NO.

REPORT
ON
THE GEOLOGICAL SURVEY
IN THE SOUTH AREA
OF
THE REPUBLIC OF PERU

FINAL REPORT

March 2002

THE JAPAN INTERNATIONAL COOPERATION AGENCY
THE METAL MINING AGENCY OF JAPAN

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PREFACE

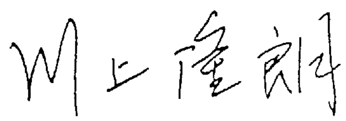
In response to the request of the Government of the Republic of Peru, the Japanese Government determined to conduct a series of survey related to exploration of ore deposits including analyses of the existing geologic information and the satellite images, for the purpose of examining the potentialities of mineral resources in the southern areas of the Republic, 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 FY2001 (Phase Ⅱ). In Phase Ⅱ, the MMAJ sent a specialist to Peru for the period from October 18 to November 21, 2001, for the analyses of existing geologic information and satellite images. The work was completed as scheduled, in close collaboration with the Peruvian government agencies concerned, especially the INGEMMET of the Ministry of Energy and Mines.

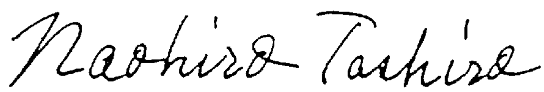
This Report consolidates the results of surveys in Phase Ⅱ.

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 Economy, Trade and Industry, the Embassy of Japan in Peru and persons concerned who have rendered assistance and support for the survey.

March, 2002



Takao Kawakami
President
Japan International Cooperation Agency



Naohiro Tashiro
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Report on the Mineral Exploration in the South of the Republic of Peru
(Phase II)

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Summary

This Report consolidates the results of the regional survey of mineral resources in Phase II (FY2001, the second fiscal year of the survey) implemented in southern areas of the Republic of Peru, under the Technical Cooperation for the Mineral Exploration. The subject survey was aimed to effectively extract areas of interest from the extensive survey area in a short period of time, by means of satellite image analysis, analysis of the existing geologic information and integrated analysis of survey findings of the subject area.

The Phase-II survey covers an area of approximately 35,000 km2, which extends over 13 quadrangles of the 1:100 000-scale topographic map published by the IGN-Instituto Geográfico Nacional of the Republic of Peru. Topographically, the subject area spreads over from the Coastal Range along the Pacific coast, the Pre-Andes Plateau to the Cordillera Occidental, where the climate varies widely from coastal arid climate to cold high land climate. Regarding the geological setup, the subject area is underlain concordantly with the Andean trend by Precambrian metamorphic rocks up to Quaternary sediments.

Conducted for the survey were analysis of the JERS-1 SAR images and the LANDSAT TM images, as well as analysis of the existing geologic information. Simultaneously with the survey, transfer of technology concerning satellite image analysis to the host nation's organization, INGEMMET-Instituto Geológico, Minero y Metalúrgico of the Peru's Ministry of Energy and Mines was implemented. Results of the satellite image analysis and the analysis of existing information were integrated and analyzed for evaluation of potentiality for occurrence of ore deposits in the entire survey area, whereby areas of interest have been extracted.

The survey findings are summarized as follows.

(1) Satellite image analysis

Locations of occurrence of vein-type deposits are unrelated with the lineament density; however, if such deposits are situated in the Cenozoic, they are always accompanied by anomalies of the iron oxide index or clay minerals index. In case of manto-type deposits, satellite image analysis gives no indications whatsoever. As regards dissemination-type and network-type deposits, it has been concluded that occurrences of these deposits are located in the vicinity of relative elevations of lineament density, and such locations are always accompanied by anomalies, though weak, of either the iron oxide index or the clay minerals index.

(2) Analysis of existing geologic information

The survey area is underlain by Precambrian to Quaternary sedimentary and volcanic rocks extending in the NW-SE trend, which have been intruded by intrusive rocks of the Ordovician to Silurian, late Cretaceous, end of Cretaceous to beginning of Paleogene, and Neogene.

