

Geochemical Exploration for Metallic Mineral Resources on the Pacitan District, East Java, Indonesia

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인도네시아 빠찌탄지역 금속광물자원에 대한 지화학탐사

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탐사 지역인 빠찌탄지역은 인도네시아 자바섬 동부의 남서익부에 위치하며, 주로 중신세 중기의 퇴적암류 및 이들을 관입한 석영반암과 암맥류들로 구성되어 있다. 빠찌탄 지역 내 금속광화작용과 관련된 이상대 및 이를 기초로 광상을 찾기 위하여 하상퇴적물, 중사 및 토양 등을 이용한 지화학 탐사가 지질학적 탐사와 함께 수행되었다. 상기 지화학탐사 결과들을 종합하여 해석한 결과 금뿔 (동), 쩌뿔 (금), 까시한 (동-연-아연) 등의 세 지역이 정밀 조사가 필요한 유망 금속 광화 이상대로 확인되었다. 이중 까시한지역은 동-연-아연의 이상치가 가장 강하게 증척된 지역으로서 정밀 토양 지화학 탐사와 함께 잠두광체 확인을 위한 지질학적 탐사가 수행되었다. 까시한지역에 대한 정밀 토양 지화학탐사 결과에 대한 통계학적 해석 결과 10 곳의 이상대가 확인 되었으며, 이 중 5개 이상대는 까시한지역 중앙부 석영반암 관입 분포 지역에 밀집 위치하고 있음이 확인되었다. 이들 이상대는 석영 반암의 관입과 관련된 함 동-연-아연 망상형 맥상 광체 및 스퀴르 광체와 관련되어 있음이 확인되었다.

주요어 : 지화학탐사, 통계학적 해석, 이상대, 빠찌탄, 인도네시아

The geology of the Pacitan district which occupies Southern mountain zone in the southwestern margin of East Java, Indonesia, consists of a pile of clastics and pyroclastics grading upwards into a series of sediments of Middle Miocene age which are intruded by a number of quartz porphyries and subvolcanic dacitic to andesitic bodies in after that time. The geochemical exploration in the Pacitan district to find out anomalous areas related with metallic mineral dispersion from the concealed ore deposits had been carried out using traditional exploration techniques of geological mapping, stream sediment, panned concentrate and outcrop sampling. The anomalous zones of each element were detected in the following areas: Gempol for Cu; Jompong for Au; Kasihan for Cu-Pb-Zn. The strongest Cu-Pb-Zn anomalous values are overlapped at the Kasihan area. The geochemical survey of soil was conducted with the geological survey at the Kasihan area. The statistical values were calculated by the statistical analysis method. The patterns for Cu, Pb and Zn are similar to the normal distribution. The anomalous values of copper-lead-zinc and/or copper and zinc are overlapped at five zones surrounding quartz porphyry at the central part of the Kasihan area. The area was interpreted and chosen as an anomalous zone related with stockwork and skarn mineralization, extending to approximately NNW-SSE direction.

Key words : geochemical exploration, statistical analysis, anomalous areas, Pacitan district, Indonesia

1. Introduction

The Pacitan district lies on the south western portions in the East Java, near the boundary of

central Java (Fig. 1). The partial geological survey of the Pacitan and Ponorogo area had been carried out by many geologists since 1908 and the occurrences of hydrothermal vein type ore mineralization had been recognized in the district, as the potential area of gold and copper. Small quantities of gold and

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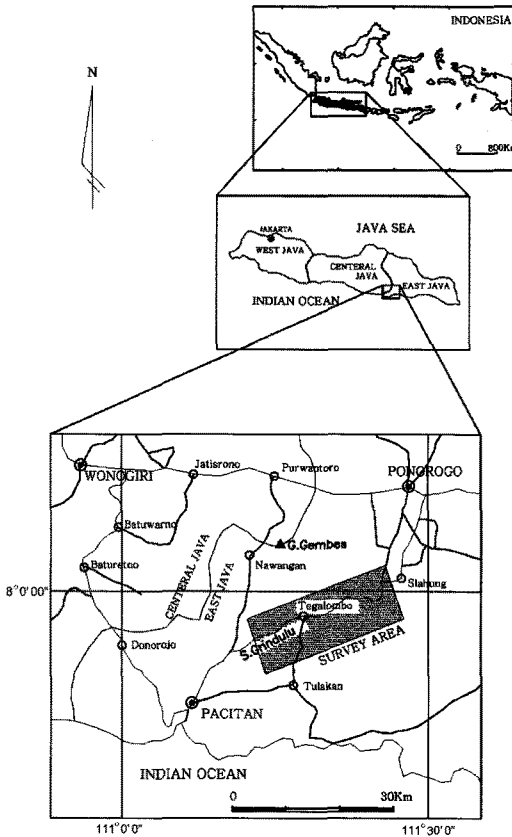


Fig. 1. Location of the Pacitan district, East Java, showing the survey area.

copper had mined at hydrothermal vein deposits in the district before World War II. There are some old adits and pits which had been worked at that time.

