REPORT ON THE COOPERATIVE MINERAL EXPLORATION IN THE KHUZDAR AREA OF BALUCHISTAN THE ISLAMIC REPUBLIC OF PAKISTAN PHASE II OCTOBER 1988 JAPAN INTERNATIONAL COOPERATION AGENCY METAL MINING AGENCY OF JAPAN

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JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

NO. 34

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PREFACE

In response to the request of the Government of the Islamic Republic of Pakistan, the Japanese Government decided to conduct Mineral Exploration in Khuzdar Area and entrusted the survey to Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ).

The JICA and MMAJ sent to the Islamic Republic of Pakistan a survey team headed by Mr.T.Ichinose from November 16, 1987 to August 16, 1988.

The team exchanged views with the officials concerned of the Government of the Islamic Republic of Pakistan and conducted field survey in the Khuzdar area. After the team returned to Japan, further studies were made and the present report has been prepared. We hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

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

October 1988

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

Junichiro Sato

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President
Metal Mining Agency of Japan

SUMMARY

This report discusses the results of the second phase cooperative mineral exploration in the Khuzdar District in the Islamic Republic of Pakistan. The aim of the survey is to clarify the mineral deposits and the mineral potential of the area by geological survey, geochemical prospecting and drilling.

In the second phase, geological and geochemical survey was carried out in the Northern Khuzdar District situated adjacent to the first phase area (hereafter we call the first phase area as 'Southern Khuzdar District'). Drilling survey was also carried out in the Surmai area for promising zone of lead-zinc sulfide which were delineated by the first phase survey. The filed survey was performed from November 1987 to August 1988.

Outline of the survey results is as follows:

(1) Northern Khuzdar District

The Jurassic limestone of the area rconcerned are those of Early Jurassic Shirinab Formation and they are divided into three members; Spingwar Member consisting of calcareous sandstone, Loralai Member consisting of alternation of limestone and shale, and Anjira Member, in ascending order. The Shirinab Formation is distributed in eight areas and the formation strikes in east-west direction gently protruding northward. The members constituting this formation shows complex structure with anticlines and synclines, their axes trending to the direction of the formation.

The mineral showings in the first and second phase areas are distributed around the ophiolite zone in the southwestern part of the Southern Khuzdar District in the Surmai～Sekran Zone. The Northern Khuzdar District lies to the north, outside, of the zone and mineral showings were not observed.

The geochemical prospecting did not reveal promising anomalies in the Northern Khuzdar District. Comprehensive study of geochemical data of

both phases showed that the promising lead-zinc anomalous zones were all in the Surmai~Sekran Zone and its vicinity.

Thus, it is concluded that the potential for mineral deposit occurrence in the Northern Khuzdar District is very low.

(2) Surmai Area

Drilling survey was carried out for mineralization of Surmai I and Surmai Ⅲ,which were delineated by the first phase survey. By the drilling, the geological units between Loralai Member Unit-I and the overlying Anjira Member Unit-I were investigated. The major units of this zone are limestone and shale with 0.2~10 m thickness of individual alternating beds. These beds dip westward at 60°~70° with gentle folding. The central part is transected by steeply westward dipping normal fault with 300~400 m displacement.

Mineralized zones of lead and zinc sulfides considered to be of Mississippi Valley type were confirmed by five drill holes MJP-2~6 aimed at the lower parts of the oxide outcrops. The only hole which did not intercept a mineralized zone was MJP-1. The mineralization consists of disseminated powdery to granular sphalerite and galena in limestone, and siderite and calcite vein~veinlets which transects the zone. The mineralized horizon confirmed by drilling belong to Loralai Member Unit-Ⅱ and can be divided into three horizons A,B,C in descending order.

The most promising mineralized zone confirmed by drilling in Surmai-I is the A horizon of MJP-3, between 169.1 m and 172.9 m (approximately 180 m below surface), it is 3.8 m wide with Pb+Zn 5.11 %. Also, the promising mineralization in Surmai-Ⅲ is in two parts in A horizon of MJP-6, 168.5~172.4 m and 185.6~188.1 m (approximately 140 m below the surface). They are 3.9 m wide with Pb+Zn 9.60 % and 2.5 m wide with Pb+Zn 6.87 %.

The mineralization in A horizon of both Surmai-I and Ⅲ is promising in both grade and size, there is a strong possibility of this zone being fully developed. Those in B and C horizons are of smaller scale and appear to lack continuity, but since there are high-grade parts, we conclude that they warrant further prospecting. It is recommended, to drill the vicinity of the ore deposits during the third phase in order to assess the scope and grade of the sulfide mineralization which have been confirmed during the present work.

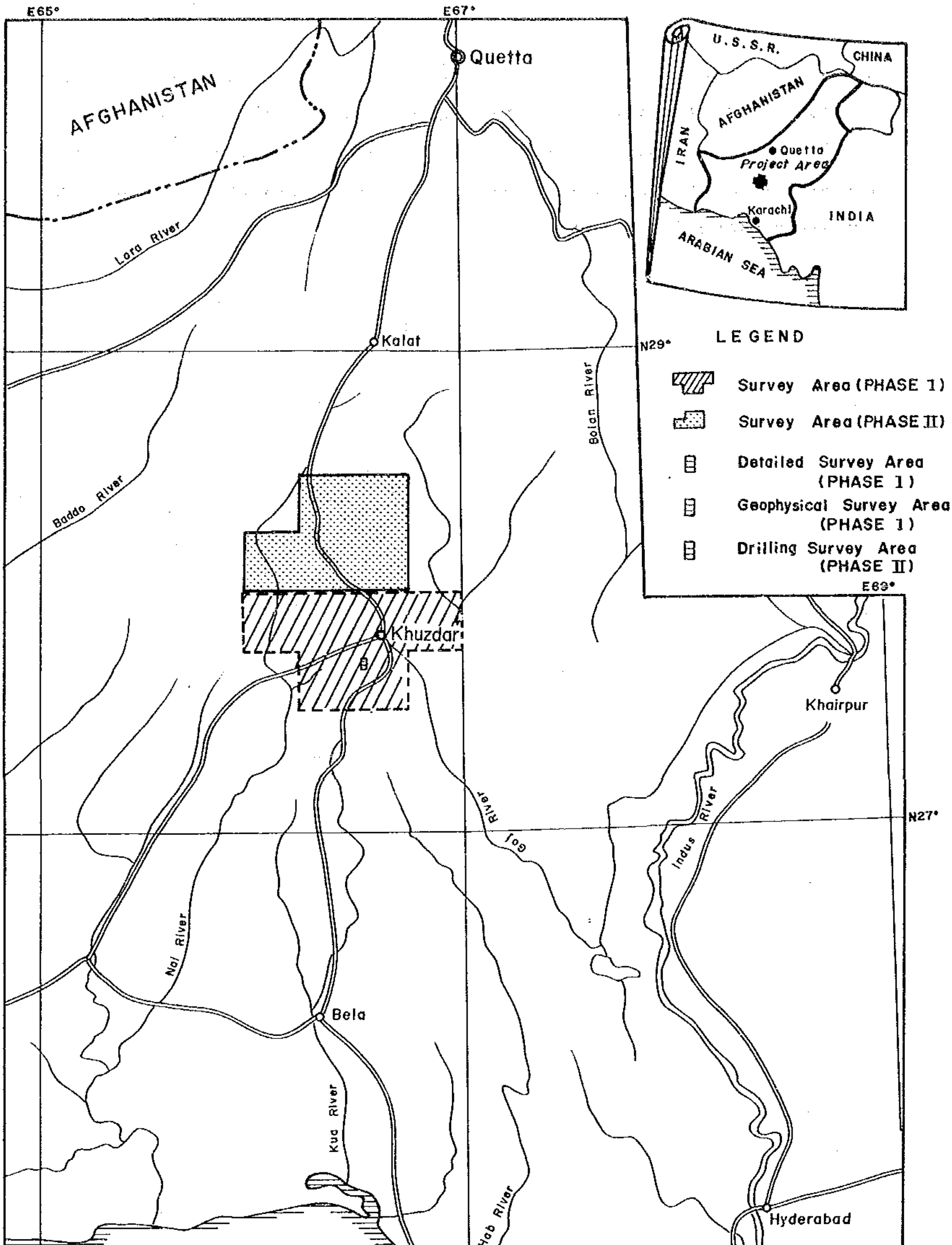

Fig. 1 Index Map of the Survey Area

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"DISTRICT" will be use instead of "AREA" for Khuzdar in order to avoid confusion with area of Surmai area

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PART I OVERVIEW

CHAPTER I INTRODUCTION

1－1 Background of the Survey

The Japanese Government, in response to the request of the Government of the Islamic Republic of Pakistan (henceforth Pakistan) to conduct mineral exploration, sent a mission to consider the ways and means of implementation and upon its recommendations, concluded the Scope of Work (SW) with the Pakistan Government regarding mineral exploration in Khuzdar District of the State of Baluchistan in October 1986. The SW stipulates that the objective of the survey is to determine the mineral potential of the area with work comprising geological survey, geochemical prosecting, geophysical prospecting and drilling.

On the basis of this SW, it was agreed that the work of the first phase would consist of the following activities. Geological and geochemical reconnaissance survey of Jurassic limestone area in the vicinity of Khuzdar Town•••1,350 km^2 (Southern Khuzdar District, in 6 sheets of 1:50,000 topographic maps; the total area of the 6 sheets 3,900 km^2) together with detailed geological survey and geochemical prospecting of Surmai Area (10 km^2) where the occurrence of lead-zinc mineralization is known. Also geophysical prospecting of the Surmai Area and its vicinity was planned. MMAJ organized a survery team consisting of seven experts and conducted field work from December 1986 to April 1987 and completed the report of the first phase in June 1987.

During the second phase, field work was conducted in accordance with the conclusions and recommendations of the first phase. The Jurassic limestone area of 940 km^2 (Northern Khuzdar District, in five sheets of 1:50,000 topographic maps; the total area of the five sheets, 3,250 km^2) located to the north of the survey area of the first phase in Khuzdar District was investigated geologically and geochemically. Also drilling was done in the Surmai Area. The work was carried out between November 1987 and August 1988.

1－2 *Conclusions and Recommendations of the Phase I Survey*

1－2－1 Conclusions of the Phase I Survey

1－2－1－1 Southern Khuzdar District

(1) The Jurassic limestone in this area consists of Shirinab Formation which is of Early Jurassic age. This formation comprises, in ascending order, Spingwa Member consisting mainly of calcareous sandstone, Loralai Member composed of limestone, shale alternation and Anjira Member.

(2) The general trend of the geological structure of this area, affected by the large structure of Khuzdar Knot, is N-S to NNW～SSE in the southern and eastern parts and it changes to E-W to NE-SW in the northern and western parts. The members have complex folded structure of anticlines and synclines with the trend of axes conforming to the general geology.

(3) Mine prospects Malkhor, Ranj Laki, East Sekran and Sekran as well as Gunga and Surmai occur in a narrow zone extending 25 km in the central part. It is considered that these were formed by Mississipi Valley type mineralization associated with ophiolite activities. All of these showings crop out as gossan, but it is inferred that primary sulfide ores exist below the water table. The major constituents are lead-zinc-barite in Gunga and lead-zinc in other prospects.

(4) All mineral showings are combinations of bedded mineralization replacing the host rock along the bedding planes and those filling the fissures and faults. Of the bedded mineralization, that of Gunga occur in the Anjira Member and those of other areas in Loralai Member, while the fissure-filling type occur throughout the Shirinab Formation. From the grade and size, the bedded type seems more promising.

(5) There are four mineral showings in the Malkhor～Sekran mineralized

zone. These all show evidences of intense mineralization and some parts appear to have promising lower portions. But the structures are very complex and the subsurface continuity is not clear.

(6) The results of geochemical prospecting show that elements Pb,Zn,Hg show high positive correlation to each other and form anomalous zones around gossan while Ba form anomalous zone outside of the Pb,Zn,Hg zone. This fact indicates, that geochemical prospecting is effective for delineating the promising zones regarding the occurrence of Mississippi Valley type lead-zinc mineralization in this area. Lead,zinc,mercury anomalous zones of A-rank were found in Surmai Area and also in Malkhor～Sekran showing area. It is concluded, therefore, that further detailed geological and geophysical investigation of the Malkhor～Sekran mineral showing is warranted.

1 − 2 − 1 − 2 Surmai Area

(1) In this area, three members of the Shirinab Formation are distributed and the Loralai Member is divided into I ~IV Units and the Anjira Member into three, I ~III Units.

(2) The structural trend of this area is north-south and the eastern half is the uplifted zone with anticlinal structure while the western part is the subsided zone with synclinal structure.

(3) There are three mineral showings consisting of gossan, the weathered product of lead-zinc mineralization, along the uplifted zone. They are called Surmai-I ,II ,III from the north. These showings are considered to be of Mississippi Valley type mineralization. The mineralization of these showings is combination of replacement along the host rock bedding and filling of faults and fissures. The bedded type is seen in Surmai-I ,III and large-scale mineralization is developed in Loralai Units II and III . The fissure filling type is distributed in Surmai-II and in the vicinity of the bedded type, but they are of small scale and are not promising. The mineralized parts with good structural

and geochemical indications on the surface and in deeper parts are located in the lower parts of the Main Orebody of Surmai-I and at the northern-most part of the westward dipping west ore body (henceforth: West Orebody) of Surmai-III.

(4) The results of geochemical prospecting showed high positive correlation among Pb, Zn, Hg in the high anomalies around gossan and with Ba on its outerside. This is similar to the results of the Southern Khuzdar District.

(5) Geophysical prospecting showed A-rank anomalies believed to be caused by sulfide minerals in the lower parts of the Main Orebody of Surmai-I and the West Orebody of Surmai-III.

(6) From the above results, the lower parts of the Main Orebody of Surmai-I and the Northwest Orebody of Surmai-III are the two localities where ore deposits, particularly the lead-zinc sulfide deposits are anticipated.

1-2-2 Recommendations of the Phase I Survey

1-2-2-1 Khuzdar District

(1) Geological reconnaissance and geochemical prospecting in the Jurassic limestone area outside of the designated area.

It was proven by the work of the first phase that geochemical prospecting is very effective for exploration of the Mississippi Valley type mineralization in this area. It is recommended that geological reconnaissance together with geochemical prospecting be conducted in the Jurassic limestone area not included in the survey of the first phase. This would delineate new promising areas.

1-2-2-2 Surmai Area

(1) Drilling in Surmai-I and III

The geological survey showed that the surface indications of the

Main Orebody of Surmai-I and the Northwest Orebody Surmai-III was the most promising in the area. And continuation of the mineralized zones to the lower parts can be expected from the geological structure. Also the geophysiccal work showed A-rank results for the lower parts of these two prospects. It is recommended that drilling aimed at the lower parts of the two prospects be carried out in order to confirm the continuation of the mineralization and the change from oxide to sulfide mineralization.

1－3 Outline of the Phase II Survey

1－3－1 Survey Area

The area of the Phase II Survey is located to the south of the central part of Pakistan as shown in Figure 1 and Figure 1-1-1. The coordinates are as follows.

(1) Northern Khuzdar District

[Latitude]	[Longitude]
N-28° 30′	E-66° 15′
28° 30′	66° 45′
28° 00′	66° 45′
28° 00′	66° 00′
28° 15′	66° 00′
28° 15′	66° 15′

(2) Surmai Area

[Latitude]	[Longitude]
N-27° 43′ 17″	E-66° 31′ 26″
27° 43′ 17″	66° 32′ 41″
27° 40′ 37″	66° 31′ 38″
27° 40′ 37″	66° 32′ 51″

The area of the Northern Khuzdar District is included in five topographic sheets (1:50,000 scale), Nos.34-L/4, 34-L/7, 34-L/8, 34-L/11 and 34-L/12, published by the Survey of Pakistan and that of the Surmai Area 35-I/10.

1－3－2 Objective of the Survey

The objective of the survey is to clarify the mineral potential of the area by geoscientific investigation.

(1) Geological survey, geochemical prospecting

This work was conducted with the purpose of delineating promising areas by considering the relation between the Mississippi Valley type *mineralization and geological structure together with geochemical* characteristics and other relevant features.

(2) Drilling

Drilling will was carried out in the Surmai Area in order to clarify the geochemical characteristics and the detailed geologic structure of the mineralized zone. This will provide the key data for considering the genesis and the shape of the mineralized zone.

1 − 3 − 3 Methods and Contents of the Survey

(1) Northern Khuzdar District

Geological survey	survey area	940 km^2
Geochemical prospecting	number of samples	1,883 pcs

(2) Surmai Area

Drilling, MJP-1～6 (6 holes)	total length	2,255.8 m

(3) Laboratory studies

Thin sections (prepared by GSP)	10 samples
Polished sections (prepared by GSP)	15 samples
X-ray powder diffraction	10 samples

Chemical analysis

Total rock: SiO_2, TiO_2, FeO, Fe_2O_3, MnO, MgO, CaO, K_2O, BaO, Na_2O, Al_2O_3, P_2O_5, LOI	5 samples
Ore assay: Pb, Zn, Ba, Ag	78 samples
Geochemical analysis: Pb, Zn, Ba, Mg, Hg, S	1,883 samples

(NB) GSP: Geological Survey of Pakistan

1 − 3 − 4 Organization of the Survey Team

(1) Planning and Coordinating

Japanese Side		Pakistan Side	
Name	Office	Name	Office
Naotaka Adachi	MMAJ	A. H. Kazmi	Director General of GSP
		M. Ishaque Durrazai	GSP
		Waheeduddin Ahmed	Previous Director General of GSP

(2) Field Survey

Japanese Side			Pakistan Side		
Name	Work	Off.	Name	Work	Off.
Tsutomu Ichinose	Team Leader	NED	A. Mahmood Subhani	Team Leader	GSP
Hideo Suzuki	Geol., Geoc.	NED	C. Ferozuddin	Geol., Geoc., Dril.	GSP
Takashi Yoshie	Geol., Geoc.	NED	S. Mukhtar Zaidi	Geol., Geoc., Dril.	GSP
Yukio Kawamura	Dril.	NED	Bhagwandas	Geol., Geoc., Dril.	GSP
Mitsuo Sasaki	Dril.	NED	M. Dawood Khan	Geol., Geoc., Dril.	GSP
Masaya Wakamatsu	Dril.	NED			

(NB) MMAJ : Metal Mining Agency of Japan
NED : Nikko Exploration & Development Co., Ltd.
Off. : Office   Geol. : Geological survey
Dril. : Drilling   Geoc. : Geochemical survey

(See Photograph 1~2)

1 − 3 − 5 Period of the Survey

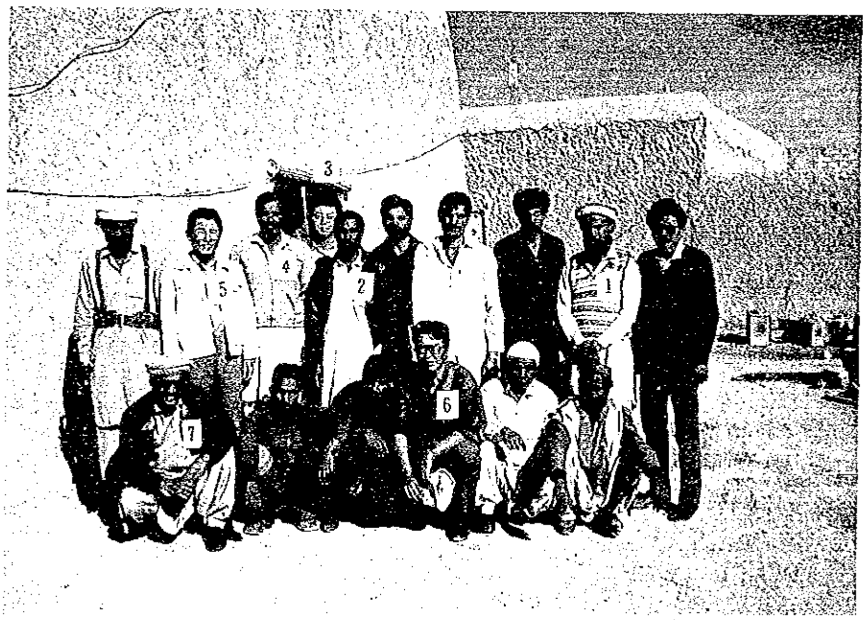
The Phase II Survey was conducted from 16 November 1987 to 20 October 1988. The field work was carried out during the following period.

