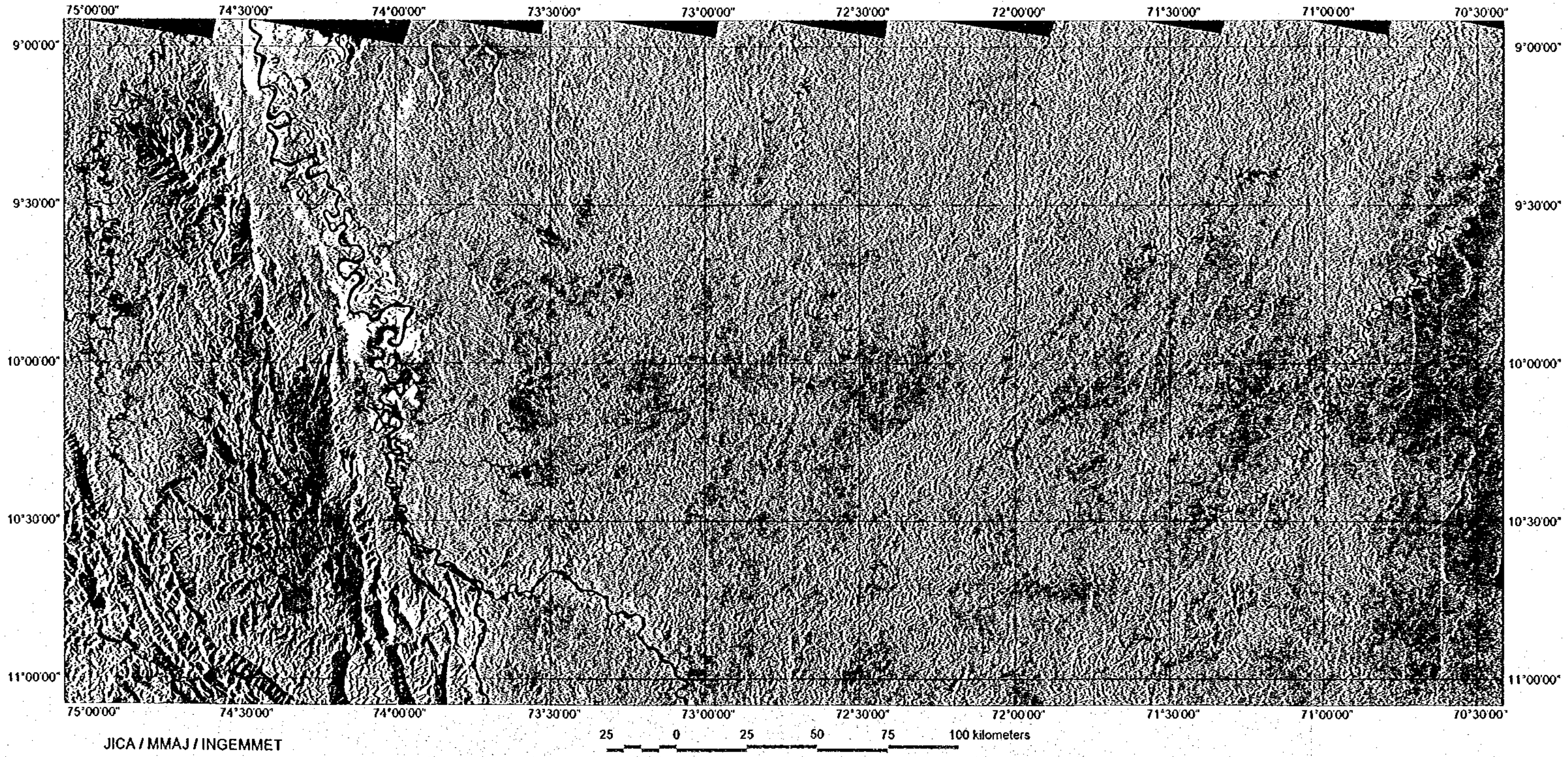
(4) Unit Q1
The unit forms higher terrace surfaces. It has light and somewhat large-sized patchwork pattern, while the surface texture looks somewhat coarse. (Quaternary terrace deposit)

(5) Unit T4
The area of occurrence is very limited. The unit is a thin bed covering the flat parts of the Unit T2. Although it has rather smooth surface texture, patchwork-like or pinnate drainage pattern is slightly seen. (Upper Tertiary)

(6) Unit T3
The Tertiary unit is seen overlying the Unit T2 in the east part of the interpretation