Extensive base-metal and/or gold bearing skarn and hydrothermal mineralizations have been found recently in the Pacitan district of East Java, Indonesia. These are the new discoveries of base-metal (and/or gold) occurrences in the district which are the results of the systematic exploration for the mineral resources in the Pacitan district had undertaken by the Joint Mineral Exploration between Korea Resources Corporation (KORES), Korea and the Directorate of Mineral Resources (DMR), Indonesia (1991, 1992, and 1993).

In 1991, the first phase survey was carried out a regional survey involving geological, geochemical and geophysical investigations to find out potential area of the base metal and/or gold in the district of approximately 280 km². During the second phase

survey in 1992, a follow-up survey was carried out four potential mineralized areas; Gempol, Jompong, Kasihan and Tukung, resulting from the geochemical exploration with stream sediment and panned concentrate samples of the first phase. From the result of the second phase survey, the Kasihan area was thought to be prospective for finding new deposits. During the exploration, several base metal outcrops were discovered at many sites in the Kasihan area.

This paper presents the result of the geochemical prospecting work undertaken during 1991-1993 in the district.

2. Geology

The geology of the Pacitan district within the Southern mountain zone in the southwestern margin of East Java, Indonesia is shown on the geologic map in Fig. 2. Five main lithostratigraphic units are recognized in the district: Arjosari, Mandalika and Watupatok Formation of the Late Oligocene to Early Miocene, and Jaten and Wuni Formation of the Middle Miocene sedimentary rocks, and younger intrusive rocks.

A number of small porphyritic intrusions of dacitic to andesitic compositions crop out within most of the Pacitan district. Many porphyritic intrusions and andesitic dykes ubiquitously intrude the above mentioned volcanics and sedimentary rocks. Later ore-bearing quartz veins crosscut the sedimentary rocks, volcanics, intrusions and andesite dykes. The lack of significant metamorphic aureoles around these intrusives and the fine grained nature of their groundmass imply they were relatively cool, shallow emplacements. The ore mineralization in the district is likely to be associated with quartz porphyry.

3. Geochemical Exploration

The main objectives of the geochemical exploration were to explore metallic mineralization, and to find out anomalous areas related with mineral dispersion from the concealed ore deposits.

Exploration carried out in the Pacitan district between 1991 and 1993 consisted of:

- semi-regional stream sediment sampling and pan concentrate sampling

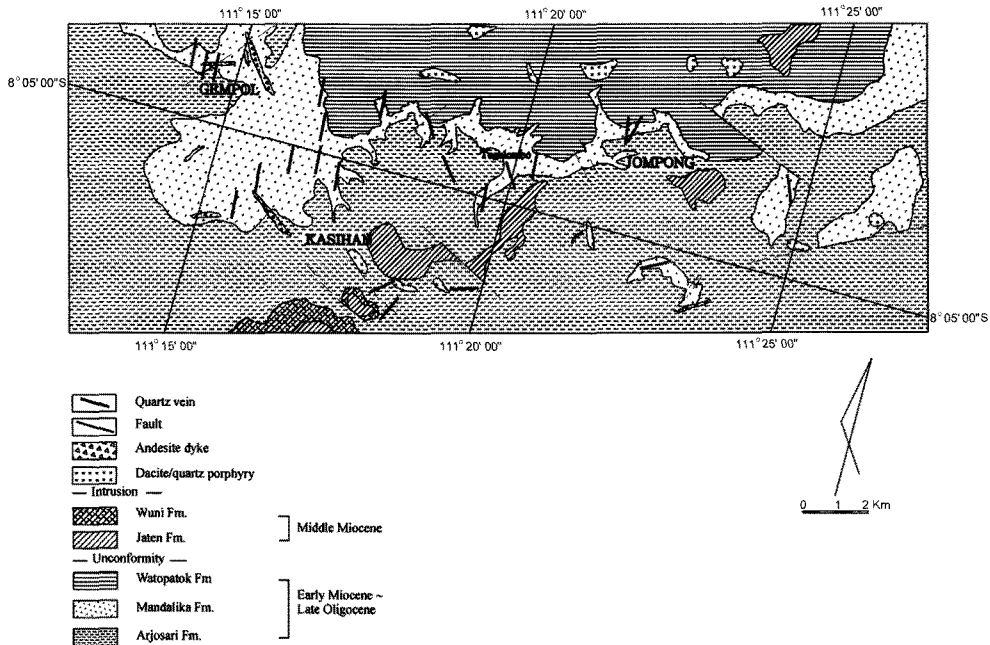


Fig. 2. General geology of the Pacitan district, and location of the each mineralized area.

- geological mapping at a scale of 1:25,000~10,000
- gravity, magnetic, resistivity and VLF-EM surveys
- detailed geological survey with topographical measurement at a scale of 1:1,000
- assaying for Au, Ag, Cu, Pb, Zn, As and Sb.

The aim of Phase I was to determine the location of base metal mineralization within the prospect area and carried out stream sediment, pan concentrate, outcrop and float sampling. Regional geological mapping at scale of 1:25,000 proceeded. For the main objective of the Phase I, the geochemical survey was carried out and found out anomalous area related mineral dispersion from the concealed ore deposits. The geological mapping delineated the distribution of the main rock units and alteration types.

Phase II exploration work delineated the surface extent of the quartz veins and the distribution of orebodies along strike, revealing the resources potential of the prospect. On the basis of results from the reconnaissance geological and geochemical survey of the Phase I, exploration methods included a sub-detailed geological mapping at scale of 1:5,000 and geochemical survey with soil sampling. Based on the detailed geological, geochemical and geophysical data, the Kasihan as the most prospective area was selected for a scout drilling program.

The sampling for stream sediment and panned concentrate was conducted in the survey area of 280 km², keeping pace with regional geological survey. During this survey, 232 stream sediment and 239 panned concentrate samples were taken and prepared in the field. Samplings were made at the interval of approximately 800 m along the river mainly in the first and second order creeks. The sample locations are shown in Fig. 3.

From the results of the regional geochemical exploration of Phase I, three prominent potential mineralized zones are selected: namely Gempol, Jompong and Kasihan. Because the scale of the mineralization and the grade of ore outcrop in the Kasihan area are more relatively favorable than other mineralized zones, the Kasihan area of 6km² was recommended to conduct soil sampling for the follow-up exploration in Phase II. Soil sampling was carried out randomly on the ridge ("spur-ridge system") and on the left or right banks of stream sediment sampling sites ("base-slope system"). These samples were taken at the B horizon, using a wood bar to avoid metallic contamination, with sampling intervals from 80 to 100 meters, approximately.

Sample locations were chosen to avoid all known contamination such as domestic, agriculture, and mining.

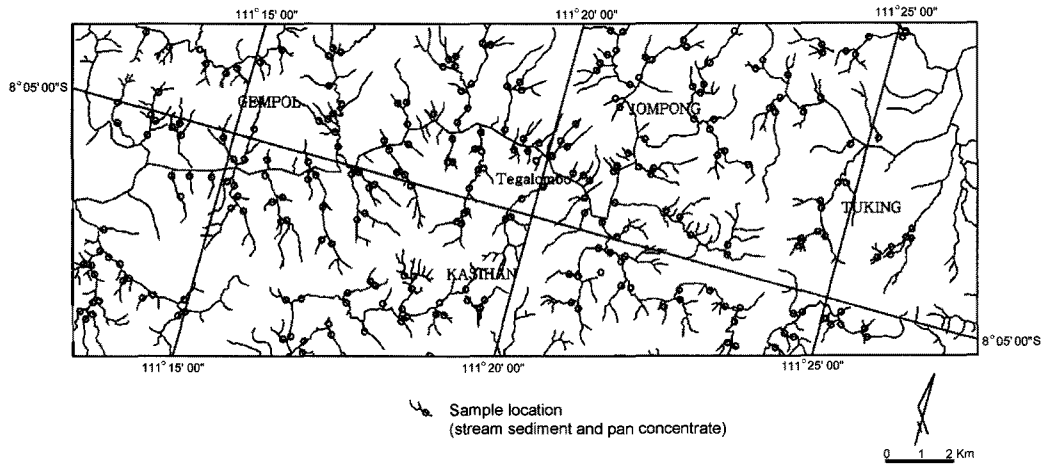


Fig. 3. Sampling location map of stream sediments and panned concentrate samples.