(1) Geological survey and geochemical prospecting; From 16 November 1987 to 14 February 1988

(2) Drilling survey; From 15 February 1988 to 16 August 1988

Phot. — 1 Drilling team at Surmai - Ⅲ

1. Mr. SUBUHANI
2. Mr. KAWAMURA
3. Mr. ICHINOSE
4. Mr. SASAKI
5. Mr. WAKAMATSU



1. Mr. SUBHANI
2. Mr. BHAGWANDAS
3. Mr. YOSHIE
4. Mr. ZAIDI
5. Mr. SUZUKI
6. Mr. ICHINOSE
7. Mr. DAWOOD

Phot. — 2 Geological, geochemical survey team at GSP camp

CHAPTER 2 GEOGRAPHY AND DRAINAGE

2－1 Morphology and Drainage

The survey area is located near the centre of the State of Baluchistan of western Pakistan. The Town of Khuzdar with a population of 20,000 is located at the centre of the survey area of Phase I which lies adjacent to the south of the present survey area. Daily provisions are available in this town. Quetta, the capital of the State is about 270 km to the north and Karachi lies approximately 35 km to the south. It takes about five hours to Quetta and seven hours to Karachi by car.

The elevation of the plains is around 1,200 m and the highest peak is 2,100 m above sea level. The geology of the vicinity consists mainly of Jurassic and Cretaceous calcareous sedimentary rocks. The topography is steep reflecting the intense folding and faulting. The Cretaceous limestone overlying the Jurassic limestone often forms small mountains of 300～500 m in height and their peripheries are steep cliffs.

The area is located in the vicinity of the uppermost stream of Nal, Kua, Hab, Goji and several other rivers which flow southward for 300～400 km into the Arabian Sea. The drainage system of the eastern part of the survey area is north-south consisting of the tributaries of the Nal River while that of the central to the western part is east-west formed by Anjira River, the upstream Goji River, and its tributaries. The rivers are usually dry, wadi, but during rain they become muddy streams in very short time.

The official language is Urdu and English. The mountain people speak Buluchi, and Urdu is often not understood. The people are pious Moslems and are honest.

2－2 Climate and Vegetation

The climate is largely divided into summer, April~October, and winter, November~March. During the hottest season of May~August, the temperature exceeds 40°C in the shade and reaches 50°C in the sun. The minimum temperature drops below freezing during December~January. Mid June~mid August is the monsoon season and it often rains heavily with strong winds, but other seasons are dry. The annual rain fall is around 150 mm and the humidity is about 50 %. Meteorological data are not available for the area. Those of Jacobabad which has similar climate and is located about 150 km east of the survey area, are laid out in Table I-2-1. The survey area is rock desert and vegetation consists of sparse and small shrubs along wadis and sparse grass on the flat land and mountains.

Table I-2-1 Average Monthly Temperature and Rainfall at Jacobabad

Month	1	2	3	4	5	6	7	8	9	10	11	12	Av./Y
Temp. (°C)	14.9	18.3	24.2	30.3	34.7	37.0	35.0	33.6	31.9	27.9	22.0	16.8	27.2
Rf. (mm)	7.8	3.8	6.2	1.6	4.6	4.6	38.5	5.9	0.3	3.3	1.3	2.9	93.9

(Average of 1951~1980)

(NB) Av. : Average

Temp. : Temprature

Rf. : Rainfall

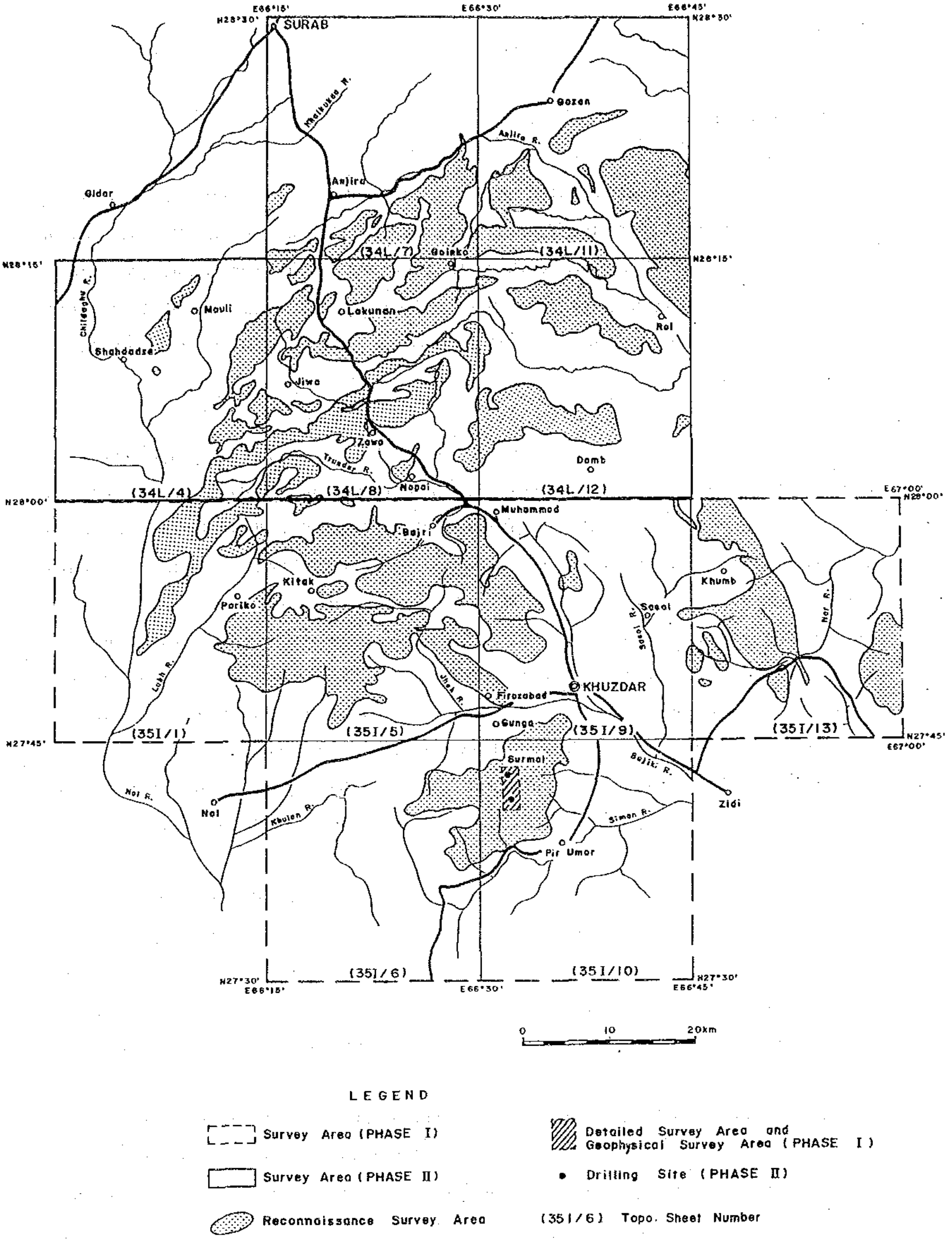


Fig. I-1-1 Location Map of the Survey Area

CHAPTER 3 GENERAL GEOLOGY

3 − 1 Geologic Setting

The Indian Subcontinent which separated from Gondowana in Late Cretaceous drifted northward and collided with the Asian Continent in Eocene. This formed a vast fold zone represented by the Himalayas and a thrust zone extending parallel to the folding causing the most violent diastrophism in earth's history. The geology of Pakistan clearly reflects this diastrophic event.

The east-west trending fault and the fold zone between the two continents in the Himalaya region forms syntaxis protruding northward and it turns southward at Kashmir Pakistan in the west and Nepha of India in the east end. The western fault and fold zone which extends southward along the western side of Pakistan is divided into the marginal zone called the Pakistan Axial Belt and the Major Fold Belt. The Axial Belt is connected to the Owen Fracture Zone which is the transform fault extending north-south in the Arabian Sea. The geology of Pakistan is largely divided into the Indo-Pakistan Plate, namely the Indian shield and the overlying shelf sediments to the east, and the Lut-Afghan Block consisting mainly of Tertiary flysch sediments to the west of the Axial Belt.

The Khuzdar District belongs to the Kirthar Fold Belt which is a branch of the Major Fold Belt in its southern part. The geology consists of Mesozoic to Tertiary sediments. The Kirthar Fold Belt extends from near Karachi in the south to the vicinity of Khuzdar in the north for approximately 400 km. This fold belt has a general north-south trend, but it changes abruptly to east-west direction at Khuzdar. Thus, the vicinity of Khuzdar is called Khuzdar Knot in structural classification(Fig.I-3-1). The major geologic unit of the Khuzdar District are Jurassic∼Cretaceous calcareous sedimentary rocks. The Jurassic system consists of Shirinab Formation said to be Early-Middle Jurassic. It is subdivided, in ascending order, into Spingwar Member, mainly calcareous sandstone;

Loralai Member, mainly alternation of limestone and shale; and Anjira Member.

3 − 2 Previous Surveys

The published systematic geologic map of the State of Baluchistan is the "Reconnaissance Geology of Part of West Pakistan" a 1:253,440 scale geologic map published by Hunting Survey Co., Ltd. in 1961 [henceforth HSC map (1961)]. In this map, the Jurassic limestone accompanied by shale and sandstone was lumped together as Zidi Formation.

The GSP named the Jurassic system as Shirinab Formation and further subdivided it to the above three members (Geology of Pakistan; GSP, 1977) and is using this as the basis for geologic mapping of the State.

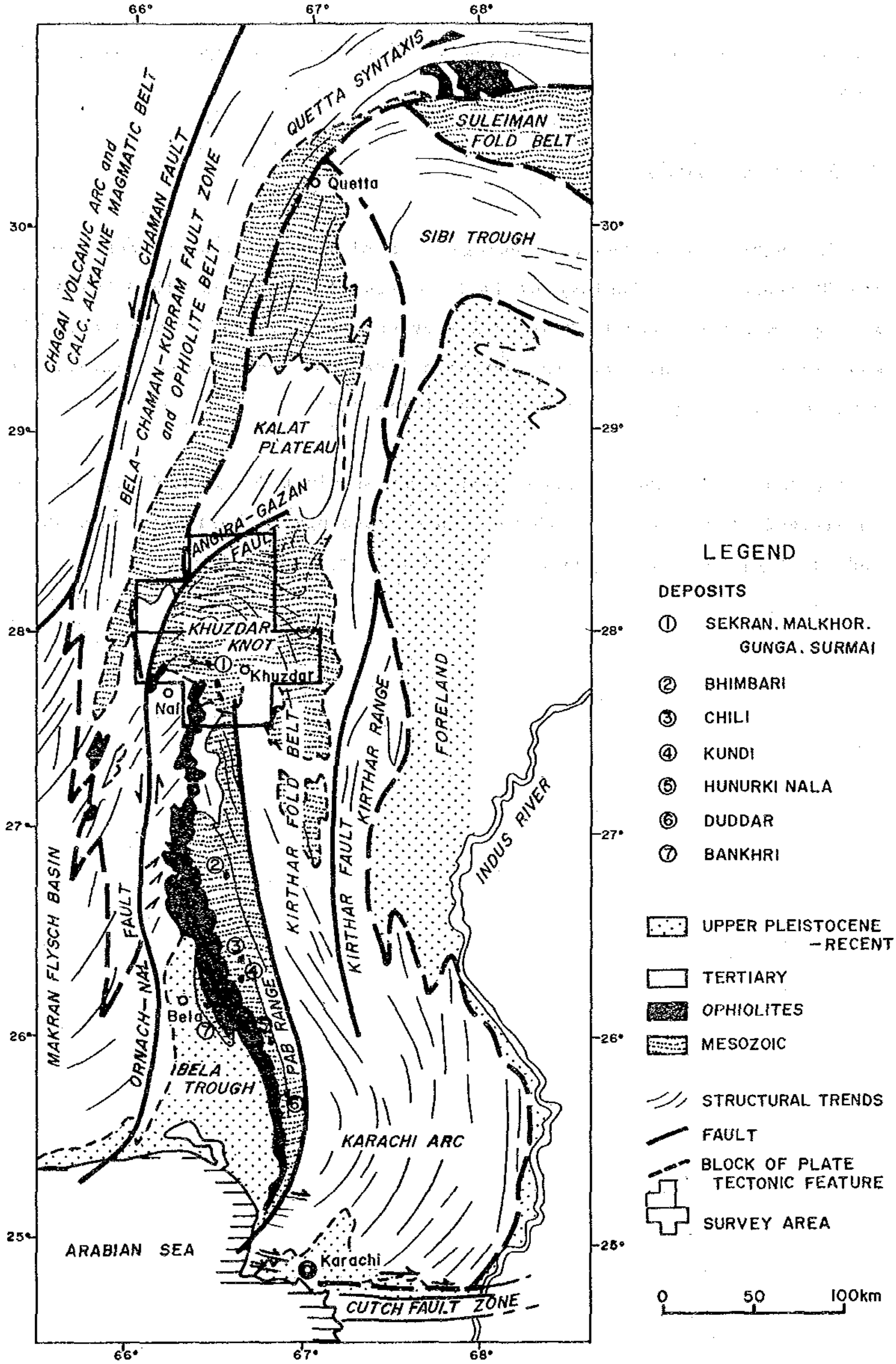


Fig. I-3-1 Geology, Structural Features and Distribution of Mississippiy Valley Type Pb・Zn・Ba Deposits Around the Survey Area

CHAPTER 4 RESULTS OF THE SECOND PHASE SURVEY

4－1 Characteristics of the Geologic Structure and Mineralization

4－1－1 Northern Khuzdar District

Mineral showings, such as those of the Surmai～Sekran Zone, were not found during the course of the present survey. The zoning of mineralization in the whole Khuzdar District, including the area surveyed last year, was studied and the position of the second phase area in relation to this mineral zoning was considered.

4－1－2 Surmai Area

The lead-zinc mineralization below the lead-zinc oxidized (gossan) zones were confirmed by drilling. These are under the Main Orebody of Surmai-I and the West Orebody of Surmai-III. This sulfide ore-bearing horizon was determined, and the structural control of the emplacement of the sulfide ores as well as the restriction of the mineralization by the fault and the groundwater table were investigated in detail. The genetical process of the Mississippi Valley type lead-zinc deposits which occur in the Khuzdar District was considered on the basis of the results of the drilling and the surface geoscientific investigation.

4－2 Geochemical-Geophysical Anomalies and Mineralization

4－2－1 Northern Khuzdar District

Promising geochemical anomalous zones such as those delineated last year were not found in the area surveyed this year. The distribution and the zoning of the anomalous zones of the whole Khuzdar District including the area prospected during the first phase, were studied. Particularly the position of this year's field in relation to the large scale zoning of anomalies was considered.

4 − 2 − 2 Surmai Area

The results of the drilling conducted during the present phase and the geophysical work of the previous phase were correlated. The relation between the lead-zinc mineralization and the geophysical anomalies were studied.

4 − 3 Mineral Potential of the Area

4 − 3 − 1 Northern Khuzdar District

The potential of this area for Mississippi Valley type lead-zinc mineralization was investigated. The scale, characteristics and distribution of the mineralization and geochemical anomalous zones were studied. Importance of the geological position of the second phase area was studied in relation to mineralization.

4 − 3 − 2 Surmai Area

The mineral potential was investigated from the scope, grade and continuity of the lead-zinc sulfide ore horizon confirmed by drilling. Also the promising zones were studied using the above and the surface outcrop data.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5－1 Conclusions

5－1－1 Northern Khuzdar District

(1) The Jurassic limestone of this district consists of the Early Jurassic Shirinab Formation. This formation is subdivided into Spingwar Member consisting of calcareous sandstone, Loralai Member consisting of limestone and shale alternation, and Anjira Member in ascending order.

(2) The Shirinab Formation is distributed largely in eight zones, and it extends in east-west direction gently protruding northward, in conformity with the large scale structure of Khuzdar Knot. The members of this formation show complex anticlinal and synclinal structure with axes along the above direction.

(3) The mineral showings are distributed around the ophiolite zone in the Surmai～Sekran Zone. This zone is located in the southwestern part of the Southern Khuzdar District. The area surveyed during this second phase lies on the outerside of the Surmai～Sekran Zone, and mineral showings were not observed.

(4) The results of the second phase geochemical prospecting did not yield promising anomalous zones. The highest rank for complex anomalous zones was C for barium and the lead-zinc zones were ranked the lowest E. The lead-zinc anomalous zones, which include the Surmai～Sekran Zone mineral showings, are distributed around the ophiolite zone and the barium anomalous zones occur on the outer side of the lead-zinc zones. These are in the southwestern part of the first phase area. The lead-zinc zones with rank E in the southernmost part of present phase area are located on the northernmost part of the anomalous zone.

(5) The study of all geochemical data, obtained by this project during the last two phases, clearly shows that the promising geochemical

anomalies all exist in the first phase area, the Surmai~Sekran Zone.

(6) Thus, it is concluded that the mineral potential of the Northern Khuzdar District is very low.

5 - 1 - 2 Surmai Area

(1) The units clarified to contain mineralized zone by drilling range between Loralai Unit-I to the overlying Anjira Unit-I. The rocks of these units are mainly limestone and shale with minor amount of two types of limestone, shale and marly shale alternation. These four types of rocks form alternation with individual beds of 0.2~10 m thick.

(2) The geologic units of the drilled area dip 60°~70° westward with gentle folding in both Surmai-I and III area. Also the central part dips steeply westward and fault with 300~400 m displacement transects the formation.

(3) Mineralized zones of lead-zinc sulfides considered to be of Mississippi Valley type were confirmed by five drill holes MJP-2~6 aimed at the lower parts of the oxide outcrops. The only hole which did not intercept a mineralized zone was MJP-1. The mineralization consists mainly of disseminated powdery to granular sphalerite and galena in limestone, and siderite and calcite vein~veinlets which transects the above.

(4) The stratigraphic horizon of lead-zinc mineralization is the same in all drill cores as well as for the outcrops. Thus it is clear that the mineralization is stratigraphically controled. The mineralized horizons confirmed by drilling are all in Loralai Unit-II and are divided into A,B,C in descending order.

(5) The distribution of the lead-zinc sulfides is controled by the water table at about 100 m depth and the fault mentioned in (2).

(6) The promising mineralization confirmed in Surmai-Ⅰ area is that located by MJP-3, at depth 169.1~172.9 m (approximately 180 m below surface) in A horizon, it is 3.8 m wide with grade of Pb+Zn 5.11 %. Those in Surmai-Ⅲ occur at two depths in MJP-6, in A horizon, 168.5~172.4 m and 185.6~188.1 m (approximately 140 m below surface) and they are 3.9 m wide, Pb+Zn 9.60 % and 2.5 m wide, Pb+Zn 6.87 %.

(7) In the Surmai-Ⅰ area, the mineralization zone confirmed by MJP-3 corrseponds to the PFE anomaly detected in geophysical traverse C (IP,SIP) carried out during the first phase. Also mineralized zone was confirmed by MJP-6 in Surmai-Ⅲ area at a location where geophysical anomalies were not very clearly detected. It is inferred that the reason for not detecting this mineralized zone is that the length of the intervals in Surmai-Ⅲ was too long(100m in Surmai-Ⅲ and 50m in Surmai-Ⅰ areas).

(8) The mineralization in the A horizon of both Surmai-Ⅰ and Ⅲ is promising in both grade and scale. Their development is anticipated. The *mineralization in B and C horizons is small and discontinuous, but as* high grade parts exist, we recommend the prospecting to be continued.