Table 6 List of geologic units

No.	Units	Units in Geologic Maps after INGEMMET		Inferred Lithology and Geologic Age
		1:2,000,000 (1995)	1:100,000 (1997-1998)	
1	Q4	Qh	Qhal	sand, gravel (Quaternary)
2	Q3		NQ-u	lower terrace deposit (Quaternary)
3	Q2	Qpl		middle terrace deposit (Quaternary)
4	Q1		N-i∼NQ-u	higher terrace deposit (Quaternary)
5	T4	Nc		sandstone, conglomerate (Late Tertiary)
6	T3			sandstone, conglomerate (Middle Tertiary)
7	T2			
8	T1	P		sandstone, conglomerate (Early Tertiary)
9	K4	Ks	Ksh, Ksv, Ks-ch	sedimentary rocks (Late Cretaceous)
10	K3		Ki-o	sedimentary rocks (Middle Cretaceous)
11	K2		Pi-c	
12	K1			sedimentary rocks (Late Jurassic to Early Cretaceous)
13	J	Js	Js-s, TrJi-pu, PsR-e	sedimentary rocks (Jurassic)
14	P	Pi-c	Pe-cm	sedimentary rocks (Permian)



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JERS-1 SAR MOSAIC IMAGE OF THE URUBAMBA RIVER INFERIOR AREA, PERU
THE GEOLOGICAL SURVEY IN THE URUBAMBA RIVER INFERIOR AREA OF THE REPUBLIC OF PERU