3.1. Geochemical Survey with Panned Concentrates

3.1.1. Sample preparation and analyses

The procedures of sampling for panned concentrates are as follows.

- digging until 30 cm in depth to collect coarse materials about 12 liters.
- panshaking under water to collect heavy minerals
- collecting heavy mineral of 200-400 g in weight.

The distribution and content of the heavy minerals can be known by mineralogical analyses in panned concentrate samples. From the characteristic distribution of each mineral content in panned

concentrate samples, the maximum and minimum percentages of minerals can be determined.

3.1.2. Distribution of main minerals

From the mineralogical analyses, the distribution percentages of main mineral content in the survey are shown in Table 1 and Fig. 4.

3.2. Geochemical Survey with Stream Sediment

3.2.1. Sample preparation and analyses

Stream sediment samples were collected at a density of 2 to 4 samples per km² with at -80 mesh

Table 1. Distribution of main heavy minerals

Minerals	Content (%)		Frequency (%)	Population	Max. Distribution Area
	Max.	Min.			
Gold	44 C	1 C	1-10 color	18	K. Picisan
			44 color	1	
	Total population			19	
Chalcopyrite	0.98	trace	trace	88	K. Kandangan
			0.003-0.009	7	
			0.01-0.09	21	
			0.1-0.8	8	
Total population			124		
Galena	1.29	trace	trace	53	K. Gedungbiru
			0.007-0.01	4	
			0.011-0.04	4	
			0.10-1.29	2	
Total population			63		
Sphalerite	0.01	trace	trace	32	K. Salak
			0.01	1	
Total population			33		