5 − 2 Recommendations for Phase Ⅲ Survey

5 − 2 − 1 Surmai Area

(1) Drilling in Surmai-Ⅰ and Ⅲ

During the work of the second phase, lead-zinc sulfide mineralized zones were confirmed by drilling in the lower parts of the Main Orebody of Surmai-Ⅰ and of the Northwest Orebody of Surmai-Ⅲ. It is recommended that drilling be carried out in the vicinity of the findings of this year to confirm the shape, grade, continuity and the feasibility of developing these zones.

PART II

REGIONAL DISCUSSIONS

PART II REGIONAL DISCUSSIONS

CHAPTER 1 NORTHERN KHUZDAR DISTRICT

1-1 Survey Methods

1-1-1 Geological Survey

The lead-zinc mineralization of this area occurs only in the Jurassic formation which consist mostly of limestone. We consider it to be of Mississippi Valley type. Based on this basic concept, the geological survey was conducted with the purpose of clarifying the detailed distribution of the above formation which are shown in HSC (1961) 1:253,440 geologic map and exposed in the area. The Jurassic formation of this area was treated as one unit, Zidi Formation, in HSC (1961), but we divided this formation into three members in order to clarify its structure.

The field work was carried out by using a 1:50,000 topographic map enlarged into 1:25,000 scale and the survey results were expressed in 1:50,000 geologic map. Regarding the field study of mineralized zones, 1:2,000 scale route maps were prepared, sketched and photographed in colour where necessary. Also representative rocks and ores were sampled, sectioned, and fully analyzed. The results are laid out in Table II-1-1 and II-1-2.

1-1-2 Geochemical Prospecting

This survey was conducted parallel to the geological survey with the objective of clarifying the geochemical characteristics of the mineralization of this area and also for delineating new promising areas. The field data were processed statistically, as in the case of the first phase and then data from both the first and second phases were used for integrated basic analysis and principal component analysis.

1 − 2 Geologic Setting

The basement of this general area is said to be the Triassic shale-prevalent Wulgai Formation, but this formation does not occur in the Khuzdar District. The geological units of the Khuzdar District is largely divided into Jurassic, Cretaceous and Tertiary systems. The Jurassic system consists of Shirinab Formation of early～middle period and is composed of limestone accompanied by shale and sandstone which is listed as Zidi Formation in HSC (1961). The Cretaceous system is divided into the early Goru and Sembar Formations which is marl accompanied with limestone, and the later Parh Formation consisting of limestone with chert and the Pab Sandstone. The Tertiary system is Jamburo Group consisting of limestone and shale with sandstone in the basal part, this is said to be Eocene. Also in addition to the above, intrusion of the allochthonous melange of various basic rocks is observed in relatively small areas. This melange is a part of the ophiolite zone.

The Shirinab Formation is distributed in an area of 940 km^2 and this was the part investigated during this phase. The rest of the total survey area of approximately 3,125 km^2 (5 sheets of 1:50,000 topographic map) is covered by formations of Cretaceous, Tertiary, and Quaternary systems in higher stratigraphic horizons. The general trend of the geological structure is NW-SE～E-W in the northeastern part and NE-SW～E-W in other parts of the area. The Shirinab Formation is distributed in eight parts of the total survey area, and in this report, they are named Blocks-Ⅰ, Ⅲ, Ⅴ and Ⅶ～Ⅺ in accordance with that of the first phase. These form a east-westerly bent structure gently protruding northward along the general trend mentioned above (Fig.Ⅱ-1-1). The Shirinab Formation is tightly folded locally, but it has a general anticlinal structure with uplifted older beds are exposed in the central part.

The topography is controlled by the geologic structure and the ridges are mostly developed along the axes of anticlines. Also larger streams are developed along the lineaments.

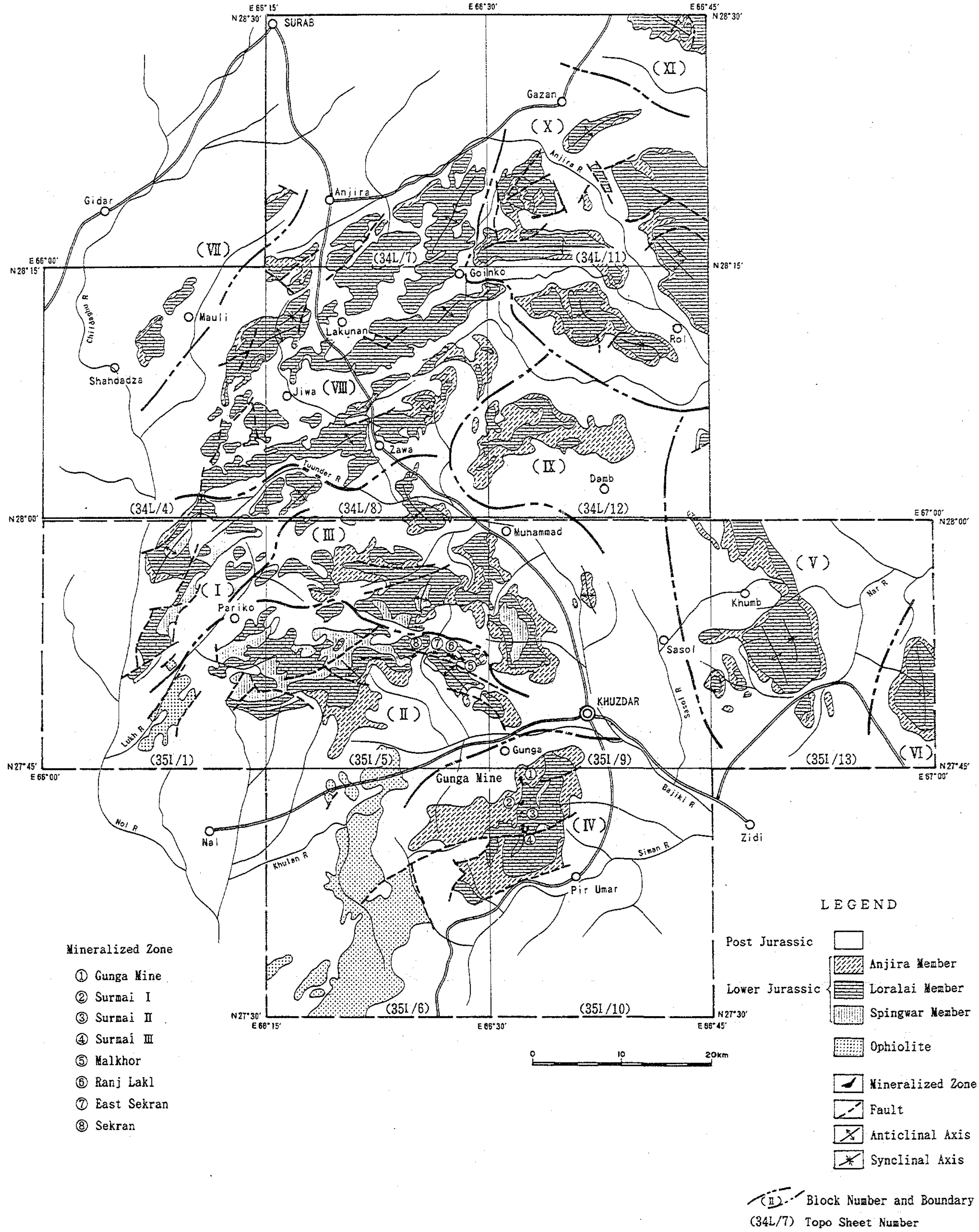


Fig. II-1-1 Geological Map of Khuzdar District

Generally, the Jurassic system can be distinguished fairly easily by its intense folding and the greenish dark gray colour and the Cretaceous system by the box-like topography formed by steep scarps and the lighter colour.

The stratigraphic sections of the vicinity of the survey area is correlated with that of the HSC (1961). Geological maps and profiles of the survey area are shown on PL.Ⅱ-1-1~Ⅱ-1-6 (Scale 1:50,000).

The limestone is described after Folk (1959), the rock is divided into orthochem which corresponds to the matrix of igneous rocks (further classified into micrite and sparite) and allochem corresponding to phenocrysts of igneous rocks. And we classified them by their constituents and their composition as in the following table.

Fig. Ⅱ-1-2 Stratigraphy of Khuzdar District and Vicinity

Geologic age		Hunting Survey Corp. (1961)		JICA and MMAJ (1987)		Thick-ness	Lithology
Tertiary		Jamburo group		Jamburo group		+100	Ls,shale,ss
Cret-aceos	Late	Parh series	Pab S.s.	Pab Sandstone		+490	Sandstone
			Parh group	Parh Limestone		+270	Ls,chert
	Early			Goru formation & Sembar formation		+540	Marl,ls
Jura-ssic	Late	Zidi formation					
	Mid						
	Early			Shirinab formation	Anjira member	+290	Ls,shale
					Loralai member	+380	Ls,shale
					Spingwar member	+240	Ss,shale,ls

1－3 Results of the Survey

1－3－1 Geological Survey

1－3－1－1 Stratigraphy

The Shirinab Formation is the objective of this survey and it is divided into of three members, all conformable. They are, in ascending order, Spingwar, Loralai and Anjira Members. The formation is distributed largely in eight parts of the studied area and in this report they are named Blocks Ⅰ, Ⅲ, Ⅴ and Ⅶ～Ⅺ as in our report of the first phase (Fig. Ⅱ-1-1).

(1) Spingwar Member

This member is composed mainly of calcareous sandstone with minor intercalation of shale and limestone. Spingwar Member occurs in very small parts of Blocks-Ⅰ and Ⅷ in the area of the Topographic Map 34L/4.

The sandstone is pinkish gray to white and becomes brown upon weathering. It consists of medium to fine-grained quartz with minor amount of feldspars with calcareous matrix and is orthoquartzitic to calcareous (Table Ⅱ-1-1). The quartz is rounded to subrounded and the sorting is not very good. The matrix is composed of transparent coarse-grained calcitic cement and argillaceous fine clastics. Also dissemination of idiomorphic to hypidiomorphic magnetite altered to limonite is locally observed.

The thin beds of shale intercalated in sandstone are gray to pale brown and becomes brownish gray by weathering. This shale is composed mainly of fine-grained, rounded to subrounded and partly corroded quartz and of brown microcrystals of calcite. Also magnetite grains mostly altered to limonite and acicular to fibrous illite are associated. Limestone is micritic and is poor in fossils.

(2) Loralai Member

This member consists mainly of alternation of limestone and shale. The beds are a 0.2~5 m thick. The limestone is hard and occurs as thin and thick beds as well as in massive form. The shale is soft and forms the topographic depressions on the surface. It is often covered by weathered sediments. This member often forms mountains with anticlinal structure and is distributed throughout the survey area.

Limestone is gray to dark gray and becomes brownish gray by weathering. Calcite veinlets occur in the limestone. Irregular reddish brown to orange patches of 2~10 cm in diameter occur along the bedding and the rock as a whole often has a mottled appearance (Phot. 3). This mottled colour was at first thought to be caused by dolomitization. The geochemical and rock analyses and x-ray diffraction, however, showed relatively high content of iron rather than magnesium or magnesium minerals. The drill core studies showed that the limestone of this member generally contained irregular patches of shale~marlish shale and that these patches became reddish brown by selective hematitization between the surface and 100 m depth. From these evidences, we believe that the mottled appearance is the result of weathering. The limestone is mostly micrite and partly biomicrite, oomicrite and intramicrite. The allochem of the biomicrite consists of fossil fragments filled by mostly round, egg-shaped, oblong or acicular spar calcite. Gastropods, brachiopods (Spiriferina sp.), bivalves (Pecten Weyla, Girvillia), crinoids (Isocrinus) and corals occur in this member. In the upper parts of this member, 0.1~0.5 m thick coquina layers often occur. Also several layers of oomicrite and intramicrite are observed in the lower parts (Phot. 5). Calcite, rounded to subrounded fine quartz, disseminated or irregular patches of limonite are observed microscopically. This member is generally cut by coarse sparry calcite veinlets.

(3) Anjira Member

This member is mostly composed of regular alternation of limestone and shale. The unit beds are 0.3~1 m thick. This overlies the Loralai Member conformably and is distributed around the periphery of the mountains. It occurs particularly widely in Block Ⅸ and in the southeastern part of Ⅷ. The limestone is hard, greenish gray to dark gray and becomes yellowish gray by weathering. Schlieren texture is often observed. Shale is soft, friable and gray to black changing to pale yellowish gray by weathering.

Limestone is mostly micrite, partly biomicrite, and pelmicrite. Well-preserved brachiopods (Spiriferina, Terebratula) and corals (Montlivaltia sp) and other fossils filled by calcite spar occur in the allochem of the biomicrite. Ammonites and nautiloids (Protogrammocera, Dactylioceratids, Cenoceras) of Toarcian stage occur in the shale.

Many radioralian fossils were observed microscopically in limestone and shale allochem (Table Ⅱ-1-1). The rock analysis showed the relatively high content of SiO_2 for both limestone and shale (Table Ⅱ-1-2).

(4) Sedimentary environment of Shirinab Formation

The limestone of this formation is mostly micrite. Most of the micrite is said to be formed by rapid chemical or biochemical precipitation from sea water in quiet environment. The limestone of the Loralai Member forms alternations with shale and the limestone also has patches of shale. Also in some of the limestone beds of this member, concretions are found (Phot. 4). This indicates low rate of sedimentation. Thus we see that there were significant variation of sedimentation rate during the deposition of Loralai Member. Also the limestone with patches of shale are believed to have been formed by slow supply of argillaceous material and rapid deposition of micrite occuring simultaneously.

Oolitic limestone is developed into very thick beds in the central part of the Loralai Formation. These oolitic limestones are said to be formed under high energy conditions with rapid movement of sea water, thus in shallow marine environment. Crawling traces are found in the Loralai Formation and this also is an evidence of shallow sea facies.

The above evidences indicate the following depositional environment for the Shirinab Formation of this area. During the early phase (Spingwar

Member), the deposition of detrital material (sandstone) of the unstable shallow sea prevailed. The deposition of the middle phase (Loralai Member) occurred first in quiet marine environment - limestone and shale - then limestone in shallow seas and again limestone and shale in quiet waters. The late phase (Anjira Member) limestone and shale alternation containing ammonites and radiolarian fossils was formed under quiet marine environment. Thus this area became shallow marine during a brief period, but during most of the time it had stable conditions similar to that of the continental shelf.

1 - 3 - 1 - 2 Geologic structure

The Khuzdar District tectonically belongs to the Kirthar Fold Zone. This zone is composed of Mesozoic to Tertiary sedimentary rocks. Kirthar Fold Zone extends continuously for about 600 km from the vicinity of Karachi in the south to near Quetta in the northern end. It has a general structural trend of north-south. This zone is divided into Karach Arc in the south, Khuzdar Knot in the central part and Karat Plateau in the north. The term knot was used for the Khuzdar Knot because of the very tight arc formed by the sharp change of the structural direction and the complex structure. Khuzdar-Karach Block consisting of Karachi Arc and Khuzdar Knot rotated anticlockwise as a unit due to the northward movement of the India-Pakistan plate. The Khuzdar Knot protruded westward and formed a folded zone with the trend of axis changing from N-S through NW-SE and E-W to NE-SW by northwestward compression. The survey area of the first and second phases covers the whole Khuzdar Knot.

The Shirinab Formation is largely distributed in eight subareas in the survey area of the second phase, and these subareas are arranged in east-west trending curved structure gently protruding northward with the Khuzdar Knot structure (Fig.Ⅱ-1-1). In other words, the strike of the formation, the beddings and the fold axes of the Shirinab Formation is NW-SE～E-W in the northeastern Blocks-Ⅹ,Ⅺ and NE-SW～E-W in the central-western Blocks-Ⅰ,Ⅶ,Ⅷ. Anticlines and synclines repeatedly occur in the Shirinab Formation and there are no significant thrusts or fractured *zones. In mountains, the lower units of the Shirinab Formation often* forms anticlinal structure and are exposed as ridges.

1 − 3 − 1 − 3 Mineralization

Various mineral resources of Pakistan are distributed with very close relationship to the geological composition and structure. The metallic mineral resources are largely divided as follows; chromite deposits associated with Chagai Volcanic Arc and calc-alkaline magmatic belt, group of porphyry copper deposits, and deposits associated with Bela-Chaman-Kurran Fault Zone and ophiolite belt. The last group includes chromite, copper (skarn and veins), asbestos, fluorite, manganese and the lead-zinc-barite deposits in carbonate rocks - those investigated during this phase -. The Khuzdar District belongs to the metallogenic province which comprises the last group of deposits. The lead-zinc-barite deposits in carbonate rocks distributed near the ophiolite belt in Lasbela— Khuzdar District is considered to be strata-bound deposits formed by epithermal fluid. This is different from other carbonate-hosted lead-zinc-barite deposits in West Asia in that there are no igneous activity in the vicinity.

There are a series of mineral prospects of carbonate-hosted lead-zinc oxides in the Surmai, Gunga as well as Malkhol～Sekran districts in the survey area of the first phase. These prospects occur in the 25 km long and 2 km wide narrow zone (Surmai～Sekran zone). This zone is situated in the central part of the first phase area from Blocks Ⅳ to Ⅱ.

There are no gossan occurrences which indicate the above type prospects in the area of the second phase. The mineral showings found by this survey are small limonite, siderite network and calcite network in the Loralai limestone in Block-Ⅲ (southernmost 34L/8) and Block-Ⅷ (easternmost 34L/4, central 34L/8).

Table-Ⅱ-1-1 Descrption of Microscopic Observation of Thin Section

Sample No.	Locality (Sheet No)	Rock Name	Rock Facies	Allochems /Grain	Orthochems /Matrix	Unit
2G-40	34L/8	Ls.	Oomicrite	ooids, bioclasts.	micrite.	An
2G-113	34L/8	Ls.	Sparite	Sparry calcite. Fe-oxide.		An
2G-169	34L/11	Ls.	oomicrite	ooids :0.1mm bioclasts:0.35.	micrite/sparite.	Lo
2G-171	34L/11	Ls	biomicrite	bioclasts :0.53mm calcite vein,Fe-oxide	micrite	Lo
2G-172	34L/11	Ls.	sparite	sparry cal(0.06mm).	sparite›micrite	Lo
2G-176	34L/11	Ls.	biomicrite	bioclasts. hematite	micrite.	Lo
2G-191	34L/8	Sh.	limy shale	bioclasts. fine Quartz, cal.	clay	An
2G-192	34L/8	Ss.	sandston	Quartz.d:0.1mm. hematite,mica.		Sp
2F- 26	34L/8	Go.	cherty gossan	bioclast.d:1mm. opaque mineral.	micrite	Lo
2F-160	34L/11	Ls.	biomicrite	bioclast.d:0.1mm. opaque mineral	micrite	Lo
2F-173	34L/11	Ls.	oomicrite	ooids,d:0.2mm ooiclast.	micrite.	An
TY-880 11-001		Dio.	diorite	hornblende pyroxene,biotite.	carbonate.	