Ore indications and deposits at 260 localities in the survey area have been described, 238 or over 90% of which are accounted for by vein-type ore deposits, followed by manto-type (at 15 localities), dissemination-type (4) and stockwork-type (3). Vein-type gold and gold-copper deposits have been described at 172 localities. The country rocks of these deposits range broadly from Precambrian to Quaternary, which suggests that mineralization possibly,

took place several times, but no concrete studies have so far been undertaken in this respect. Vein-type copper, copper-iron and iron ore deposits lie in Mesozoic sedimentary and volcanic rocks. Especially, iron vein deposits are confined in the Coastal Batholith of the Patap Super-unit. Regading the manto-type deposits, those of copper are described at 12 localities in the Marcona Formation of the Precambrian age, while an iron-copper deposit and a copper-gold deposit are respectively found in the Guaneros Formation and the Seraj Formation, both Mesozoic. Dissemination-type and network-type are indications of gold, gold-copper and copper-molybdenum deposits and lie in the Coastal Batholith and the Cenozoic unit. Gold occurs in Cenozoic volcanic rocks, which suggests possible occurrence of epithermal gold deposits and porphyry copper deposits

(3) Integrated analysis and recommendations

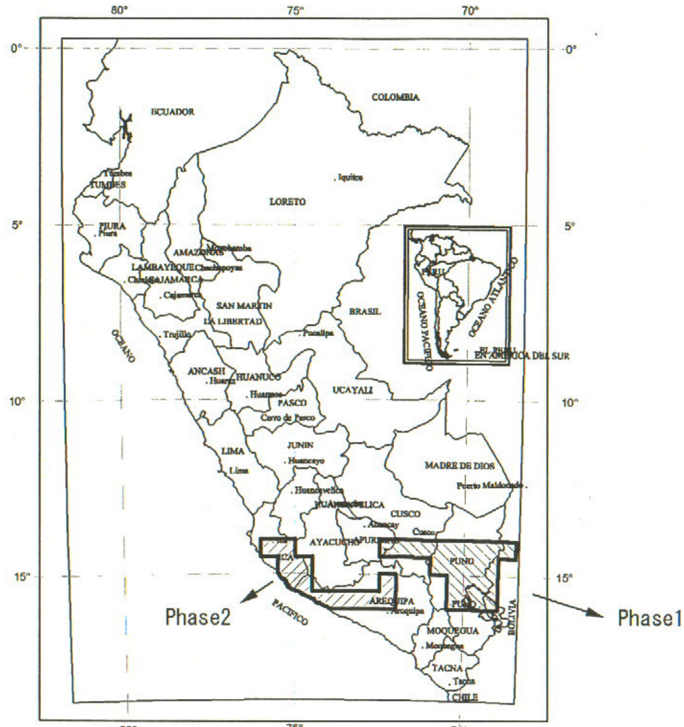
The integrated analysis was conducted on the basis of the findings of the satellite image analysis and the analysis of existing geologic information, which resulted in extraction of the five areas of interest indicated below. Areas of interest have been selected on the following criteria:

(i) Anomalies in the iron-oxide index extracted by satellite image analysis
(ii) Anomalies in the clay minerals index
(iii) Lineament density
(iv) Distribution of Miocene to Pleistocene volcanic rocks and the Guaneros Formation of the Mesozoic age, as well as distribution of the Yura Group and the Casma Group
(v) Distribution of the known mineral indications.

Following are the selected areas:

1. Nazca Area
2. Tocota Area
3. Chuquibamba Area
4. Andagua Area
5. Orcopampa Area

In order to verify the geology and mineralization in these areas, geological reconnaissance survey should desirably be implemented.