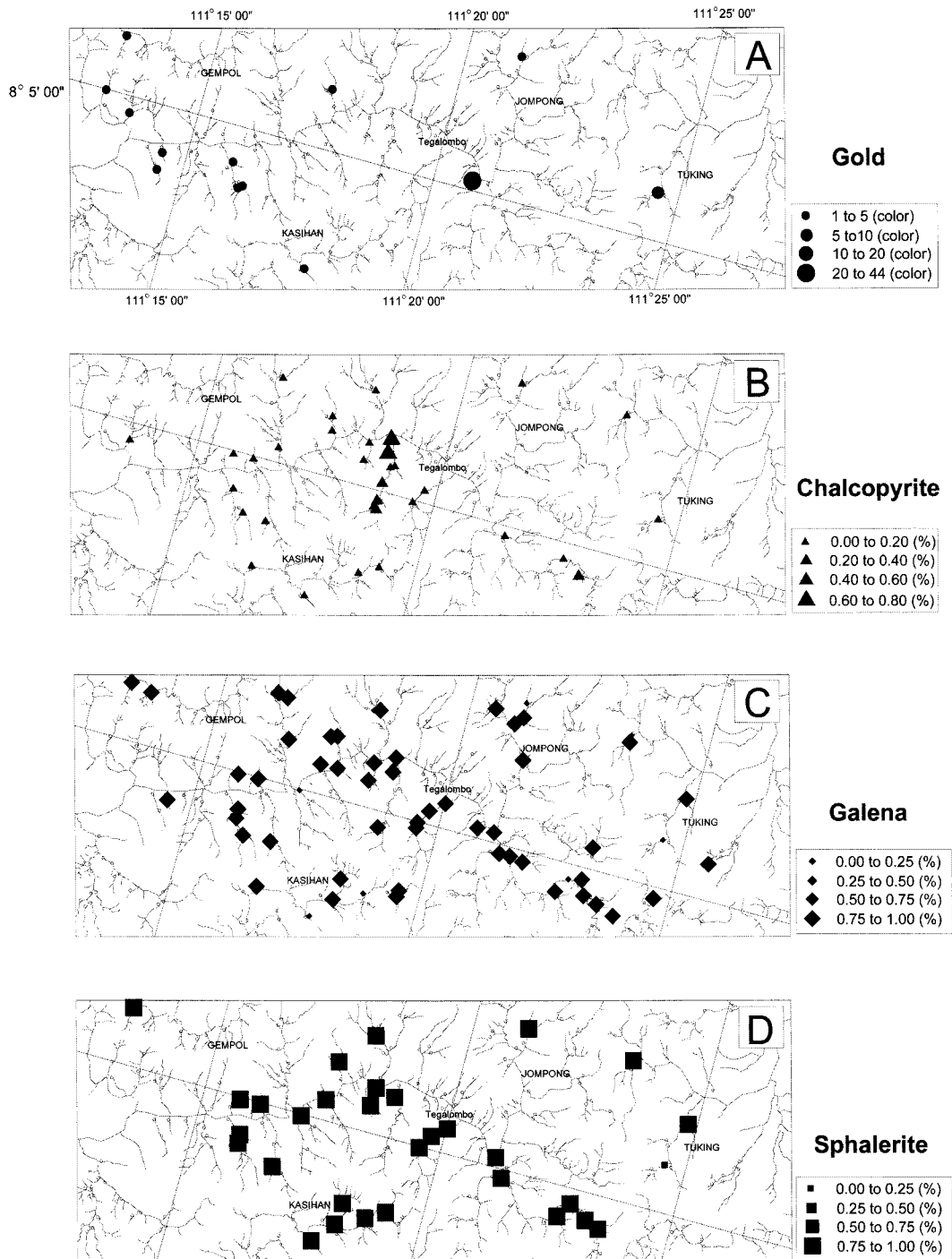


Fig. 4. Distributions of ore minerals in panned concentrates, showing the frequency of gold grains (A) and the variations of the percentage for each sulfide mineral; chalcopyrite (B), sphalerite (C) and galena (D).

fraction and dry sieved to -200 mesh in the laboratory.
 Procedures of sampling for stream sediment are

as follows;
 - collecting the fine materials from river by hand

- putting collected materials onto 80 mesh sieve and stirring
- collecting stream sediments of 400-500 g in weight under 80 mesh.

After drying, samples were crushed by mortar and sieved under 200 mesh. From sieved materials, stream sediments of 200-300 g in weight were collected. By quartering and splitting, stream sediment of 50-100 g in weight was made : one for chemical analysis and the other for duplication. Au, Ag, Cu, Pb and Zn were analyzed by Atomic Absorption Spectrophotometry (AAS), and the other elements (Sb and As) analysed by colorimetry. Their detection limits are as follows: Au, 1 ppb; Ag, 0.5 ppm; Cu, 5 ppm; Pb, 5 ppm; Zn, 5 ppm; Sb, 1 ppm; As, 2 ppm.

3.2.2. Geochemical data processing

The statistical method is modified from Sinclair's methods (1974) as follows:

- convert the analysis data to logarithms
- classify the cumulative frequency distribution into 9~19 groups to closely approach log-normal frequency distribution and select the number of intervals in frequency distribution for each element
- draw the cumulative frequency curve
- determine the background value, threshold value and anomalous value corresponding to the 50th percentile, the 95th percentile and the 97.5 percentile of the cumulative frequency distribution, respectively.

The patterns for Au, Cu, Pb and Zn are similar to the normal distribution, whereas the frequency of Ag, Sb and As are L-shaped, and many of values are less than the lower detection limit with an asymmetric L-shape tending toward lower grades. Through logarithm conversion, they were grouped

into 19 classes for the preparation of histogram. The analytical values of Ag, Sb and As were excluded for delineation of anomaly, because these elements could not produce the log-normal cumulative frequency distribution. Evaluation of the analytical data indicated three classes of 4 elements (Au, Cu, Pb and Zn): background value, threshold value (weak anomaly; $95\% \leq X < 97.5\%$) and anomaly value (strong anomaly; $97.5\% \leq X$). Distribution characteristics of each element processed by statistics are outlined in Table 2.

3.2.3. Geochemical anomaly patterns

From the data analyses, computerized anomaly areas for each element (Au, Cu, Pb and Zn) are shown in Fig. 5. These anomalous areas combined with topography can be visualized (Fig. 6 and Table 3).

The anomalous zones of each element were detected in the following areas: Gempol for Cu; Jompong for Au; Kasihan for Cu-Pb-Zn. However, the strongest Cu-Pb-Zn anomalous values are overlapped in the Kasihan zone (Fig. 6). From the results of geological and regional geochemical survey of phase I, the Kasihan area was recommended for the follow-up work to clarify the nature of the mineralization and to find out anomalous area related mineral dispersion from the concealed ore deposits.