Sur :Surmai
Ls. :Limestone
Sh. :Shale
S.s.:Sandstone

An:Anjira
Lo:Loralai
Sp:Spingwar

d :diamater
cal:calcite
Go :gossan

Table II-1-2 Whole Rock Compositions of the Carbonate Rocks

Sample NO.	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	MnO %	LOI %	FeO %	Ba ppm	Total %	Remark
2F-160	4.92	1.53	0.89	0.78	48.73	0.26	1.40	0.05	0.11	0.04	41.12	0.38	<0.01	100.25	Lora, Ls
2G- 40	3.34	0.66	1.08	0.55	50.22	0.30	1.13	0.03	0.12	0.14	41.96	0.25	0.04	99.86	Anji, Ls
2G-172	1.55	0.42	0.52	1.70	50.49	0.27	1.26	0.02	0.10	0.01	43.34	0.22	<0.01	99.94	Lora, Ls
2G-191	34.36	7.62	2.36	1.82	24.31	0.51	2.80	0.43	0.15	0.03	24.38	0.67	0.01	99.53	Anji, Sh
2G-192	80.05	6.06	1.46	0.50	3.73	0.27	2.18	0.34	0.19	0.03	5.15	0.06	0.02	100.05	Spin, Ss

Average Composition of Mainly Sedimentary Rocks in the World (Reference)

Rock Name	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	MnO %	LOI %	FeO %	Ba ppm	Total %	Remark
Ls	5.2	0.8	0.5	0.05	42.6	0.05	0.3	0.07	0.09	0.05	42.4	**		99.96	*1
Ss	78.7	4.8	1.1	1.2	5.5	0.5	1.3	0.25	0.04	0.01	6.6	0.3		100.30	*2
Pel	58.9	16.7	2.8	2.6	2.2	1.6	3.6	0.77	0.16	0.1	6.3	3.7		99.43	*3

Abbreviation

Lora-I : Unit of Loralai Member
Ls : Limestone
Ss : Sandstone
Pel : Pelitic Rock

*1 :Average of 345 Samples, Clarke(Chronological Scientific Tables, 1986)
*2 :Average of 253 Samples, Clarke(Chronological Scientific Tables, 1986)
*3 :Average of 277 Samples, Wedepohl(Chronological Scientific Tables, 1986)
** :Contained in Fe_2O_3

Table Ⅱ-1-3 Classification of Limestone

Orthochem	Allochem	Name of Limestone
Micrite > Sparite	(1) poor in allochems	Micrite
	(2) abound in intraclast	Intramicrite
	(3) abound in ooids	Oomicrite
	(4) abound in pellets	Pelmicrite
	(5) abound in fossils	Biomicrite
Sparite > Micrite	(1) abound in intraclast	Intrasparite
	(2) abound in ooids	Oosparite
	(3) abound in pellets	Pelsparite
	(4) abound in fossils	Biosparite

1 − 3 − 2 Geochemical Prospecting

1 − 3 − 2 − 1 Outline

It was decided that the geochemical samples for analysis would be rocks. Within an area of 940 km^2, 1,883 rock samples were collected. An average of two samples per square kilometer was used so that the sampling density would be uniform. And care was taken to collect specimens representing the geology of the area (PL. II −1−7∼PL. II −1−11) .

The samples were crushed, about 50 g were extracted by quartering, ground to under 80 mesh and 10 g were extracted for analysis.

Analysis was done for six elements, namely Pb, Zn, Hg, Ba, Mg, S. The samples were analysed by the Chemex Labs, Ltd. of Canada by atomic absorption spectrometry (AAS). The limits of detection were;

Pb………………1 ppm	Ba………………10 ppm
Zn………………1 ppm	Mg………………50 ppm
Hg……………… 10 ppb	S …………… 0.001 %

The results of the analysis are laid out in Appendix 2.

The interpretation of these results were conducted for each geologic member and the Blocks.

1 − 3 − 2 − 2 Processing of geochemical data

The statistical values such as the mean values(M) and standard deviation(σ) for each element are listed in Table II −2−5, the frequency distribution in Figure II −1−3 , the cumulative frequency distribution in Figure II −1−4 and the scatter diagram of each two elements are shown in Figure II −1−5.

The threshold values for the elements were determined by Lepeltier (1967) and Sinclair (1974) methods. That is, when the cumulative frequency distribution (Fig. II-1-4) curve is linear, the 2.5 % point, and when it breaks below 50 %, the bending point was taken as the threshold value. As for Pb, the content of most samples was below the limit of detection. Also there was no clear break in the cumulative frequency distribution curve, thus, $M+2\sigma$ was used as the threshold. Since Hg, Ba, Mg and Hg show clear positive skewers, they were separated into anomalous unit groups and background unit groups. The cumulative frequency distribution of S, however, is almost linear and it indicated a unified population.

With the above process, the threshold for the second phase area became lower than the value used in the first phase area (Table II-1-4).

During the analysis and interpretation of the Northern Khuzdar District, however, the threshold values of the Southern Khuzdar District were used. This was done with the purpose of using identical standard for the neibouring two areas. The threshold values are as follows.

Table II-1-4 Threshold values at Khuzdar District

	Survey Area	Pb (ppm)	Zn (ppm)	Hg (ppb)	Ba (ppm)	Mg (ppm)	S (%)
Threshold	Southern Khuzdar District	29.0	225	340	350	11,000	0.074
	Northern Khuzdar District	1.9	52	240	220	5,000	0.053

The value contour lines were constructed by using 500 m grid moving average method.

1 − 3 − 2 − 3 Results of analysis

(1) Element distribution in the Shirinab Formation

a. Distribution tendency of the assay values in various members of the formation

The samples collected during this phase were 77.6 % from Lorarai, 22.2 % from Anjira and 0.2 % from Spingwars. There were only three samples from Spingwar Member and thus they were excluded in the interpretation.

The mean contents (M) of all elements of Anjira are somewhat higher than those of Loralai, but the maximum values are higher in Loralai than those in Anjira, particularly those of lead, zinc and magnesium in Loralai are overwhelmingly higher. The standard deviation (σ) values for both members are not very different, but those for lead and sulfur are slightly higher in Loralai and vice versa for other metals.

Lead: Concentration in particular member not observed (Mean value: Anjira 1.11 ppm, Loralai 1.03 ppm), similar standard deviation values (0.117-0.155). Maximum content 10 ppm for Anjira and 54 ppm for Loralai.

Zinc: The mean values 16.43 ppm for Anjira and slightly lower for Loralai, 11.60 ppm. The difference of the standard deviation of both members negligible, 0.286～0.258. The maximum values, 96 ppm for Anjira and very high for Loralai, 2,400 ppm.

Mercury: Not concentrated in any particular bed, the mean values 47.9～57.0 ppb. The standard deviation 0.436-0.497 and the maximum values 4,500-5,500 ppb.

Barium: The mean value higher in Anjira 139 ppm, in Loralai 54 ppm. No difference in maximum values, 5,800 ppm～6,200 ppm. The standard deviation similar for the two members, 0.552～0.557, but these values higher than those of lead and zinc.

Magnesium: The mean values 3,812 ppm for Anjira and 3,440 ppm for Loralai, the standard deviation 0.202 and 0.259 for the two members. The maximum values differ; higher 92,500 ppm for Loralai and 37,500 ppm for Anjira.

Sulfur: The mean value for Anjira (0.004 %) higher than Loralai (0.002 %) as in the case of barium, but the maximum value 0.313 % (Anjira) and 0.394 % (Loralai) similar. The standard deviation high (0.720～0.634), but no signicant difference between the two members.

b. Geochemical characteristics of each Block

As mentioned earlier, the Jurassic limestone in the Khzudar District is divided into eleven Blocks of which eight Ⅰ, Ⅲ, Ⅴ, Ⅶ, Ⅷ, Ⅸ, Ⅹ and Ⅺ, occur in the second phase area. The general geochemical characteristics of the these Blocks are as follows.

Lead: The mean content, 1.00～1.08 ppm is similar for all The Blocks. The standard deviation is slightly higher at 0.117～0.235 for Ⅰ, Ⅷ, Ⅸ, Ⅹ and Ⅺ than others. The maximum value for Ⅷ, Ⅹ and Ⅺ at 30～54 ppm is higher than others at 0.0～7.0 ppm.

Zinc: The mean content, 10.4～14.7 ppm is similar for all the Blocks. The standard deviation is higher for Ⅲ at 0.486 than others at 0.161～0.299. The maximum value for Ⅲ, Ⅷ at 740～2,400 ppm is higher than others at 26～110 ppm.

Mercury: The mean content for Ⅴ, Ⅷ and Ⅺ at 147～212 ppb is higher than for others, 24～86 ppb. The standard deviation at 0.394～0.477 is higher for Ⅰ, Ⅷ and Ⅹ and the maximum value at 900～5,500 ppm for the same group is high.

Barium: The mean content for Ⅱ, Ⅸ and Ⅹ at 126～243 ppm is higher than for others, 16～80 ppm. The standard deviation at 0.415～0.556 is higher for I ,VIII and X than for others,0.154~0.350 and the maximum value at 5,800~6,200 ppm for VIII and IX and that for I and X at 1,700~1,800 are higher than for others at 6.0~500 ppm.

Magnesium: The mean content at 3.121~3.673 is similar for all members. The standard deviation for I ,VIII ,IX and X is somewhat higher than for other Blocks. The maximum value at 62,500~92,500 ppm is higher for I ,VIII and X than for others, 4,5000~37,500 ppm.

Sulfur: The mean content at 0.013 % is high for V , but the maximum value at 0.229~0.394 % is high for VIII ,IX and X and not for I . The standard deviation does not vary with Blocks and varies from 0.458~0.805.

It is seen from above that in the second phase area, lead and zinc content is high in Blocks III , VIII , X and XI while higher barium is accompanied by some magnesium and sulfur in Blocks I ,VIII ,IX and X .

Table II-1-5 List of Statistic Parameters of Northern Khuzdar District

		by Member of Shirinab F.				by Block Number							
		Total	Anjira	Loralai	Springwar	I	III	V	VII	VIII	IX	X	XI
Number of Sample		1,883	418	1,462	3	61	40	5	58	905	184	580	50
Pb (ppm)	min	1	1	1	2	1	1	1	1	1	1	1	1
	max	54	10	54	8	7	2	1	2	54	7	30	48
	σ	0.130	0.155	0.117		0.132	0.066	0.000	0.055	0.134	0.134	0.117	0.235
	ave.(M)	1.05	1.11	1.03		1.08	1.04	1	1.02	1.04	1.08	1.05	1.08
	M+σ	1.4	1.6	1.4		1.5	1.2	1	1.2	1.4	1.5	1.4	1.9
	M+2σ	1.9	2.3	1.8		2.0	1.4	1	1.3	1.9	2.0	1.8	3.2
Zn (ppm)	min	3	4	3	6	5	5	9	6	3	4	3	6
	max	2,400	96	2,400	28	73	740	26	66	2400	110	96	38
	σ	0.286	0.258	0.285		0.290	0.486	0.161	0.246	0.299	0.262	0.260	0.200
	ave.(M)	12.54	16.43	11.60		12.81	14.73	13.16	14.64	12.17	14.63	12.35	10.37
	M+σ	24.3	29.7	22.4		25.0	45.1	19.1	25.8	24.2	26.8	22.4	16.4
	M+2σ	46.9	53.8	43.2		48.8	138.1	27.6	45.3	48.2	49.0	40.8	26.1
Hg (ppb)	min	10	10	10	6	10	10	120	100	10	10	10	100
	max	5,500	4,500	5,500	320	1,660	90	540	500	5,500	150	900	220
	σ	0.486	0.436	0.497		0.465	0.268	0.233	0.141	0.477	0.237	0.394	0.084
	ave.(M)	54.97	47.86	57.01		46.83	23.53	211.64	159.13	86.17	32.38	28.40	146.80
	M+σ	168	131	179		137	44	362	220	258	56	70	178
	M+2σ	516	357	562		399	81	619	305	775	97	174	216
Ba (ppm)	min	10	10	10	140	10	100	10	10	10	80	10	10
	max	6,200	5,800	6,200	1,640	1,700	500	80	60	6,200	5,800	1,800	80
	σ	0.576	0.525	0.557		0.527	0.154	0.350	0.200	0.556	0.310	0.415	0.255
	ave.(M)	66.81	139.19	54.11		80.56	180.48	32.88	16.34	38.23	242.68	126.17	17.49
	M+σ	252	466	195		271	257	74	26	138	495	328	32
	M+2σ	947	1,560	704		910	367	165	41	496	1,011	853	57
Mg (ppm)	min	600	600	800	2,150	1,400	1,200	2,400	1,800	600	700	1,200	1,950
	max	92,500	37,500	92,500	62,500	70,000	13,000	4,500	13,500	92,500	37,500	62,500	17,500
	σ	0.250	0.202	0.259		0.338	0.241	0.095	0.179	0.270	0.247	0.219	0.165
	ave.(M)	3,529	3,812	3,440		3,548	3,142	3,410	3,404	3,460	3,649	3,673	3,121
	M+σ	6,281	6,065	6,239		7,718	5,478	4,247	5,237	6,448	6,438	6,080	4,563
	M+2σ	11,181	9,650	11,316		16,792	9,549	5,290	7,917	12,019	11,360	10,064	6,673
S (%)	min	0.0005	0.0005	0.0005	0.002	0.0005	0.0005	0.02	0.0005	0.0005	0.0005	0.0005	0.0005
	max	0.394	0.313	0.394	0.038	0.060	0.077	0.048	0.023	0.229	0.313	0.394	0.187
	σ	0.668	0.720	0.634		0.637	0.657	0.458	0.604	0.643	0.805	0.656	0.665
	ave.(M)	0.002	0.004	0.002		0.002	0.003	0.013	0.002	0.002	0.004	0.002	0.003
	M+σ	0.011	0.023	0.009		0.010	0.015	0.036	0.009	0.010	0.023	0.011	0.016
	M+2σ	0.053	0.120	0.038		0.044	0.067	0.104	0.038	0.043	0.144	0.049	0.072

(2) Chemical correlation

The correlation coefficient of the components in the second phase area is shown in Table II-1-6 and the scatter diagram in Figure II-1-5. The correlation coefficients of the second phase area are generally low. The strong negative correlation for Ba-Hg (-0.759) and the weak positive correlation for Pb-Zn (0.284) and Zn-S (0.251) are the only significant correlation in this area.

There are significant differences between the correlation coefficients of the first and second phase areas.The differences are; high coefficients existed for Pb-Zn (0.686), Pb-Hg (0.506) and Zn-Hg (0.520) in the first phase area, whereas in the second phase, correlation was not observed among these elements,namely Pb-Zn (0.284),Pb-Hg (0.059) and Zn-Hg (0.108), and a negative correlation occured for Ba-Hg (0.011～-0.759). Also the coefficient for Ba-S decreased from 0.316 to 0.138.

The correlation coefficient for each formation member is also generally low. In Anjira, there is a negative correlation for Ba-Hg (-0.668) and weak correlation is observed for Zn-Mg (0.413) and Pb-Zn (0.312). In Loralai, there is a strong negative correlation for Ba-Hg and only weak correlation is seen for Pb-Zn (0.259) and Zn-S (0.214).

Table II-1-6 Coefficiency of Correlation of Geochemical Analysis in Northern Khuzdar District

(Total n=1,883))

	Pb	Zn	Hg	Ba	Mg
Zn	0.284				
Hg	0.059	0.108			
Ba	0.075	0.126	-0.759		
Mg	0.079	0.121	0.009	0.024	
S	0.160	0.251	0.103	0.136	0.155

(Anjila Member n=414)

	Pb	Zn	Hg	Ba	Mg
Zn	0.312				
Hg	0.065	0.133			
Ba	0.043	0.157	-0.668		
Mg	0.213	0.413	-0.038	0.069	
S	0.201	0.224	0.114	0.127	0.114

Loralai Member (n=1,462)

	Pb	Zn	Hg	Ba	Mg
Zn	0.259				
Hg	0.049	0.120			
Ba	0.048	0.043	-0.807		
Mg	-0.012	0.040	0.010	-0.012	
S	0.115	0.214	0.118	0.067	0.126

(3) Extraction of geochemically anomalous zones and assessment

a. Extraction of geochemical anomalous zones

The geochemical characteristics of the Southern Khudar District cannot be ignored in assessing those of the Northern Khudar District. Therefore, in extrac-ting the anomalous zones of the Northern Khuzdar District, the threshold values of the first phase were used and the same standard was employed for the assessment, the results are shown in PL.II-1-12～PL.II-1-17.

The general geochemical characteristics of the Northern Khuzdar District is as follows. The anomalies for all elements are lower than those of the previous phase, the number of anomalies is also small, the continuity of the anomalies of each component is short and the overlap of the anomalies of different components is also less. Therefore, the anomalous zones are often composed of anomalies of several elements located adjoining each other. As clear from the correlation coefficient, *there are only a few samples with overlapping Pb-Zn-Hg anomalous, only* six, and most of these anomalies are detected separately.

On the other hand, the overlap of Ba-Mg-S anomalies is not rare and there are 95 samples which contain anomalous amounts. Of these samples, those with Ba anomalies are; five samples with Pb, Ba, ten with Zn-Ba and one Hg-Ba overlap anomalies.

It is thus seen that the number of anomalies is small and also that they are scattered which makes the delineation of the anomalous zones difficult. The geochemically anomalous zones are extracted by considering the overlap and concentration of anomalies of several components and the fact that Ba anomalies are distributed on the outerparts of the Pb-Zn-Hg anomaly zones.

It was determined that the anomalous zones of lead, zinc and mercury are distributed along the structural trend (NE-SW) of the Blocks VIII and

X. The magnesium zones are distributed on the outerside of the base metal zone to the north and those of sulfur are scattered throughout the area.

b. Assessment of the complex anomalous zones

The mineralization of the Khuzdar District can be largely grouped into Pb-Zn and Ba types. The geochemically anomalous zones cosist mostly of multi-component anomalies and during the first phase, the anomalous zones were accordingly assessed as multi-component zones. During the present phase, the anomalous zones were assessed on the basis of the standard shown in Table II-1-7. Regarding the ranking of the complex anomalous zones, we newly added the lowest E to the A~D of the first phase.

Table II-1-7 Ranking of Complex Anomalous Areas in Khuzdar District

rank	element	Classification Standards of Complex Anomalous Areas
A	Pb + Zn	① Anomalous area consisting of two or more neighbouring Pb or Zn anomalous values overlapping or close to each other, and associated with an overlapping or neighbouring anomalous area of another element. ② Anomalous area consisting of one Pb or one Zn anomalous value. The anomalous value overlaps or is close to an anomalous area consisting of two or more other kinds of elements formed by two or more neighbouring anomalous values.
	Ba	Anomalous area consisting of two or more neighbouring Ba anomalous values, and overlapping or near an anomalous area of another element with two or more neighbouring anomalous values
B	Pb + Zn	Anomalous area consisting of two or more continued Pb or Zn anomalous values. In addition, the anomalous area overlaps or is close to another anomalous area of a different element.
	Ba	Anomalous area consisting of two or more neighbouring Ba anomalous values, and associated with an anomalous area of anomalous values for another element. These anomalous areas are distributed overlapping or near each other.
C	Pb + Zn	Anomalous area consisting of more than two neighbouring anomalous values of Pb and Zn, surrounded by a low anomalous margin ranging from (M + σ) to threshold values. Anomalous areas of other elements accompany with overlapping or close distribution.
	Ba	Anomalous area of Ba consisting of two or more neighbouring Ba anomalous values, surrounded by a low grade anomalous margin of other elements, ranging from (M+σ) to threshold values.
D	Pb + Zn	The Anomalous area consists of several anomalous values of Pb or Zn which are discontinuously distributed with respect to each other. Their low values surround the anomalous area. Anomalous values of another element also overlaps with or are close to the Pb-Zn anomalous area.
	Ba	Anomalous area consisting of discontinuous anomalous values. Other low anomalous values are distributed overlapping or close to the anomalous area.
E	Pb + Zn	Anomalous area consists of several anomalous~low grade anomalous values of Pb or Zn which are discontinuously distributed. Low grade anomalous values of another element are clos to it.

The complex anomalous zones are listed in Table II-1-8 and the results of the analysis in Table II-1-6. It is seen that promising complex anomalous zones do not exist in the Northern Khuzdar District. The major zones are described below. They are all of low grade, E rank for Pb-Zn and C rank for Ba anomalous zones. The zone Nos. 5, 7, 9 for Pb-Zn occur on the northern periphery of the Surmai~Sekran Zone surrounding it, and Nos. 11, 12 for Ba occurs on the outerside of the above Pb-Zn zones. These larger complex anomalous zones of the second phase are described briefly below.

No.5 (Pb-Zn): This zone is located at the northwestern end of the Block-VIII. This is the only locality (2F-210) in the second phase area where anomalies of Pb, Zn and Hg overlap, there are S anomalies in the vicinity with Mg anomalies around it. At 2 km north of this locality, three anomalies, Pb-Zn, Hg and Zn, occur extending in east-west direction. Near one of these points (2G-224) is a small network of siderite veinlets. These are located at the western end of Block-VIII and folds with axes trending N 10° ~ 50° E are developed. Along the western edge of Block-VIII, low grade Zn anomalies occur scattered for about 8 km which seem to indicate the trend of mineralization. The rank of this zone is Pb-Zn E.