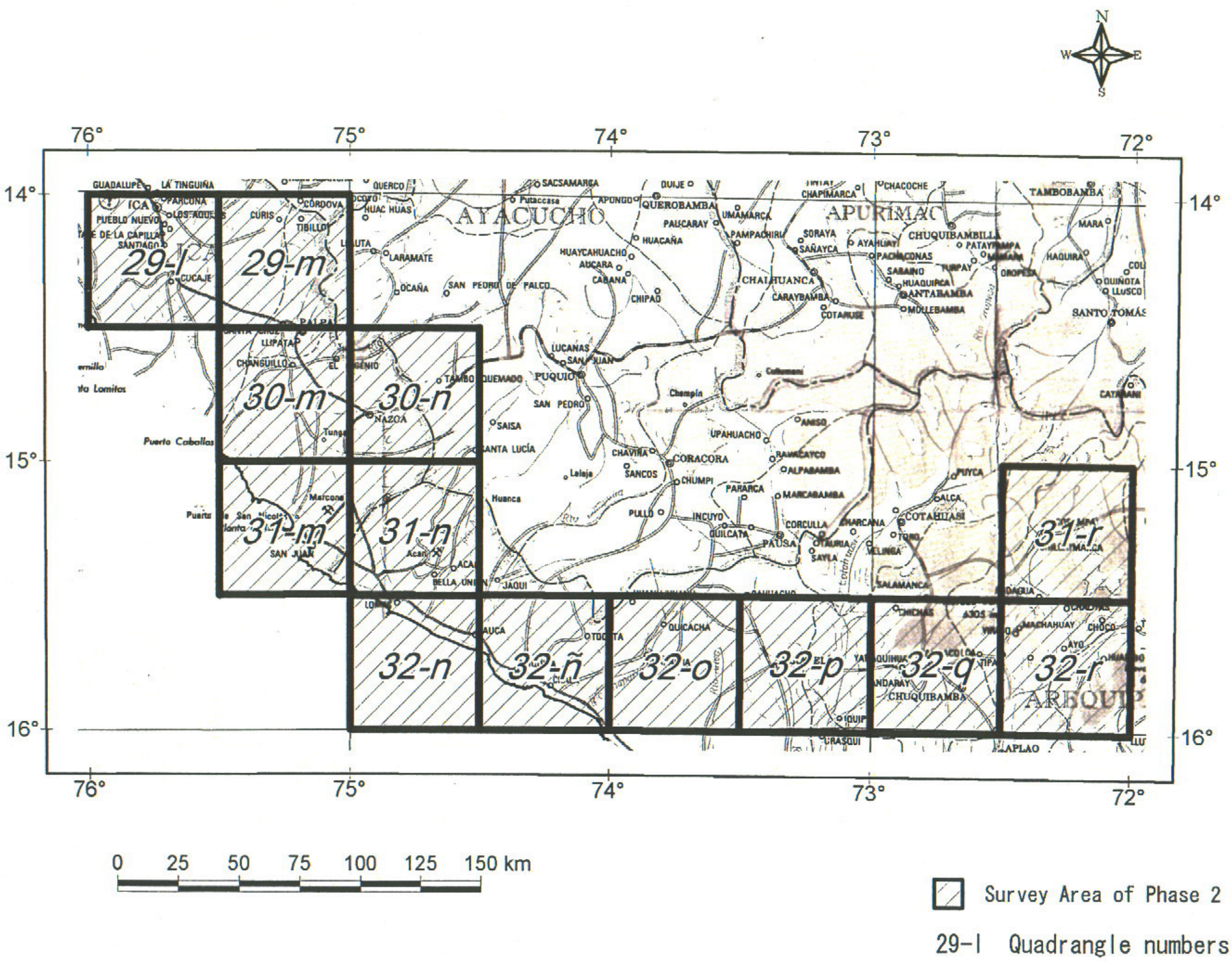


Fig. 1 Location Map of the Survey Area

PART I GENERALITIES

Chapter１ Outline of Survey

1-1 Antecedents and Purpose of Survey

The mining is one of the critical basic industries of Peru. The nation's production and export of metallic mineral products in 2000 reached 3.3 and 3 billion dollars respectively, and of which accounts for 45.9% of her total export value. The national territory of Peru is 1,285,220 km2 in area. The topography, geologic units and metallogenic provinces all extend from the Pacific side to the east, in parallel belts trending NW-SE.
The metallogenic provinces can be roughly classified into the iron metallogenic sub-province in the Coastal Cordillera, the vein-type and porphyry copper-type metallogenic sub-province on the Pacific-side slopes of the Cordillera Occidental, the vein-type Au-Zn-Pb sub-province in the volcanic rock zones in the Cordillera Occidental.
The survey area, situated between lat. 14° and 16° S and between long. 72° and 76° W, topographically consists of the Coastal Cordillera, the Pre-andean Plain and the Cordillera Occidental. In view of the relationship with the mentioned metallogenic provinces, occurrence of iron ore deposits can be expected mainly in the Cordillera Coastal and in the Pre-andean Plain and in the Cordillera Occidental, small occurrences of Au and Au/Cu vein type deposits is already well known. However, any systematic survey and investigation have not been conducted to date in the subject area.
The Peruvian government requested the Japanese government to execute collaborative survey aimed to investigate potentialities for occurrence of ore deposits, thereby helping promote mining investments in the subject area. In response to the request, the Japanese government sent a mission to Peru for the period from October 14 to 21, 2000, for consultation on the survey plan, and the Scope of Work was signed on October 18, 2000.
The subject survey is intended to extract effectively and speedily interesting areas where occurrence of ore deposits is anticipated, by integrating the findings of the satellite image analysis and the analysis of existing geologic information to be conducted in compliance with the Scope of Work. Simultaneously, it is intended to transfer the technology concerning the methods of survey and analysis to the INGEMMET - Instituto Geológico Minero y Metalúrgico, the Peruvian counterpart for the survey.