3.3. Geochemical Patterns in Soil on Kasihan Area

3.3.1. Sample preparation of soil

Geochemical survey of soil was conducted with the geological survey in Kasihan. Field observation for each location included the numbers of sample, elevation, slope, rock type, stream physical features

Table 2. Results of simplified statistical treatment from geochemical data

Elements (ppm)	Max. value	Min. value	Mean value	Background value	Threshold value	Anomalous value
Au*	58.5	<1.0	6.2	2.95	18.26	26.62
Ag	12.0	2.0	2.7		not calculated	
Cu	524.0	13.0	73.4	48.08	154.93	190.78
Pb	660.0	12.0	34.3	19.63	63.89	97.62
Zn	1,818.0	77.0	227.0	156.24	536.99	776.54
Sb	175.0	1.1	3.0		not calculated	
As	14.0	1.1	2.6		not calculated	

*Unit of Au contents is ppb.

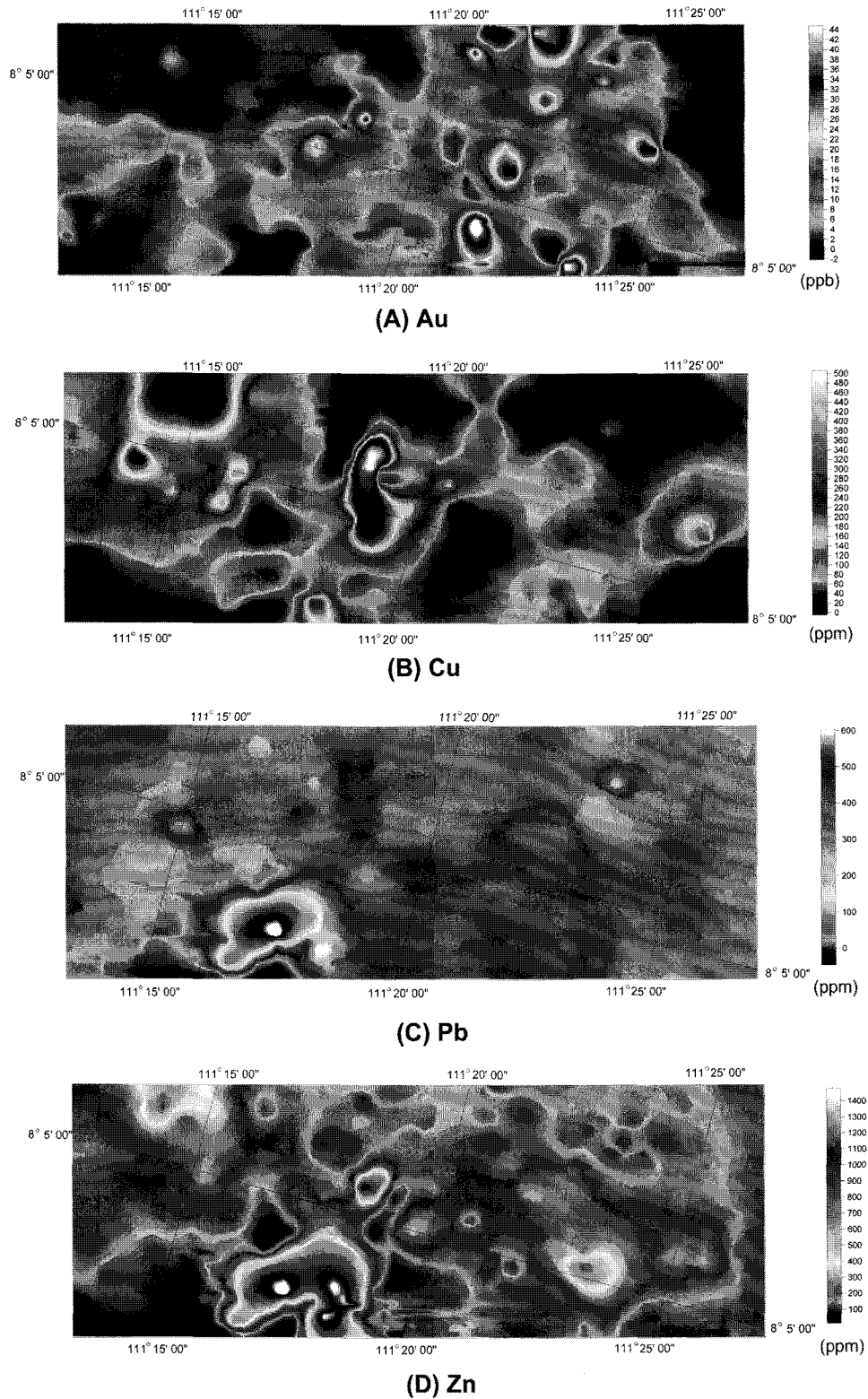


Fig. 5. Contour maps showing the concentration variations of Au (A), Cu (B), Pb (C) and Zn (D).