No.7 (Pb-Zn): This zone is located at the northern end of Block-I. Although only one Pb-Zn anomaly is found in this zone, it is very high at 2,400 ppm and Ba-S, Mg-S and Ba-Mg anomalies occur in the vicinity. Low anomalies of Zn are distributed in an echelon arrangement on the eastern extension of this zone. The rank is Pb-Zn E.

No.9 (Pb-Zn): This zone is located at the northern end of Block-III. There are two high Zn anomalies in this zone and three low Zn anomalies in the vicinity. The high Zn anomalies are believed to be caused by the small scale limonite network veinlets which occur in the Loralai limestone. In the vicinity of this zone, high to low Mg anomalies, low S anomaly and a high Ba anomaly occur sporadically. The rank of this zone is Pb+Zn E.

No.11 (Ba): This zone is located at the eastern end of Block-III. High Ba anomalies and low S anomalies occur along the strike of the Loralai

Member which changes from north-south to east-west. One high Ba-S anomaly occurs in the the centre of this zone and low Zn anomalies occur in the southern end. In general, this zone could be ranked as Ba, C.

No. 12 (Ba): This zone is located in the eastern half of Block-IX. There are many high Ba anomalies, and there are localities of high to low Mg and S anomalies overlapping each other in the periphery of this area. Also one Pb-Zn anomaly and three low Zn anomalies occur along the N 70° E direction of the axis of anticline in the Loralai. The Ba anomalies occur in the Loralai, and Pb-Zn anomalies in Anjira. As a whole, this is considered as a Ba anomaly zone and the rank was Ba, C.

Table Ⅱ-1-8 Complex Anomalous Areas in Northern Khuzdar District

No.	Locality (Sheet No.)	Amount of Anomalous Points (Maximmm Values :ppm)												Geological Enviroments	Rank of Evaluation	
		Pb		Zn		Ba		Mg		Hg (ppb)		S (%)				
		Th	M+σ	Th	M+σ	Th	M+σ	Th	M+σ	Th	M+σ	TH	M+σ		Pb, Zn	Ba
1	Northern part of Block Ⅷ			1	1		1	3	1				1	loralai	–	–
	(34 L/7)	(1)		(360)		(200)		(60,000)		(10)		(0.028)				
2	Central part of block Ⅹ					2	2	1	5				5	Loralai, Anjira	–	–
	(34 L/11, L/12)	(1)		(51)		(360)		(36,500)		(10)		(0.053)				
3	Northern part of Block Ⅹ					2	4	2	1				2	Loralai, Anjira	–	D
	(34 L/11)	(1)		(16)		(900)		(62,500)		(33)		(0.027)				
4	Eastern part of Block Ⅹ					2		5				1	4	Loralai	–	C
	(34 L/11)	(1)		(38)		(1,100)		(29,000)		(50)		(0.138)				
5	Western part of Block Ⅷ	1	1	3	1	3	1	5	2	1	2	2	1	Loralai, Anjira	E	
	(34 L/4)	(16)		(540)		(1,640)		(62,500)		(1,600)		(0.084				
6	Central part of Block Ⅷ					5		3					4	Loralai	–	C
	(34 L/8)	(2)		(15)		(2,200)		(20,000)		(360)		(0.074)				
7	Northern part of Block Ⅰ				1	3	1	3	1				4	Loralai	E	–
	(34 L/4, L/8)	(1)		(66)		(1,700)		(70,000)		(90)		(0.060)				
8	Southern part of Block Ⅷ		1		3	7		3	1			1	2	Loralai	–	C
	(34 L/8)	(8)		(150)		(2,000)		(40,000)		(160)		(0.047)				
9	Northern part of Block Ⅲ			2	3	2		1	1				5	Loralai Anjira	E	
	(34 L/8)	(1)		(740)		(500)		(13,000)		(90)		(0.036)				
10	Central part of Block Ⅷ	2		2	1	1	1	4						Loralai	–	–
	(34 L/8)	(54)		(207)		(2,000)		(52,500)		(80)		(0.066)				
11	Eastern part of Block Ⅷ				1	6	2					1	4	Loralai, Anjira	–	C
	(34 L/8)	(1)		(65)		(6,200)		(5,500)		(80)		(0.229)				
12	Western part of Block ⅩⅡ	1		1	4	27	5	3	1			2	11	Anjila, Loralai,	–	C
	(34 L/12)	(7)		(65)		(2,200)		(16,000)		(100)		(0.313)				
13	Eastern part of Block Ⅸ					6	1	1	3			2	5	Anjira, Lorala	–	C
	(34 L/12)	(2)		(25)		(5,800)		(37,500)		(110)		(0.182)				
14	Eastern part of Block Ⅹ	1			1	9							5	Loralai, Anjira	–	C
	(34 L/12)	(30)		(54)		(1,400)		(7,500)		(30)		(0.026)				
15	Eastern part of Block Ⅹ				3	7	2	2				1	2	Loralai, Anjira	–	C
	(34 L/12)	(1)		(56)		(420)		(20,000)		(50)		(0.125)				

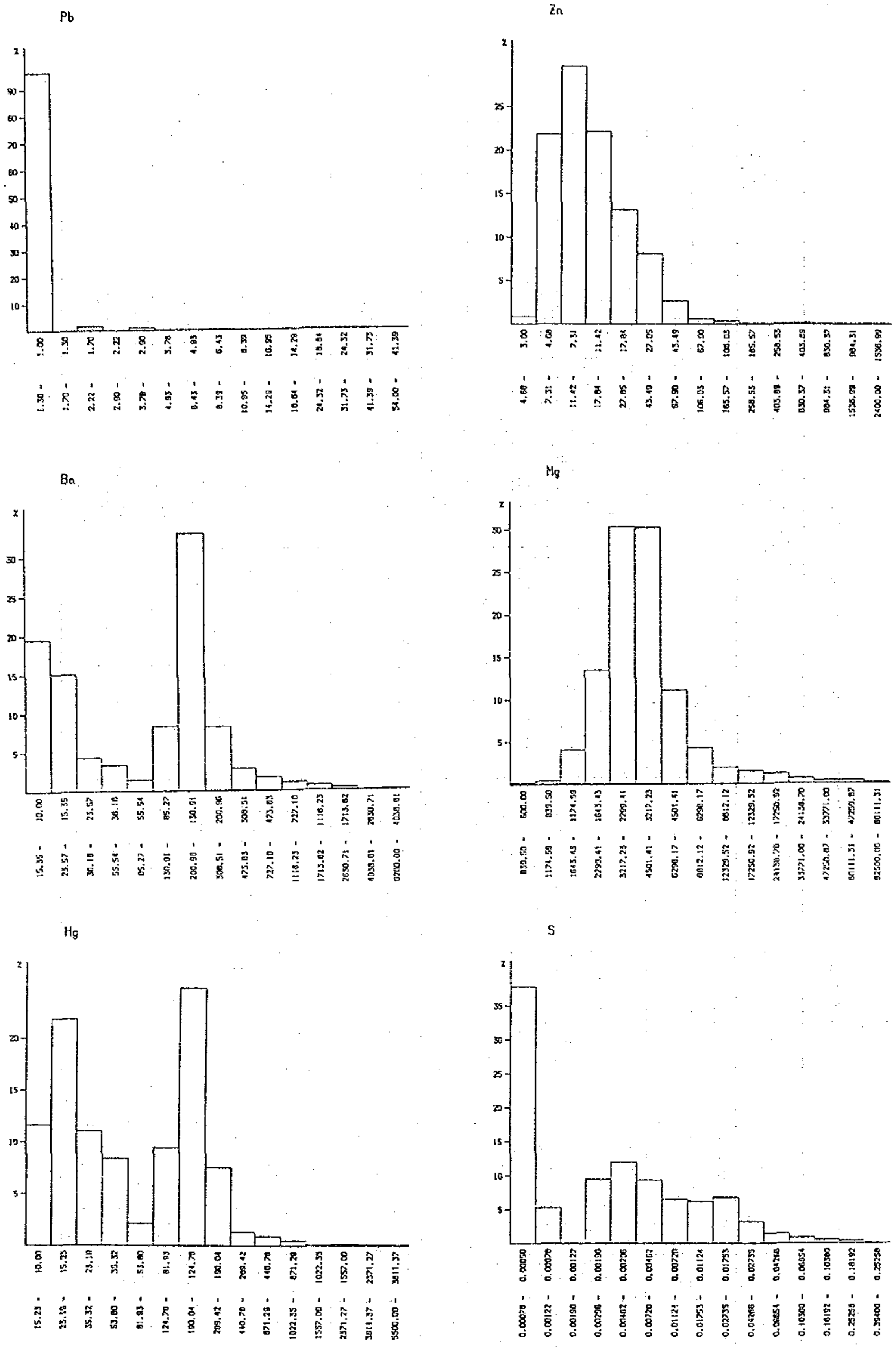


Fig. II-1-3 Histogram of the Six Elements

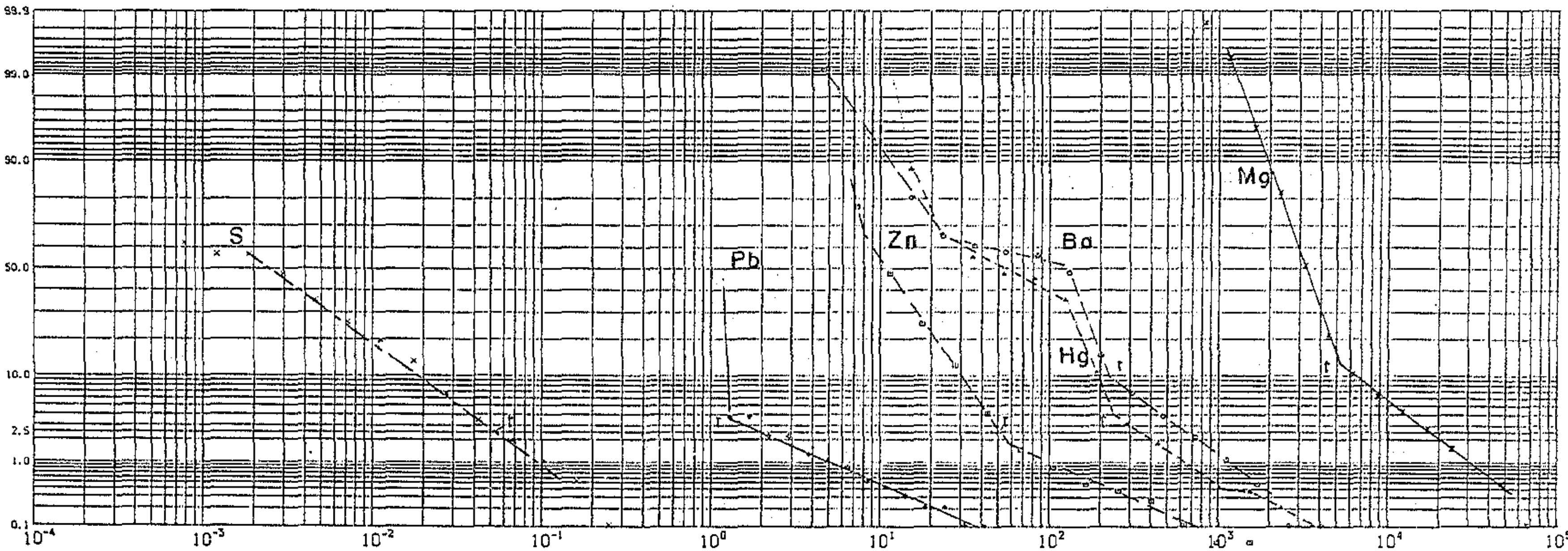


Fig. II-1-4 Cumulative Frequency Distribution Curve of the Six Elements

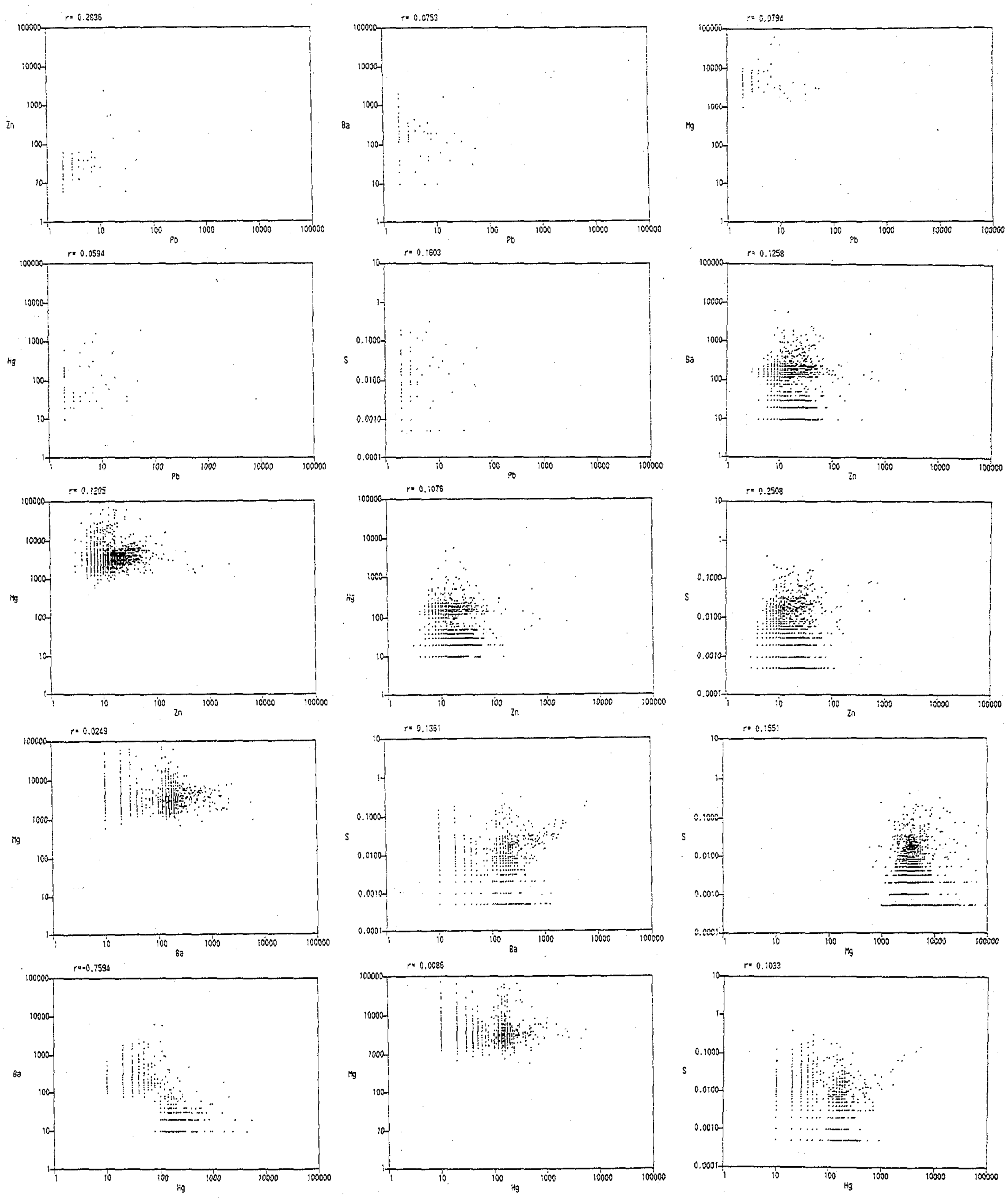


Fig. II-1-5 Correlation Diagram of Geochemical Assay

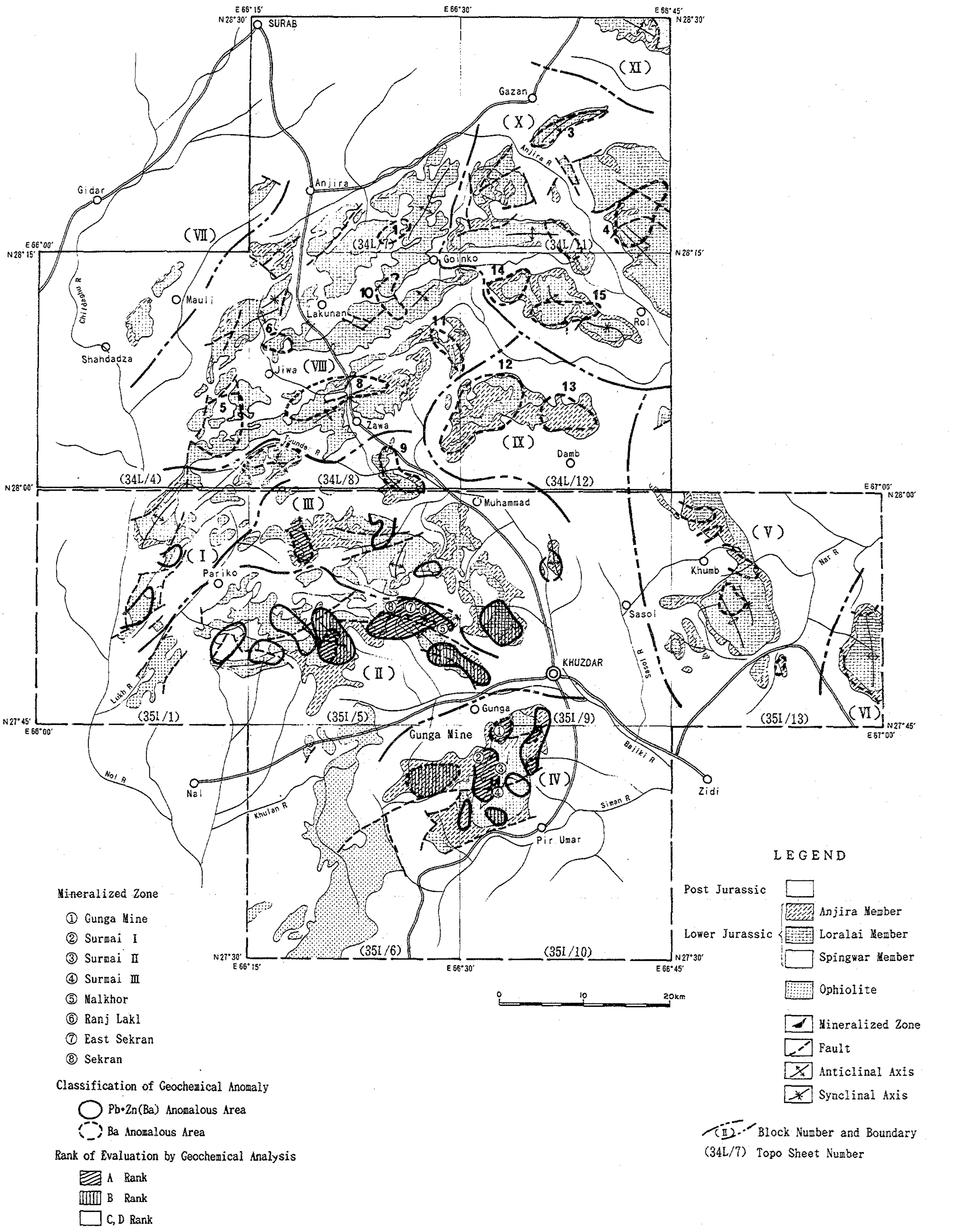


Fig. II-1- 6 Compiled Map of Geochemical Analyses

1 − 3 − 3 Integrated Gochemical Prospecting

1 − 3 − 3 − 1 Outline

Attempts were made to understand the geochemical characteristics of the total area of phases one and two. Data from both phases were used and basic statistical analyses, and principle component analysis were carried out in order to understand the nature of the geochemistry of the area. The results of this study is laid out below.

1 − 3 − 3 − 2 Processing of geochemical data

(1) Basic statistical analysis

The number of analysed samples is 4,633. The statistical data such as mean values (M) and standard deviation (σ) of each element are shown in Table Ⅱ-1-9, the frequency distribution in Fig.Ⅱ-1-7, cumulative frequency distribution in Fig.Ⅱ-1-8, correlation coefficients in Table Ⅱ-1-10, and the scatter diagram in Fig.Ⅱ-1-9.