1-2 Scope of Phase-II Survey and Outline of Survey Work

The survey area as agreed upon in the Scope of Work is an area covered by the 30 sheets of the 1:100 000-scale topographic map. In Phase II, the analyses of the JERS-1 SAR and LANDSAT TM images and of existing geologic information were conducted of the eastern part of the survey area, between lat.14° and 16° S, and between long. 72° and 76° W, which extends over the 13 quadrangles. (Fig.1)
The survey was implemented in the following procedures.
Data processing and interpretation of satellite images were carried out mainly in Japan after the JERS-1 SAR and LANDSAT TM data and the 1:100 000 topographic map were obtained. While the analysis of existing geologic information was carried out in Japan and Peru after the geological information, and the mines and mineral indications data were made available in Peru. During the survey in Peru, a part of the image interpretation and analysis work were practiced jointly with the INGEMMET engineers at their office in Lima, with a view to transferring the image analysis technology.
The geologic interpretation map, lineament map, spectral anomaly distribution map, list of the known mineral indications, integrated analysis map, etc. were prepared based upon the analyses of satellite images and existing information.

1-3 Organization of Missions

Organization of the missions for the survey is shown in Table 1.

Table 1 Mission for the field survey

Peruvian side		Japanese side	
Ing. Julio Sanchez Ing. Enzzo Viaccava	INGEMMET	Mr. Hiroshi Hama	MINDECO

MINDECO; Mitsui Mineral Development Engineering Co. Ltd.

1-4 Period and Quantities of Survey

The period for survey is shown in Table 2, and quantities of the survey work are indicated in Table 3.

Table 2 Survey Period

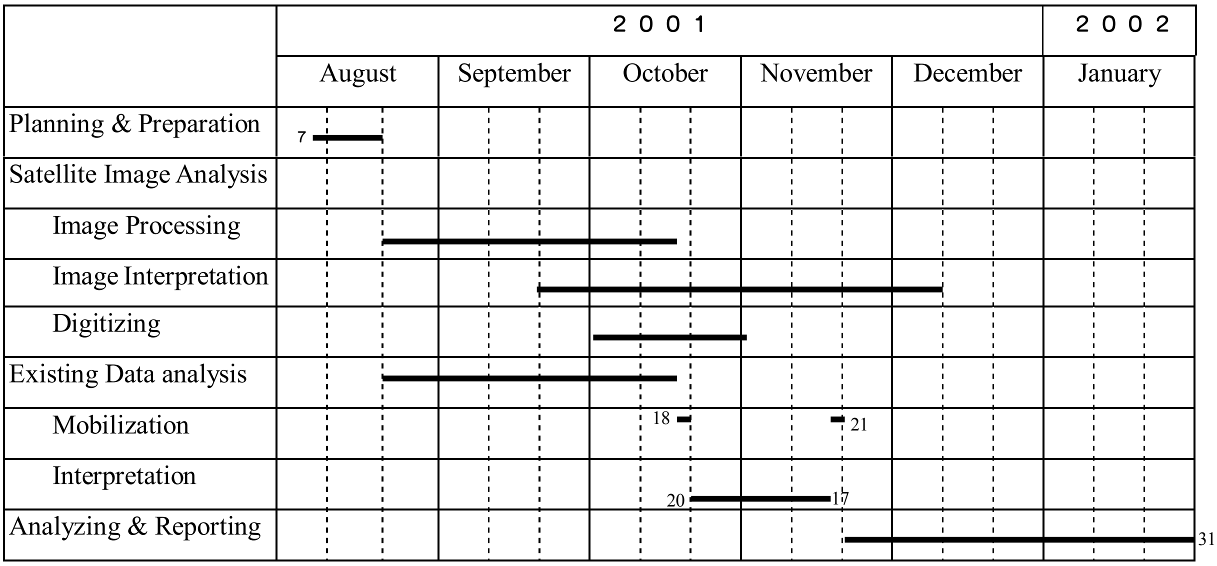


Table 3 Quantities of the Survey

Survey items	Quantities
Satellite Image Analysis	Survey area 35,000km^2
Existing Data Analysis	Survey area 35,000km^2