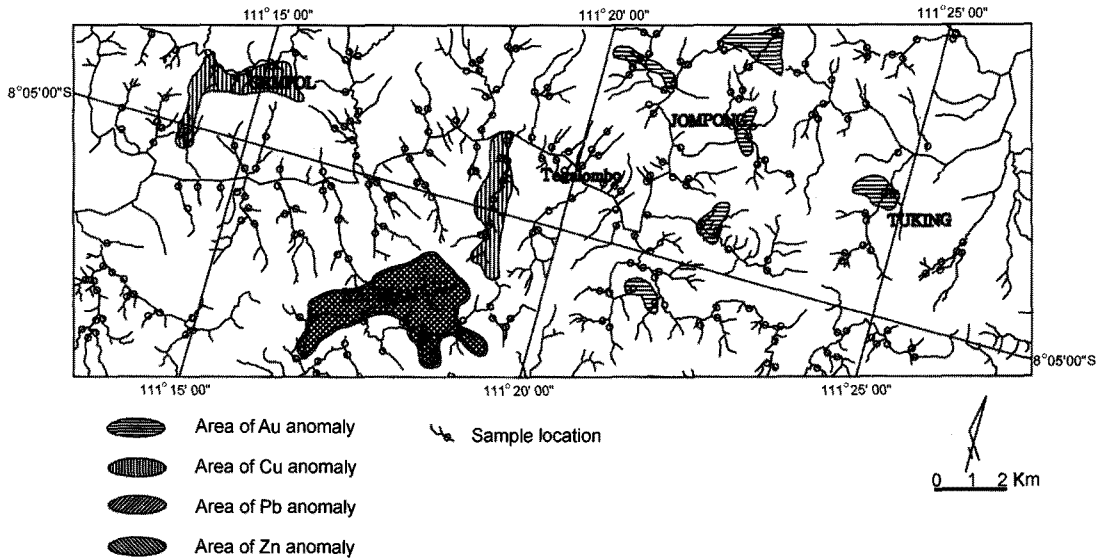


Fig. 6. Geochemical anomaly map showing the anomaly areas of each element.

Table 3. Main anomalous zones from the sediment samples

Elements	Intensity	Anomaly value	Identified anomalous zone
Au	strong	≥ 26.62	G. Bondring, G. Plaosann, G. Ngrecak, G. Plandakan, G. Kasihan, G. Tumpakmelaka, G. Banukeran, K. Tempuran
	weak	18.26-26.6	G. Pengajaran, G. Gemulung, G. Keke
Cu	strong	≥ 190.78	G. Cili, G. Pegat, G. Sropot
	weak	154.93-190.77	G. Bakalan, Tuling, Salam, G. Gede, G. Watudukun
Pb	strong	≥ 97.62	G. Gebang
	weak	63.89-97.61	G. Gemulung
Zn	strong	≥ 776.0	G. Gebang, G. Kauman
	weak	536.0-775.9	G. Cili

and possible contamination sources.

A total of 271 soil samples from Kasihan area were collected with a sampling density of 11.6 samples per km^2 . To prepare soil sample, each sample of 500 g in weight was dried under the sun and sieved -80 mesh fraction. After drying, crushing and sieving at the field, all soil samples analyzed

three elements (Cu, Pb and Zn) by AAS.

3.3.2. Results of statistical parameters

The statistical values were calculated by the statistical analysis method of Kasihan area. The patterns for Cu, Pb and Zn are similar to the normal distribution as shown in Fig. 7. The statistical

Table 4. Statistical parameters for assay values of soil samples in Kasihan area

Elements (ppm)	Max. value	Min. value	Mean value	Background value	Threshold value	Anomalous value
Cu	1,210	7.0	79.6	51.61	276.54	430.60
Pb	980	4.0	54.4	29.55	181.03	254.61
Zn	3,000	10.1	142.7	76.16	386.78	854.30