Threshold values were determined by the method explained in 1-3-2-2, all samples from the first and second phases were used for this process. Also the contour map of each element were prepared by using the moving average method for 1 km grid. The integrated interpretation map is laid out in Figure Ⅱ-1-10 (PL. Ⅱ-1-18) and Figure Ⅱ-1-11 (PL. Ⅱ-1-19).

(2) Principal component analysis

This is a method of summarizing the values of a large number of variants into a smaller number of major variations with as small loss of information as possible. Principal component analysis was carried out for the six elements analysed and the correlation matrix is shown in Table Ⅱ-1-11 and eigenvalue•eigenvector in Table Ⅱ-1-12, the results of factor analysis in Table Ⅱ-1-13, score distribution map of factor analysis in Fig. Ⅱ-1-12～14.

1 − 3 − 3 − 3 Results of analysis

(1) Basic statistical analysis

As seen in the geochemical anomaly maps for each element (PL. II -1-18∼19), all the anomalous zones are distributed in Blocks II and IV centered at Surmai∼Sekran Zone which lies within the first phase area and it was clarified that the zones warranting further investigation do not occur in the second phase area.

(2) Principal component analysis

Analysis was carried out for the six elements analysed for geochemical prospecting. The coefficient of determination of the first principal component is 32.0 %, of the second principal component 26.9 % and of the third principal component is 17.3 %(Table II -1-12). Seventy six percent of all relevant information for variation is included in the data up to the third principal component.

The first principal component: The eigenvectors of lead and zinc are very large and those of sulfur and mercury follow. Lead, zinc and sulfur are all variants related to the lead-zinc mineralization and thus the first principal component is considered to represent the intensity of the lead-zinc mineralization. The high score areas for the first pricipal component are most concentrated in the Surmai∼Sekran Zone and small high score areas are scattered in other areas (Fig. II -1-12).

The second principal component: The absolute values of the eigenvectors is highest for barium and then mercury. The former has positive value and the latter negative.The second principal component shows the intensity of barium mineralization. The high score areas are concentrated in Blocks II, IV, and V. They tend to surround the high score areas of the first principal component in Blocks II and IV. There are small scale high score areas scattered in other Blocks(Fig. II -1-13).

The third principal component: The absolute values of the eigenvectors is large for magnesium. The high score parts of the third principal component are distributed widely from Block I to Ⅷ and their distribution is clearly different from the first and second principal component (Fig. Ⅱ-1-14). In other words, it is shown that magnesium is not related to lead-zinc and barium mineralization.

<u>The fourth principal component:</u> The absolute values of the eigenvectors is in the order of sulfur and magnesium. That for sulfur is positive and is negative for magnesium. The high score parts are of relatively small scale for this component, and there is no correlation with the high score areas of the first to third components. They are distributed widely and suggest the primary nature of the elements. Since they are seen to occur in the vicinity of the high score areas of the first and second components, this could be related to lead-zinc and barium mineralization.

Table II-1-9 List of Statistic Parameters (Combined Phase-I and Phase-II)

		by Member of Shirinab F.				by Block Number										
		Total	Anjira	Loralai	Springwar	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Number of Sample		4,633	1,287	2,914	405	265	731	874	505	339	142	58	905	184	580	50
Pb (ppm)	min	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	max	10,000	10,000	10,000	950	33.0	10,000	4,600	10,000	27	13	2	54	7	30	48
	σ	0.459	0.346	0.489	0.478	0.279	0.736	0.330	0.722	0.302	0.194	0.055	0.134	0.134	0.117	0.235
	ave.(M)	1.49	1.38	1.43	2.61	1.35	3.13	1.40	2.21	1.46	1.20	1.02	1.04	1.08	1.05	1.08
	$M+\sigma$	4.3	3.1	4.40	7.84	2.6	17.0	3.0	11.6	2.9	1.8	1.2	1.4	1.5	1.4	1.9
	$M+2\sigma$	12.4	6.8	13.58	23.56	4.9	93.1	6.4	61.5	5.9	2.9	1.3	1.9	2.0	1.8	3.2
Zn (ppm)	min	1	3	1	1	4	1	1	1	3	5	6	3	4	3	6
	max	10,000	10,000	10,000	5,500	215	10,000	3,340	10,000	90	54	66	2,400	110	96	38
	σ	0.422	0.308	0.461	0.422	0.314	0.640	0.355	0.574	0.309	0.266	0.246	0.299	0.262	0.260	0.200
	ave.(M)	14.50	16.57	13.73	14.13	11.36	20.74	13.17	20.09	14.73	12.88	14.64	12.17	14.63	12.4	10.37
	$M+\sigma$	38	34	40	37	23	90	30	75	30	23	26	24	27	22	16
	$M+2\sigma$	101	68	114	99	48	394	68	282	61	43	45	48	49	41	26.1
Hg (ppb)	min	10	10	10	10	10	10	10	10	10	10	100	10	10	10	100
	max	55,000	4,500	55,000	1,640	1,660	55,000	2,000	29,000	540	90	500	5,500	150	900	220
	σ	0.495	0.406	0.535	0.393	0.392	0.507	0.443	0.559	0.295	0.222	0.141	0.477	0.237	0.394	0.084
	ave.(M)	32.87	29.14	36.38	23.10	22.75	23.90	27.14	25.68	17.55	14.57	159.13	86.17	32.38	28.40	146.80
	$M+\sigma$	103	74	124	57	56	76	75	73	35	24	220	258	56	70	178
	$M+2\sigma$	321	189	428	141	138	245	209	212	68	40	305	775	97	174	216
Ba (ppm)	min	10	10	10	20	10	30	20	50	10	100	10	10	80	10	10
	max	6,800	5,800	6,800	6,400	1,720	5,800	2,700	6,400	6,800	2,800	60	6,200	5,800	1,800	80
	σ	0.481	0.387	0.501	0.301	0.328	0.287	0.200	0.271	0.276	0.244	0.200	0.556	0.310	0.415	0.255
	ave.(M)	131.99	202.18	101.69	226.12	148.43	226.36	194.16	231.65	201.49	211.95	16.34	38.23	242.68	126.17	17.49
	$M+\sigma$	400	492	323	453	316	437	307	432	360	371	26	138	495	328	32
	$M+2\sigma$	1,210	1,199	1023	906	673	847	487	807	718	651	41	496	1,011	853	57
Mg (ppm)	min	300	450	320	300	1,200	320	300	350	800	1,900	1,800	600	700	1,200	1,950
	max	92,500	48,500	92,500	85,000	70,000	70,000	90,000	80,000	52,000	21,000	13,500	92,500	37,500	62,500	17,500
	σ	0.290	0.211	0.287	0.455	0.359	0.343	0.306	0.272	0.249	0.209	0.175	0.270	0.247	0.219	0.165
	ave.(M)	3,604	3,892	3,402	4,297	4,678	3,266	3,129	4,114	4,502	4,094	3,464	3,460	3,649	3,673	3,121
	$M+\sigma$	7,29	6,331	6,588	12,244	10,696	7,200	6,335	7,687	7,985	6,629	5,237	6,448	6,438	6,080	4,563
	$M+2\sigma$	13,709	10,300	12,757	34,890	24,454	15,877	12,828	14,365	14,163	10,734	7,917	12,019	11,360	10,064	6,673
S (%)	min	0.0005	0.0005	0.0005	0.0005	0.0005	<0.001	0.0005	<0.001	0.0005	0.001	0.0005	0.0005	0.0005	0.0005	0.0005
	max	1.21	1.21	0.86	0.64	0.167	0.862	0.123	1.210	0.221	0.301	0.023	0.229	0.313	0.394	0.187
	σ	0.659	0.637	0.638	0.678	0.627	0.661	0.607	0.675	0.604	0.512	0.604	0.643	0.805	0.656	0.665
	ave.(M)	0.003	0.006	0.003	0.004	0.003	0.004	0.003	0.005	0.005	0.007	0.002	0.002	0.004	0.002	0.003
	$M+\sigma$	0.015	0.024	0.011	0.017	0.013	0.017	0.012	0.024	0.022	0.022	0.009	0.010	0.023	0.011	0.016
	$M+2\sigma$	0.068	0.105	0.048	0.083	0.056	0.079	0.049	0.112	0.087	0.079	0.036	0.043	0.144	0.049	0.072

TableII-1-10　Coefficiency Correlation (Combined Phase-I and Phase-II)

Total (N:4,633)

	Pb	Zn	Ba	Mg	Hg
Zn	0.634				
Ba	0.155	0.139			
Mg	-0.037	0.049	0.067		
Hg	0.232	0.301	-0.550	-0.085	
S	0.187	0.247	0.240	0.162	0.071

Loralai M.(N:2,914)

	Pb	Zn	Ba	Mg	Hg
Zn	0.698				
Ba	0.157	0.107			
Mg	-0.098	-0.043	0.003		
Hg	0.279	0.331	-0.629	-0.093	
S	0.209	0.239	0.156	0.125	0.095

Anjira M. (N:1,287)

	Pb	Zn	Ba	Mg	Hg
Zn	0.485				
Ba	0.131	0.211			
Mg	0.150	0.321	0.120		
Hg	0.141	0.234	-0.363	-0.061	
S	0.165	0.239	0.252	0.175	0.110

Spingwar M.(N: 405)

	Pb	Zn	Ba	Mg	Hg
Zn	0.521				
Ba	0.027	0.105			
Mg	-0.041	0.182	0.109		
Hg	0.251	0.324	-0.068	0.034	
S	0.177	0.236	0.345	0.214	0.081

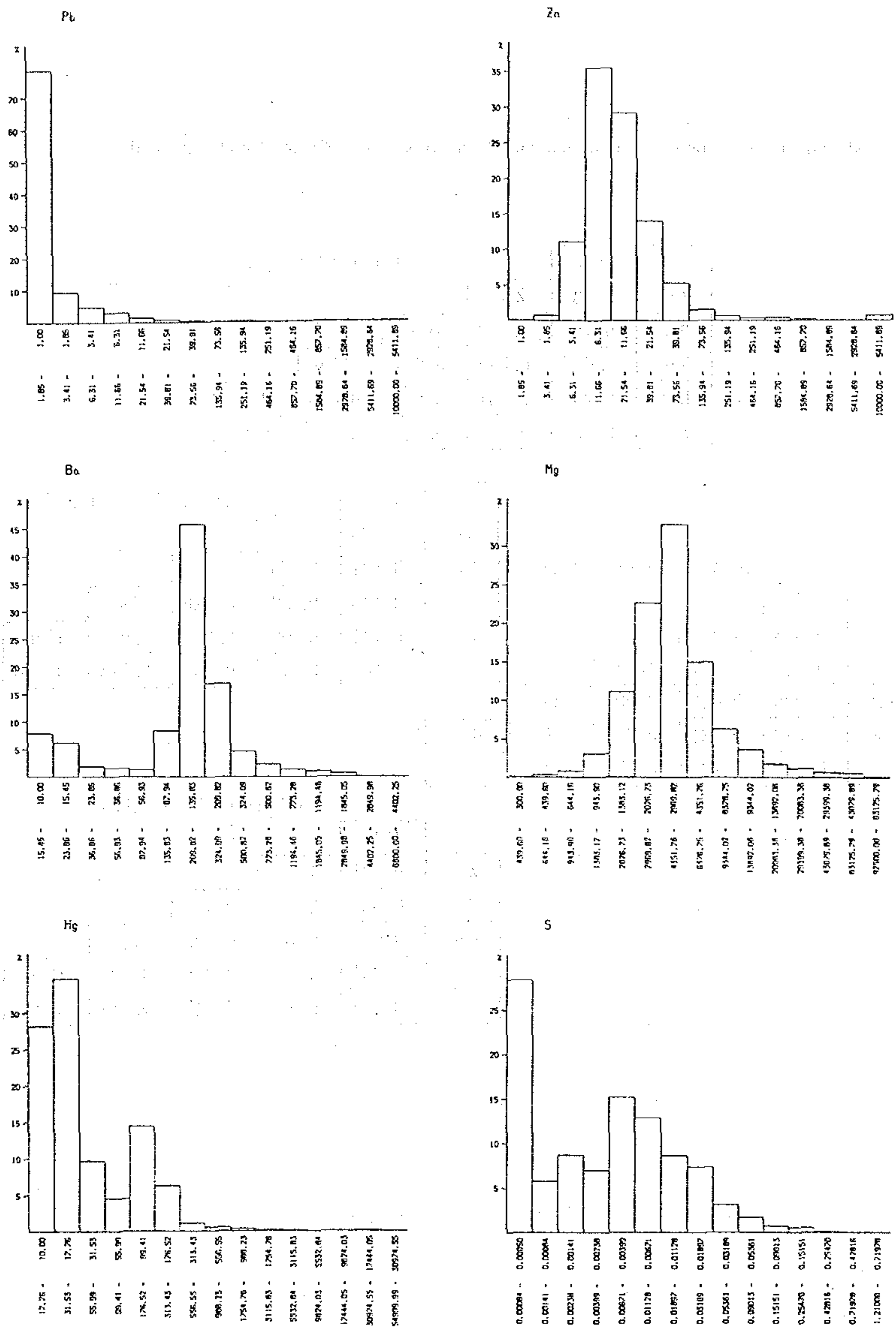


Fig. II-1-7 Histogram of the Six Elements (Combined Phase I and Phase II)

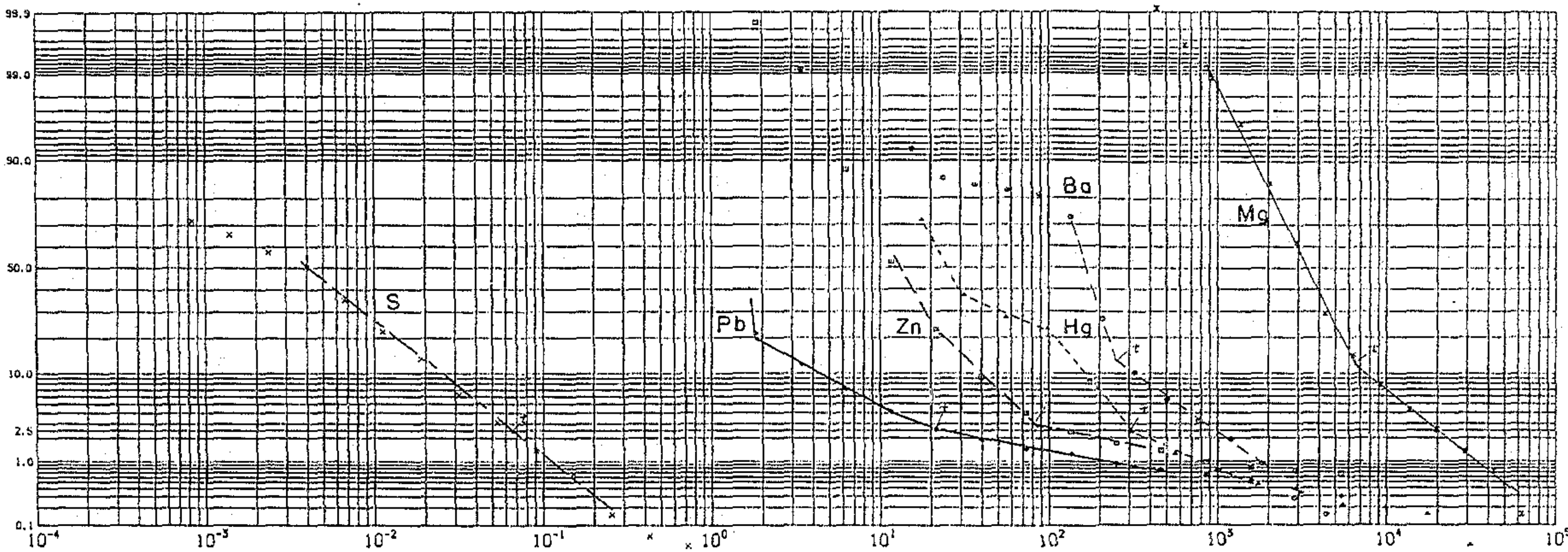


Fig. II-1-8　Cumulative Frequency Distribution Curve of the Six Elements (Combined Phase I and Phase II)

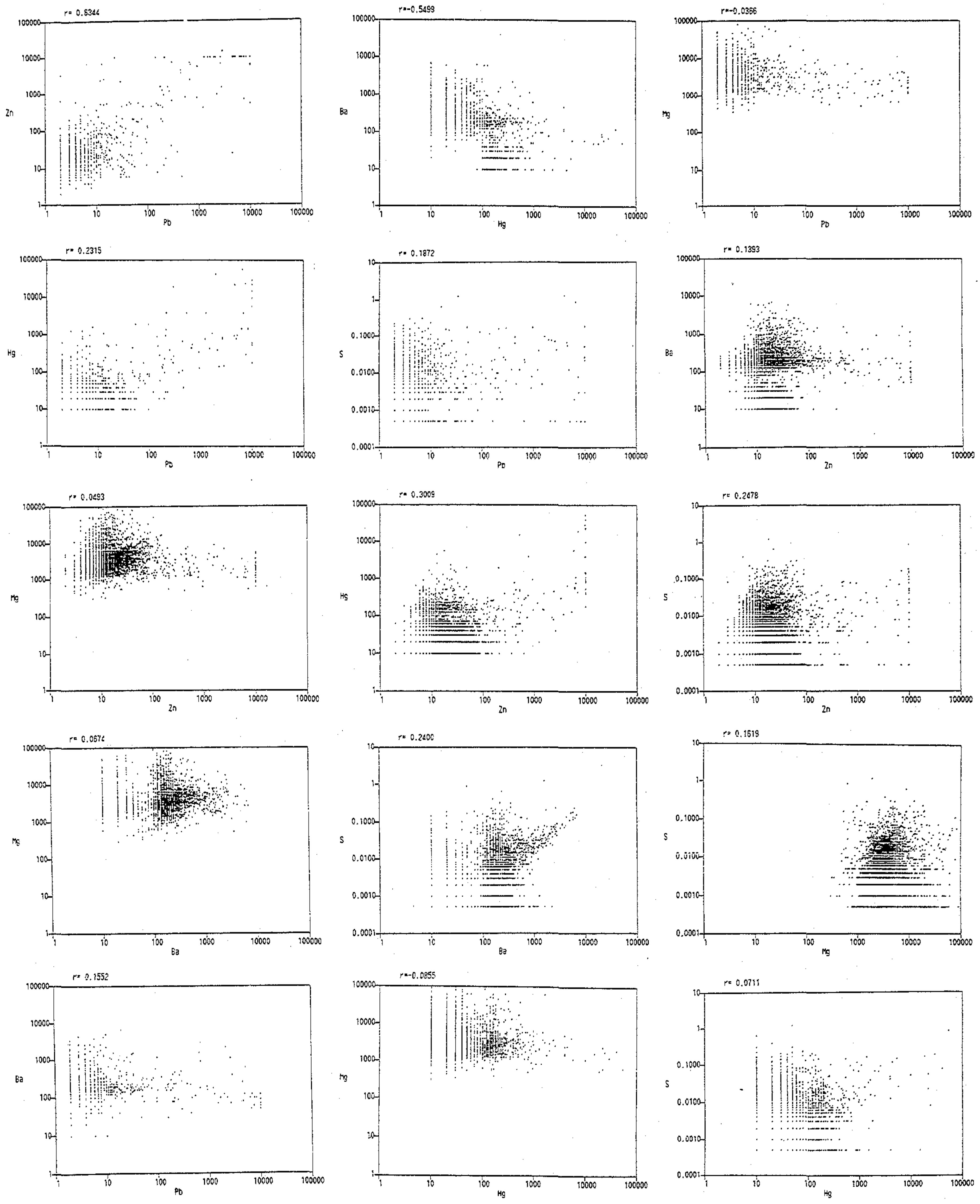


Fig. II-1-9 Correlation Diagram of Geochemical Assay (Combined Phase I and Phase II)