Figure 4 JERS-1 SAR Mosaic Image

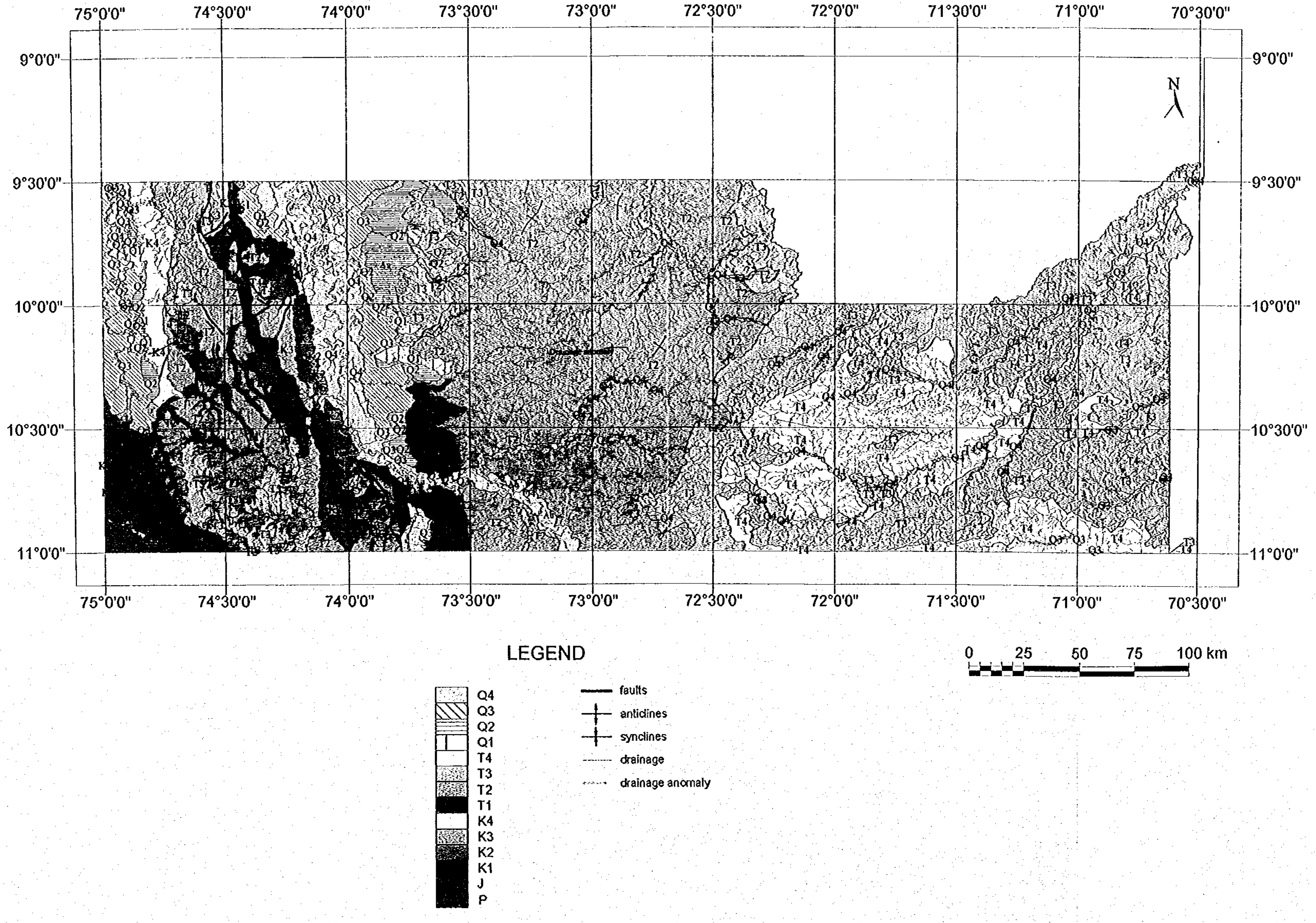

Figure 5 JERS-1 SAR Geologic Interpretation Map