Satellite data used

JERS-1 SAR ; 21 scenes

LANDSAT TM ; 6 scenes

Chapter 2 Geography of the Survey Area

2-1 Location and Transportation

The survey area, situated southeast of Lima, extends over about 400 km between long. 72° W and 76° W and about 200 km between lat.14° S and 16° S, covering an area of 35,000km^2 (Fig.1).
The survey area extends over the four Departments; Ica, Huancavelica, Ayacucho and Arequipa from north to south. The major cities in the area are Ica and Nazca in the northwest, and in the eastern area, only scatter small villages.
The survey area is accessible from Lima by car through the Panamerican highway, and by air, from Lima to Arequipa, the second largest city in Peru, then drive up north to the survey area is also available. Driving Lima to Ica takes about three hours and flying Lima to Arequipa takes about one hour.

2-2 Topography and Drainage Pattern

The topography of the survey area is divided, from west to east, into the Coastal Cordillera, the Pre-Andean Plain and the Cordillera Occidental. The Coastal Cordillera is a characteristic topographic feature in the southern Peru, which is not extended from the central Peru to the north besides near the border of Ecuador. The Pre-andean Plain is a synonym of the Coastal Plain in the northern Peru, which is extended northward to Ecuador and southward to Chile. The Cordillera Occidental is the same to the Andes Mountains.
The Coastal Cordillera in the westernmost of the survey area is composed of metamorphic rocks of the Precambrian and the lower Paleozoic systems, forming mountains of 500m to 1000m above sea level. The Pre-andean Plain is about 80km in width and 500m to 700m above sea level. The Cordillera Occidental in the survey area mainly belongs to the Western Slop of them. In the eastern apart of the survey area, however, peneplains at an altitude of about 4500m, so called the Altiplano, spreads out. Mountain glaciers are also scattered. The highest mountain in the area is the Nevado Coropuna with an altitude of 6300m. A volcanic cone belt occurs in southwestern edge of the Altiplano, where active volcanoes are also situated.
All the major rivers in the survey area stream to the Pacific Ocean, with trending NE-SW to N-S. The rivers are generally short, which flow fast in the west slope of the Cordillera Occidental and then flow of rivers become gentle in the Pre-andean Plain, and sometimes flow into underground during dry season.

2-3 Climate and Vegetation

The climate in the subject area is entirely different between a coastal area and a mountain area. The climate in the mountain area belongs to the cold highland climate type. A temperature is rather monotonous all the year round. The rainy season is from November to March and the dry season from April to October. The annual precipitation is around 900 mm and the annual average atmospheric temperature is around 10℃, although the diurnal range of temperature is so wide especially in the dry season when the maximum temperature occasionally exceeds 20 ℃ while the minimum temperature goes below minus 10℃. The vegetation is characterized by a needle grass locally called 'paja' and short shrubbery along the rivers.
On the contrary, in the coastal area including the Pre-andean Plain, from November to March is dry season and from April to October is rainy season. In the coastal area, rainfall is very rare even in rainy season, the most of the land, therefore, is covered by rocky desert with scattered bush except for oasis located in riverbed.

Chapter 3 Existing Geologic Information of the Survey Area

3-1 Outline of Existing Geologic Information

In the survey area, precious metals, copper, etc. had been mined since the Pre-Inca times. Then, during the Colonial period, mineral prospecting was conducted vigorously, if not systematically, in search of precious metals; and, huge amounts of gold and silver were produced.

Modern geologic survey was commenced in the 1950's by the SERGEOMIN, the former organization of the INGEMMET. The national geologic map at a scale of 1:1 000 000 of the whole of Peru was compiled by the INGEMMET in 1977. A series of geologic mapping of the scale of 1:100 000 was implemented from 1960, and completed in 1999 which covers entire Peru with 503 sheets of geologic map. A geologic map of the scale 1:1 000 000 was also published in 1999. Local geologic survey and study on the mineral deposits have been conducted by the INGEMMET, Banco Minero del Perú, Universidad Nacional San Antonio Abad del Cuzco, and also by private mining companies.