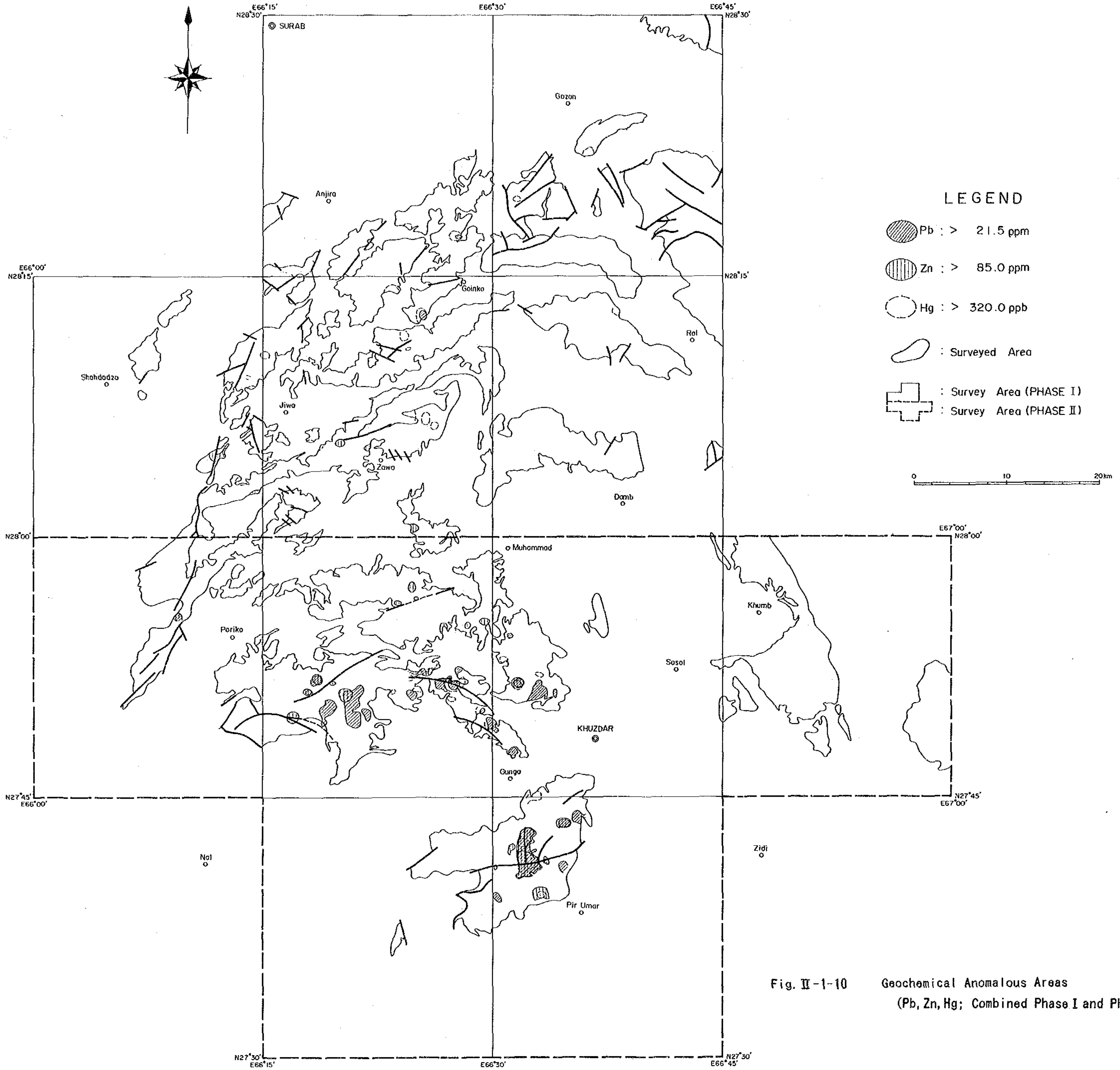


Fig. II-1-10 Geochemical Anomalous Areas
(Pb, Zn, Hg; Combined Phase I and Phase II)

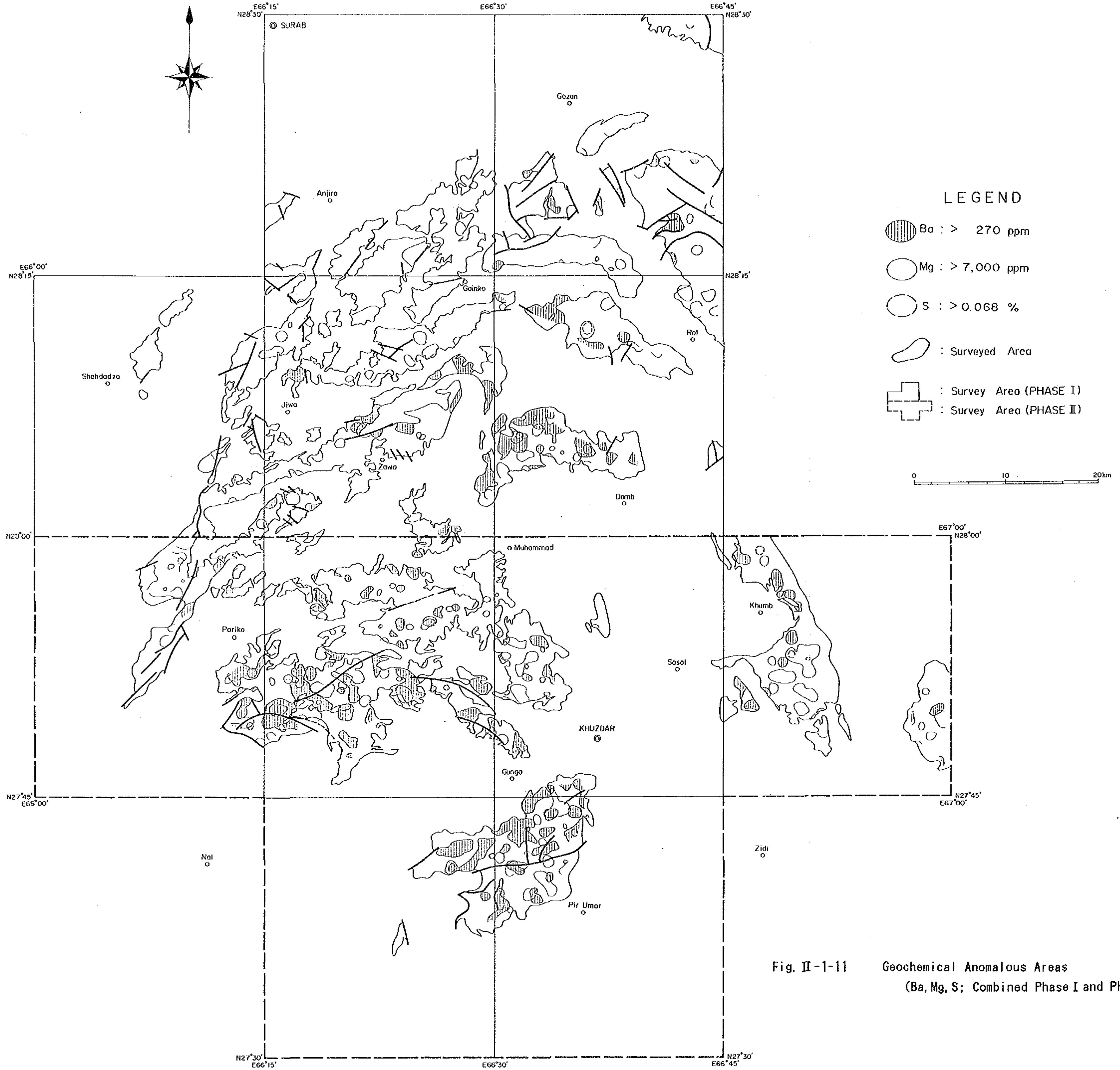


Fig. II-1-11 Geochemical Anomalous Areas
(Ba, Mg, S; Combined Phase I and Phase II)

Table II -1-11　　Correlation Matrix

	Pb	Zn	Hg	Ba	Mg	S
Pb	1.000	0.634	0.231	0.155	-0.037	0.187
Zn	0.634	1.000	0.001	0.139	0.050	0.248
Hg	0.231	0.301	1.000	-0.550	-0.085	0.071
Ba	0.155	0.139	-0.550	1.000	0.067	0.240
Mg	-0.037	0.050	-0.085	0.067	1.000	0.162
S	0.187	0.248	0.071	0.240	0.162	1.000

Table II -1-12　　Eigenvalue and Eigenvector

	1	2	3	4	5	6
Pb	0.600	0.021	-0.257	-0.259	-0.709	0.042
Zn	0.632	0.008	-0.092	-0.225	0.630	-0.382
Hg	0.319	-0.618	-0.251	0.151	0.166	0.655
Ba	0.102	0.698	-0.251	0.008	0.232	0.621
Mg	0.050	0.236	0.823	-0.504	-0.060	0.088
S	0.352	0.275	0.386	0.778	-0.127	-0.173
固　有　値	1.921	1.610	1.042	0.777	0.362	0.288
累積寄与率	0.320	0.589	0.762	0.892	0.952	1.000
標準偏差 *	1.386	1.269	1.021	0.882	0.602	0.537

*:Score Standard Deviation

Table II -1-13　　Factor Loading

	1	2	3	4	5	6
Pb	0.834	0.027	-0.263	-0.228	-0.426	0.022
Zn	0.875	0.010	-0.094	-0.198	0.379	-0.205
Hg	0.443	-0.784	0.196	0.133	0.100	0.352
Ba	0.141	0.885	-0.256	0.007	0.140	0.333
Mg	0.069	0.299	0.839	-0.444	-0.035	0.047
S	0.488	0.349	0.394	0.686	-0.076	-0.093

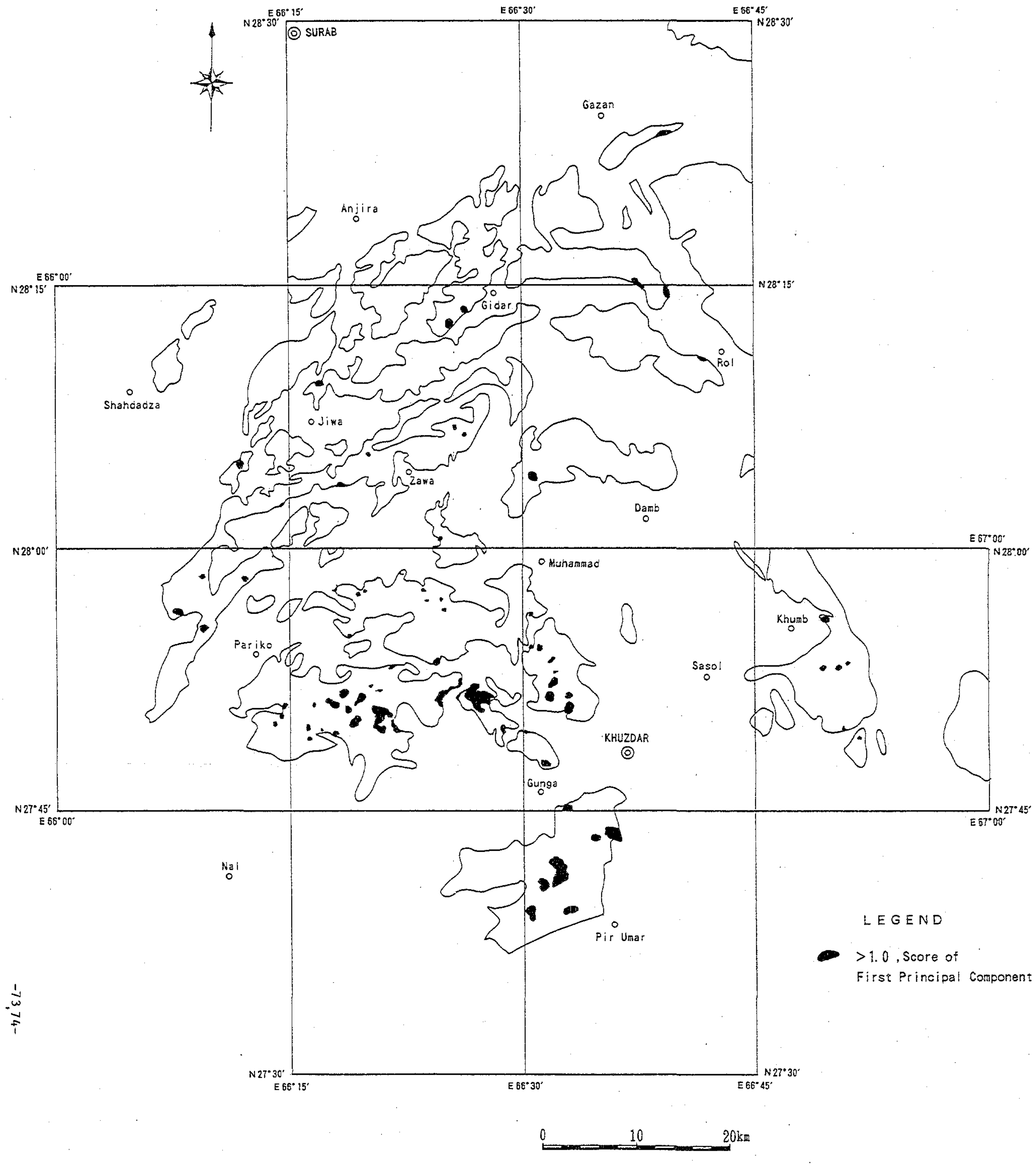


Fig. Ⅱ-1-12 Distribution Map of First Principal Component

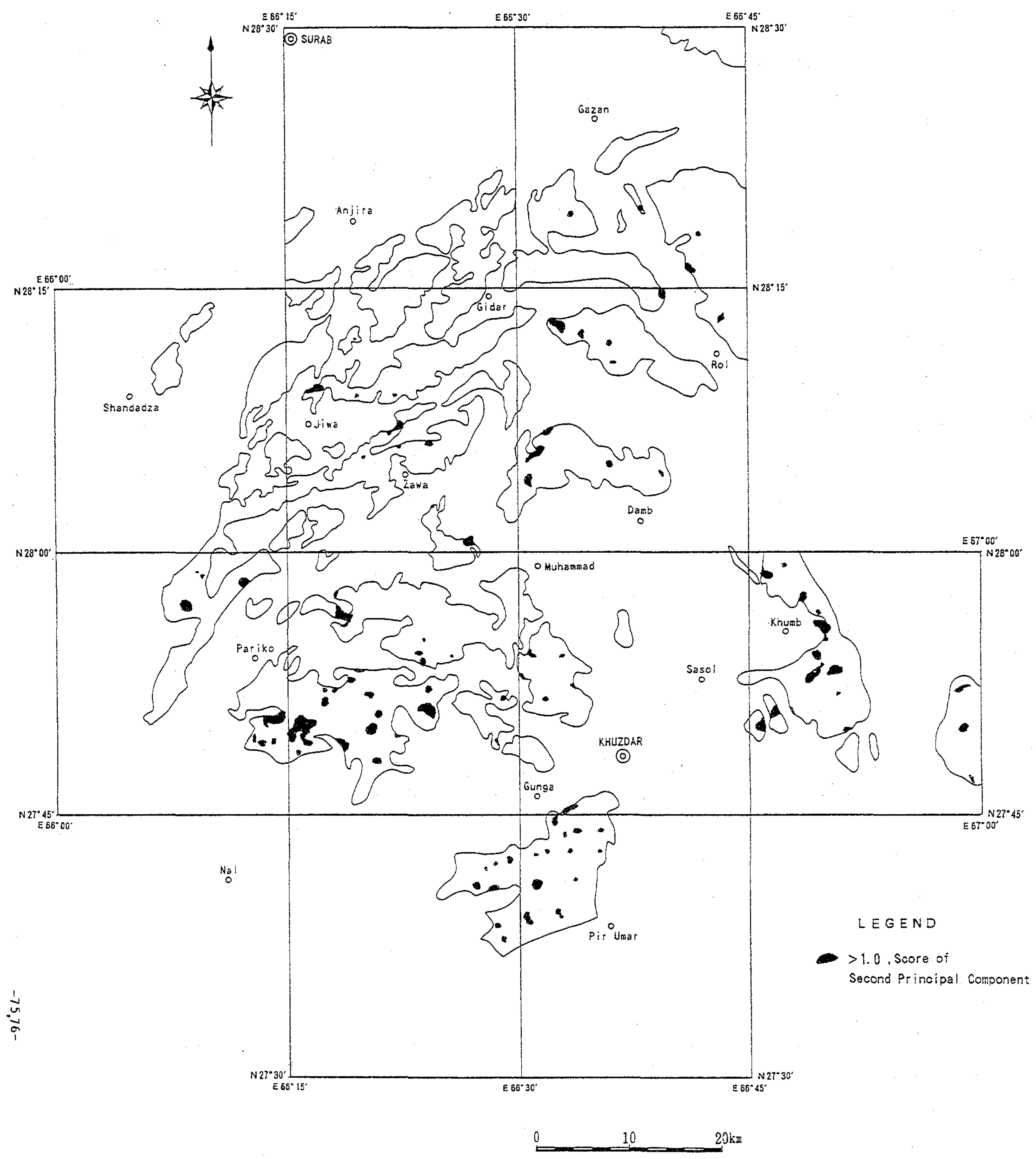


Fig. II-1-13 Distribution Map of Second Principal Component

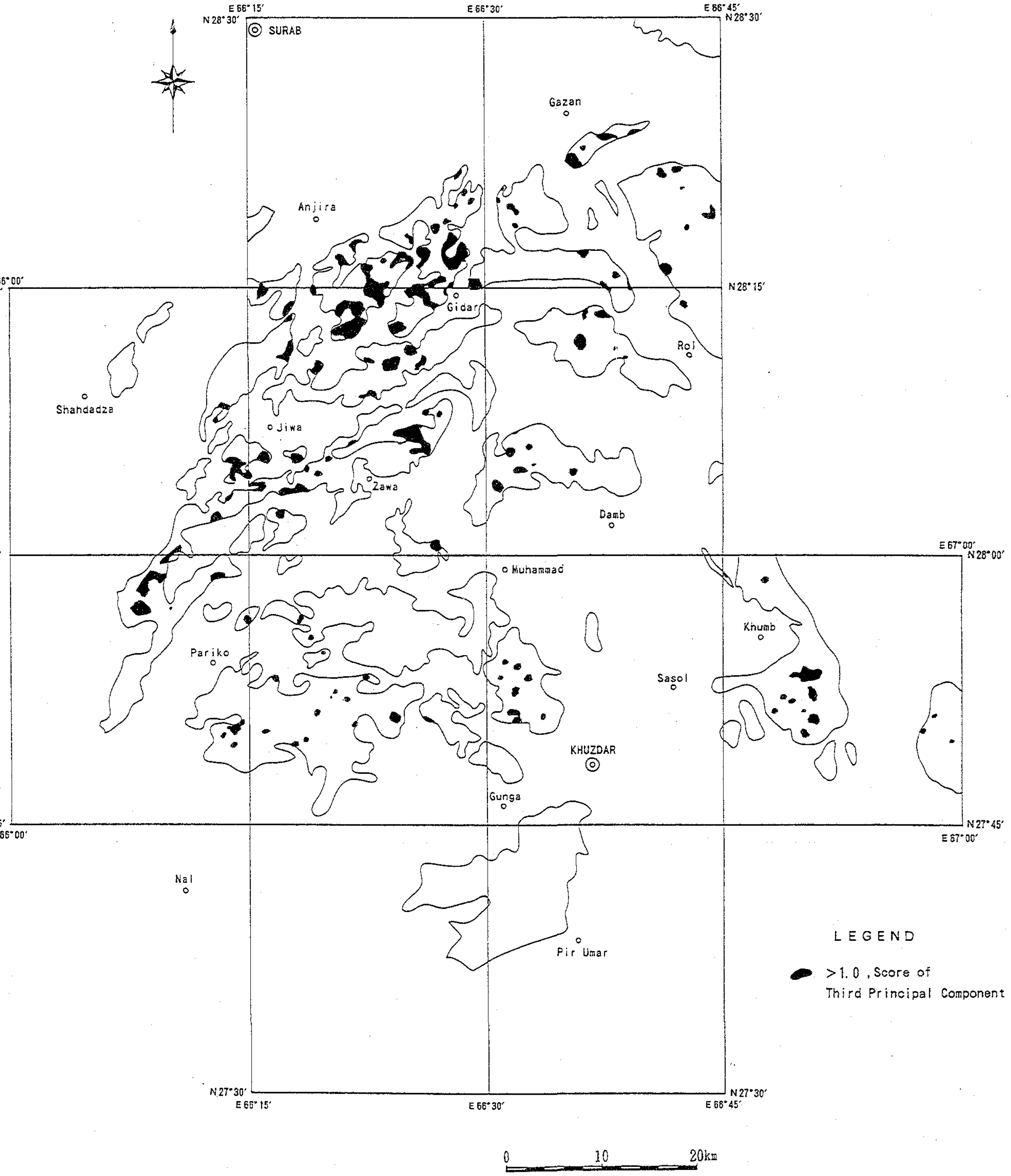


Fig. II-1-14 Distribution Map of Third Principal Component

1 − 4 Discussions

1 − 4 − 1 Characteristics of the Geologic Structure and Mineralization

Within the Khuzdar District, the Surmai Prospect, Markhol～Sekran Prospect and Gunga Deposit occur in a narrow zone, about 25 km long and 2 km wide from Block-Ⅳ to Block-Ⅱ in the area of the first phase survey. This zone is situated in the part where the trend of the Khuzdar Knot structure bends from north-south to east-west. It also surrounds the subsided part where Anjira and the Cretaceous system are distributed. Thus this zone is interpreted to be the uplifted zone near the former sedimentary basin. The Surmai～Sekran Zone divides the Kirthar Fold Belt and the ophiolite belt, and is located in the area of the northern extention of the fault zone trending in north-south direction. It is belived that a large lineation exists in the lower part. The northern end of the ophiolite belt which continues for approximately 200 km from western Karachi, is distributed in the subsided part.