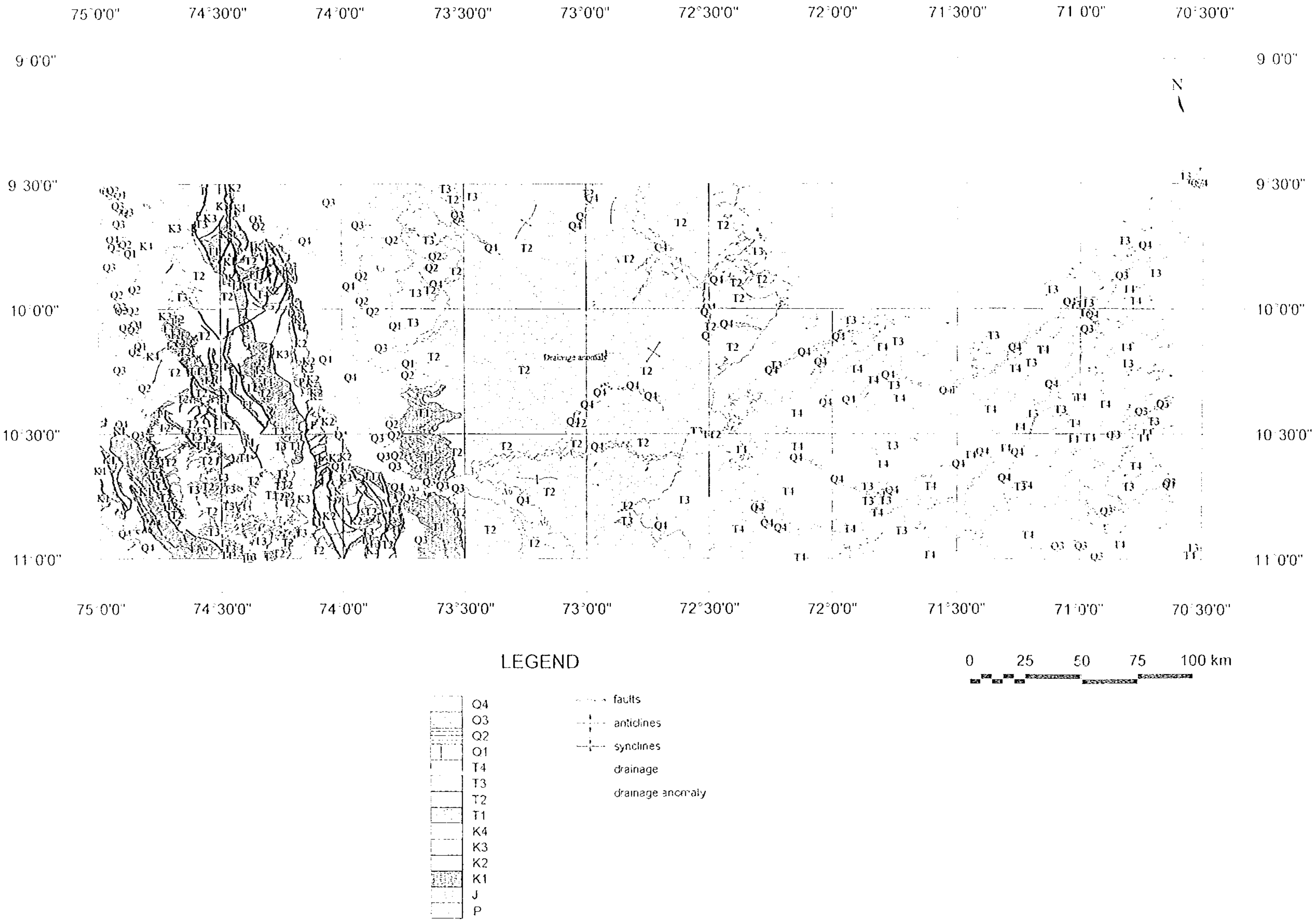

Figure 5 JERS-1 SAR Geologic Interpretation Map

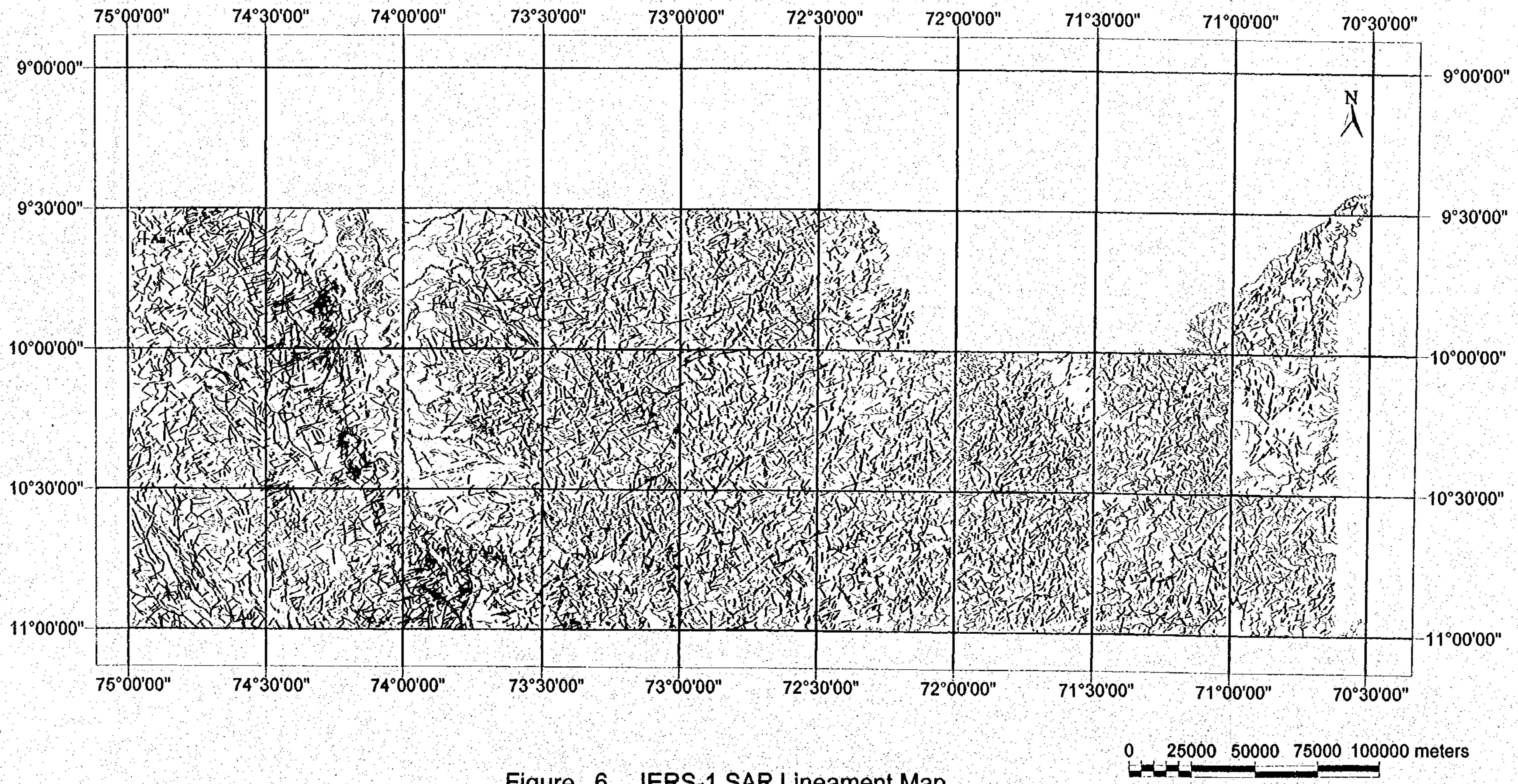

Figure 6 JERS-1 SAR Lineament Map