In accordance with completion of publishing the geologic map series, the study of the mineral resources of Peru (Estudio de los Recursos Minerales del Perú) in consideration of strtigrafical correlation and adjusttment between the above mentioned geologic map sheets was started in 2000. The study was begun from southern Peru, covering an area of 2° latitude in every year. The report of the first zone (Franja No.1) which covers between latitude 18° and 16° S, was published in 2000. The second zone, which covers between lat. 16° and 14° S, is presently investigated and the report is scheduled to be published at the end of 2001.

The whole survey area is covered by the following published geologic map series of the INGEMMET; Vol. 30, 34, 37, 46, 47, 50 and 53. For the area of the volcanics in the east of the survey area, there is a report on geothermal resources between Caylloma and Puquio in the southern Peru (INGEMMET, 1998).

Regarding the general geology, ore deposits and metallogenic provinces in the survey area, a number of researches and studies have been elaborated by various authors, such as Bellido, E. et al.(1972) on the general conditions for metallogenic provinces in Peru; Ponzoni, E.(1980) on the metallogenesis of Peru; Chacon, N. et al.(1995) on the metallogenic provinces-guidelines for prospecting of metallic ore deposits; Steinmuller, K.(1999) on the metallogenic provinces, models for genesis, prospecting and ambience; etc.

3-2 Outline of Geology

Precambrian metamorphic rocks forming geologic basement of Peru, sedimentary and volcanic rocks of Paleozoic to Quaternary age are distributed in the survey area with extending in the NW-SE direction. They are intruded by the San Nicolas Batholith of Ordovician to Silurian, the Coastal Batholith of late Cretaceous to early Paleogene, the Bella Union Complex of late Cretaceous and andesitic intrusives of early Neogene (Fig.2).

The geologic setting of the subject area is basically parallel to the Andean trend (NW-SE). Precambrian basement is located in the southwest of the area and the younger geologic units are sequentially distributed toward northeast. As a characteristic geologic structure the Abancay Deflection (strike of formation changes NW-SE to ENE-WSW to NW-SE) is located in the north of the survey area. A similar small-scaled bending structure conformable to the Abancay Deflection was observed in the east of the survey area. The folding structure in the area is also conformable to this structure. Regarding to faulting, a strike fault formed by compressive stress is conformable to the Deflection structure and a cross fault formed by tension stress strikes NE-SW, oblique to the strike fault, are observed.