The mineralization which occur in this area is clearly of the Mississippi Valley type lead-zinc concentration. THis is confirmed by the surface survey, drilling in the Surmai Area and the mode of occurrence of the deposit in the Khuzdar District. Also, the Mississippi Valley type lead-zinc-barite deposits of Pakistan mainly occur in the Jurassic limestone in the vicinity of the above ophiolite belt (Fig. I -3-1). The genesis of these deposits is believed to be closely related to the ophiolitic activity.

The Shirinab Formation in the second phase area is distributed around the Surmai～Sekran Zone with repeated folding. The mineral showings of this formation are network of veinlets of limonite, siderite and calcite in the southern part of the area. In other words, the second phase area lies to the north of the lead-zinc prospects of the Surmai～Sekran Zone on the periphery of the ophiolite.

1 − 4 − 2 Relationship of Geochemical Anomalies and Mineralization

Promising geochemical anomalies do not exist in the second phase area in spite of the fact that mineral showings such as Surmai, Gunga and Malkhol∼Sekran were found in the first phase area. The anomalies are scattered and the values are low in the present area. The highest rank of the complex anomalous zone is rank C for barium and only E rank complex anomalous zone are found for lead-zinc.

The distribution of the geochemical anomalous zones of the project area are the lead-zinc anomalies around the ophiolite belt in the southern part of the first phase area which reflect the mineral showings of the Surmai∼Sekran Zone, and the barium anomalies outside of the above.

The rank E anomalies, Nos.5,7,9 in the southernmost part of the second phase area lie at the northern end of the above lead-zinc anomalous zone. And other than that, only the barium anomaly exists in the second phase area. It was clarified by the integrated analysis of the two phases that the promising lead-zinc anomalies exist in the Surmai∼Sekran Zone and its vicinity, these are in the first phase area.

1 − 4 − 3 Mineral Potential of the Survey Area

The mineral showings at Surmai∼Sekran Zone consists of gossan comprising beds∼veins of lead-zinc oxides. And the scale is a hundred to several hundred meters long and several to several tens of meters wide. Veins and veinlets of limonite, siderite and calcite often occur in the vicinity of these prospects. On the other hand, only a few small occurrences of these veins were confirmed by the second phase survey. Also as mentioned in 1-4-1, the second phase area is at the outerside of the lead-zinc mineralized zone.

Regarding the results of geochemical prospecting, the anomalies in the first phase area which are associated with the prospects occur in the rank A lead-zinc complex zone and they extend for several kilometers along the strike of the bedding with barium complex zone on the outside. The anomalous zones of the second phase area, on the other hand, are rank C barium zones and rank E lead-zinc zones. This area is, as mentioned in 1-4-2, lies on the outerside of the high lead-zinc zone of first phase area.

From the above, it is concluded that the mineral potential of the project area lies in the first phase area.

CHAPTER 2 SURMAI AREA

2－1 Survey Methods

2－1－1 Drilling

The mineral showings in this area were long known, but systematic survey started with the sheet mapping of the area by GSP in 1984~1985 (maps unpublished). Three lead-zinc showings (gossan) of Mississippi Valley type occur in three localities arranged in north-south direction. They are called Surmai-Ⅰ, Ⅱ and Ⅲ.

During the first phase, geological survey at 1:2,000 scale, geochemical and geophysical prospecting were carried out for an area of 2 km E-W and 5 km N-S in the vicinity and between the mineral showings. Drilling was recommended for Surmai-Ⅰ and Ⅲ as a result of the above.
A total of six holes were drilled from a station each at Surmai-Ⅰ and Ⅲ. The localities, directions and lengths of each holes are shown in Table Ⅱ-2-1. The sites are shown in Figure Ⅱ-2-1 and Ⅱ-2-2. The order of the drilling operation was from MJP-3,2,1,4 in Surmai-Ⅰ to MJP-6 and 5 in Surmai-Ⅲ. The geologic cross section of the Surmai Area is shown in Figure Ⅱ-2-3.

The core section (column) was prepared in 1:200 scale and the whole core was photographed in colour. The results of ore assay, x-ray powder diffraction, ore microscopy and other laboratory work of the cores were used in the considering the drilling results.

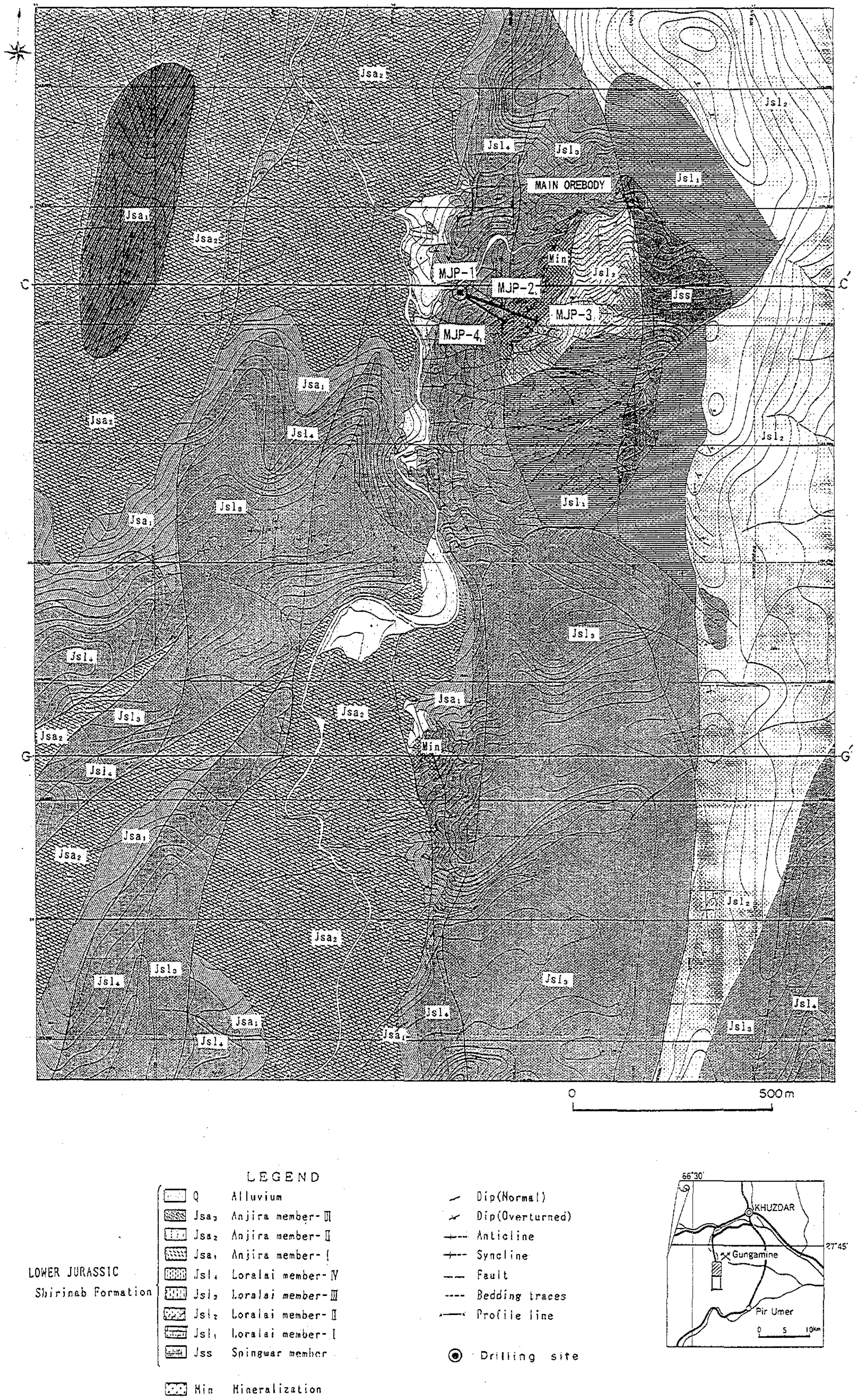
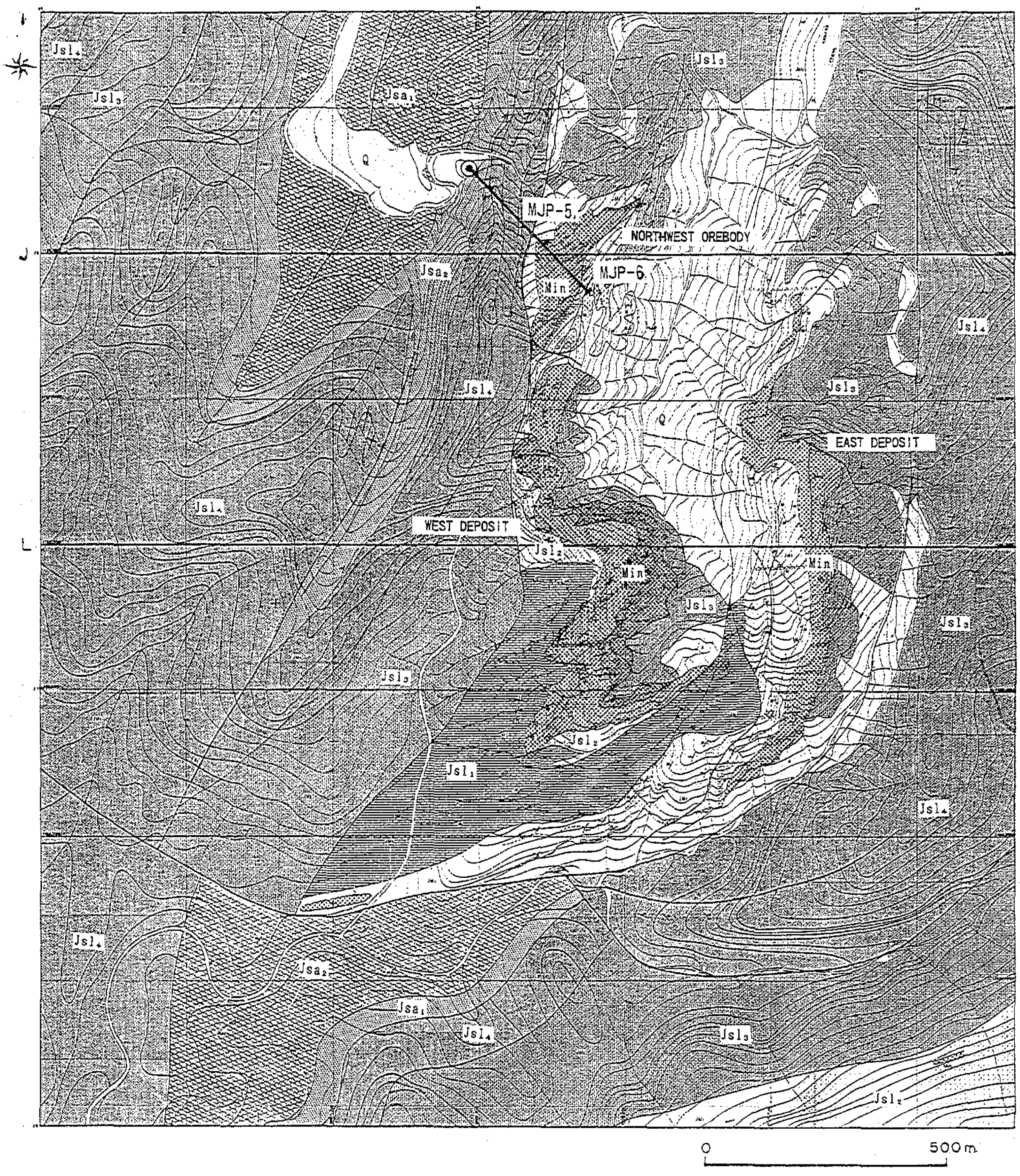


Fig. II-2-1 Geological Map of Surumai-I Area with Location of Phase-II Drillings



LEGEND

LOWER JURASSIC
Shirinab Formation

- Q — Alluvium
- Jsa3 — Anjira member-Ⅲ
- Jsa2 — Anjira member-Ⅱ
- Jsa1 — Anjira member-Ⅰ
- Jsl4 — Loralai member-Ⅳ
- Jsl3 — Loralai member-Ⅲ
- Jsl2 — Loralai member-Ⅱ
- Jsl1 — Loralai member-Ⅰ
- Jss — Spingwar member
- Min — Mineralization

- Dip(Normal)
- Dip(Overturned)
- Anticline
- Syncline
- Fault
- Bedding traces
- Profile line
- Drilling site

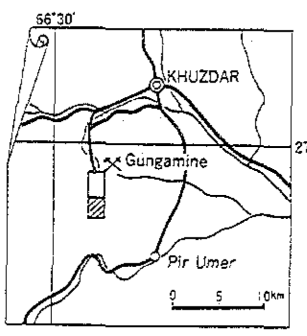


Fig. Ⅱ-2-2 Geological Map of Surumai-Ⅲ Area with Location of Phase-Ⅱ Drillings

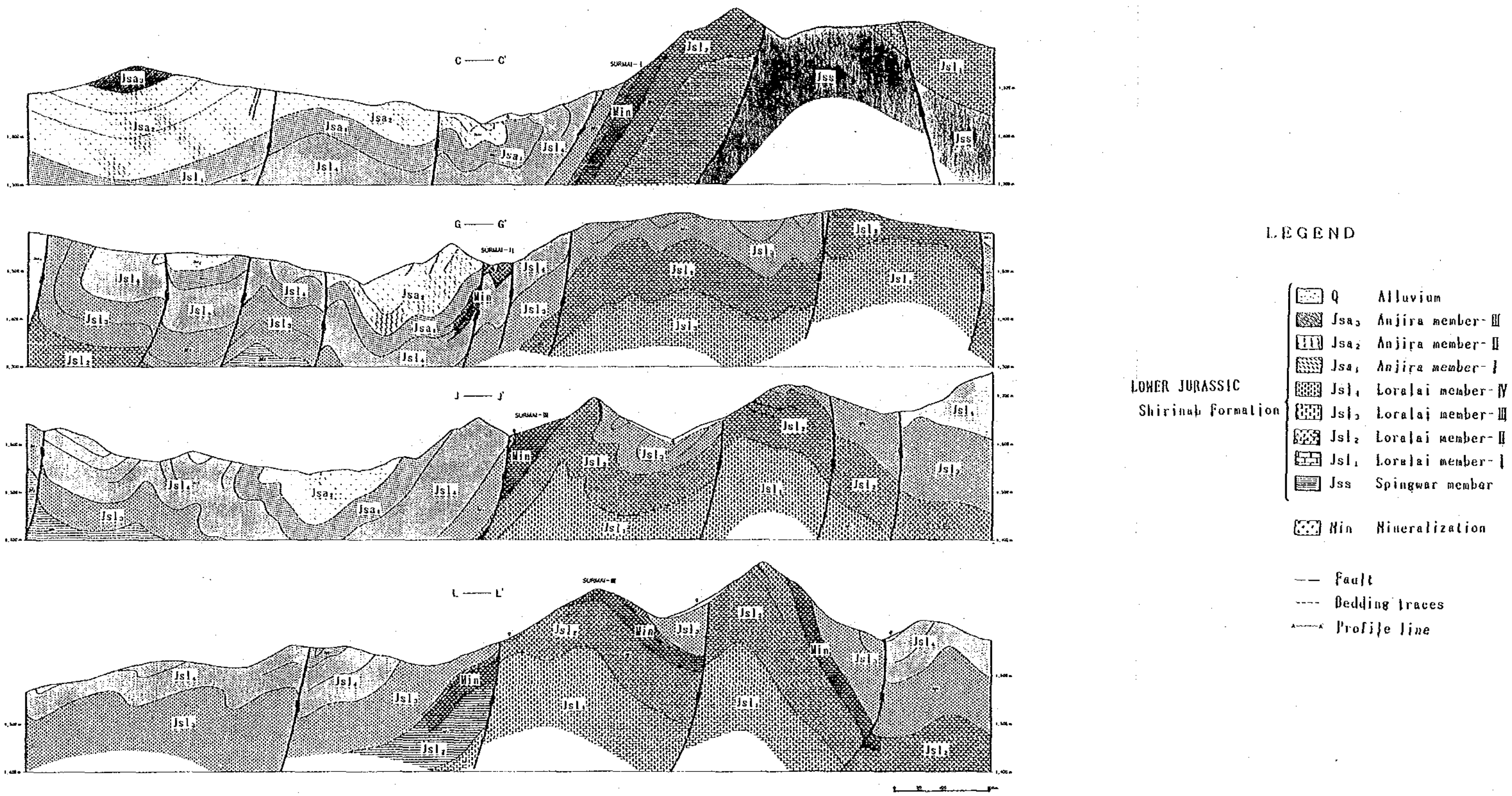


Fig. II-2-3 Geological Profiles of Surumai Area

Table II-2-1 Location, direction and length of drilling

Drill No.	Area, Cordinate (X,Y), Altitude (H)				Direction	Angle	Length
	Area	X	Y	H	from T.N.		
				m			m
MJP-1	Surmai-I	2,008,151	1,125,382	1,461.0	–	-90°	401.0
MJP-2	ditto	ditto	ditto	ditto	108°	-70°	351.0
MJP-3	ditto	ditto	ditto	ditto	108°	-45°	300.8
MJP-4	ditto	ditto	ditto	ditto	118°	-70°	401.0
MJP-5	Surmai-III	2,007,983	1,123,076	1,549.6	135°	-60°	401.0
MJP-6	ditto	ditto	ditto	ditto	135°	-30°	401.0
Total							2,255.8

2 – 1 – 1 – 1 Methods and equipment

(1) Method

For soil containing gravel (1~4 m thick), operation was as follows; drilled by HX single bit (ϕ 114.3 mm), reamed by HX casing metal bit, inserted HX casing. For the bedrock, wireline was used with NQ (ϕ 79 mm) and BQ (ϕ 62 mm) oversized bit. Fractures were developed in the rocks (particularly limestone), thus the fluid was often lost and this was prevented by injecting Tel-stop (Lost circulation material) and cement milk.

(2) Equipment

The rig used was Longyear L-38 and the specifications of the major equipment are shown in Table II-2-2. The use of diamond bit and the expendable items are listed in Table II-2-3~4 respectively.

(3) Working system

The construction, transfer and withdrawal of the drilling equipment were carried out by one shift per day and the drilling operation by three shifts (8 hours per shift) per day. Each shift consisted of one Japanese