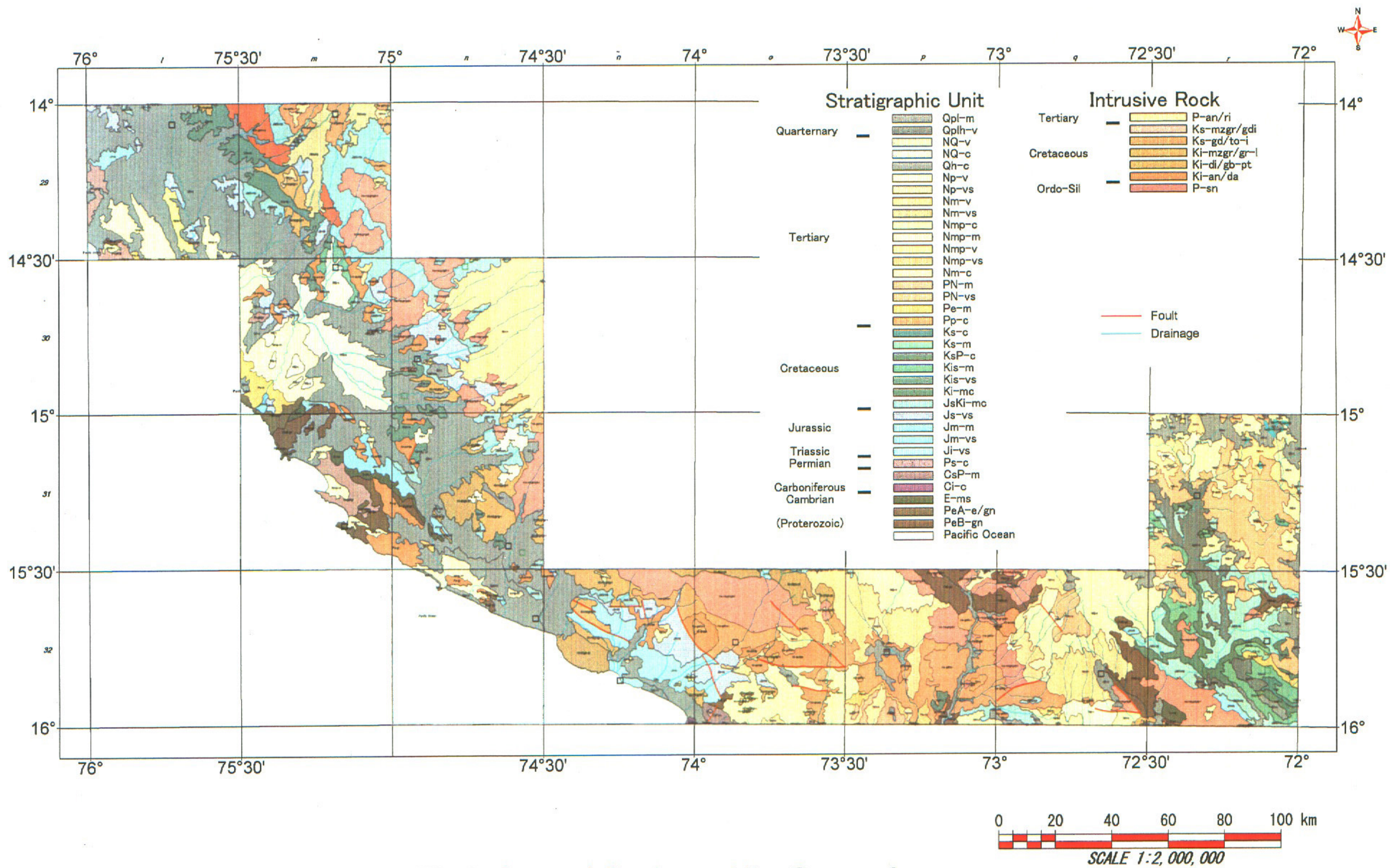


Fig.2 General Geology of the Survey Area

3-3 Outline of Ore Deposits and Indications

In the survey area, 260 ore deposits and/or mineral showings (herein after called showings) are known to occur. Among them, vein type showings is 238, correspond to over 90 percents of all showings. Then manto type showings (15), disseminated type showings (4), stockwork type showings (3) are known.

Among the vein type showings, number of Au vein and Au-Cu vein is 172 showings, corresponding to over 70 percents of all vein type showings, that clearly indicate the character of this area, since Ica-Nazca area is known to have been actively mined for gold by small-scaled operation. Host rocks of the showings are variable from Precambrian metamorphic to Quaternary volcanic rocks. The scale of Au vein type showings is several decasentimetres in width and several hundreds meters in length. The grade of Au sometimes shows the order of 100g/ton that indicate the character of veins in this area is small in scale and high in grade.

Cu vein are recognized 56 showings. Host rocks of these veins are Mesozoic sedimentary and intrusive rocks. The scale of Cu vein type showings is similar to that of Au vein or little wider in some case, though the average width is less than 1 meter. Ore minerals are mainly oxide copper, when arrived at secondary enrichment zone in operation, high grade copper ore has been produced.

Fe vein type showings occur in the Acari Diorite (the Patap Super unit of the Coastal Batholith). The scale of vein is 1 to 40m in width and 200 to 1500m in length.

The manto type showings are mainly composed of Fe ore deposits of the Marcona mine that is the only producer of iron ore in Peru. Ore deposits are conformably embedded in limestone and dolomite of the Cambrian Marcona Formation, and limestone and calcareous sandstone of the Jurassic Guaneros Formation. There is a similarity in mineral assemblage between Fe manto type showings and Fe vein type showings, though the only difference is host rocks.

Presence of a small-scale manto type Cu-Au showings is known in calcareous sandstone of the Cretaceous Seraj Formation.

All disseminated type and stockwork type showings are under investigation or in some case investigation was suspended. The host rocks are the Linga Super unit and the Incahuasi Super unit of the Coastal Batholith, the Tacaza Group of Neogene and the Barroso Group of Pleistocene. Three types ore, Au, Au-Cu and Cu-Mo, are known to occur, then showings of epithermal gold deposits and porphyry copper deposits is expected to exist.