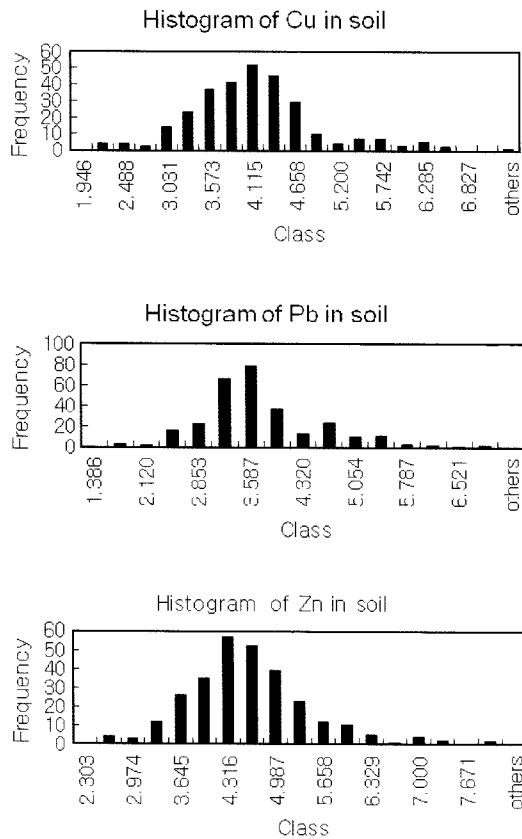


Fig. 7. Histograms showing statistical values of metallic elements in soils from the Kasihan area.

parameters, which are composed of the maximum and minimum values, background, threshold and anomalous value, are shown in Table 4.

3.3.3. Geochemical anomaly zone

A sample site, which contains an element more than two adjacent sites as anomalous value of the element, is interpreted as an anomalous site of these elements. Analytical values were plotted adjacent to the corresponding sample sites (Fig. 8). As a result of assay, 10 anomalous composition zones were identified in the Kasihan area. There are six anomalies for Cu, five for Pb, and six for Zn. The anomalous values of copper-lead-zinc and/or copper and zinc are overlapped at five areas surrounding quartz porphyry at the central part of the Kasihan area. The area was interpreted and chosen as an anomalous zone related with stockwork and skarn mineralization, extending to approximately NNW-SSE direction.

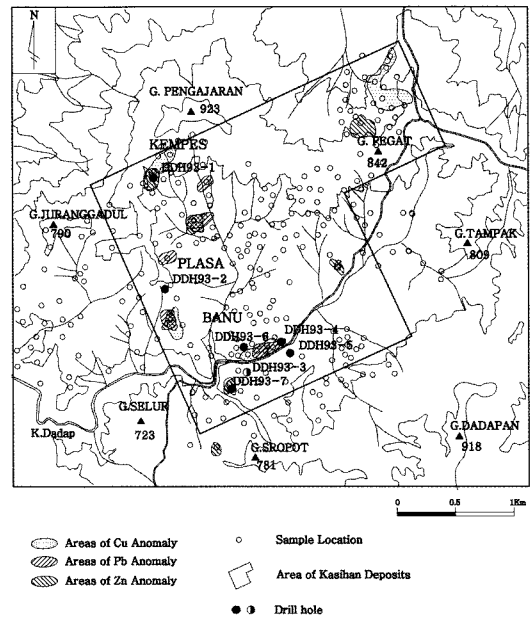


Fig. 8. Soil geochemical anomaly map of Cu, Pb and Zn in the Kasihan area. The location of sample sites and drill holes are also shown.

4. Results

The geology of the Pacitan district within the Southern mountain zone in the southwestern margin of East Java, Indonesia consists five main lithostratigraphic units of the Arjosari, Mandalika and Watupatok Formation of the Late Oligocene to Early Miocene and Jaten and Wuni Formation of the Middle Miocene sedimentary rocks, and younger intrusive rocks.

The geochemical exploration in the district to explore metallic mineralization, and to find out anomalous areas related with mineral dispersion from the concealed ore deposits had been carried out of the panned concentrates, stream sediments, and soil systems. The anomalous zones of each element were detected in the following areas: Gempol for Cu; Jompong for Au; Kasihan for Cu-Pb-Zn. The strongest Cu-Pb-Zn anomalous values are overlapped in the Kasihan area.

The geochemical survey of soil was conducted with the geological survey in Kasihan area. The statistical values were calculated by the statistical analysis method of Kasihan area. The patterns for Cu, Pb and Zn are similar to the normal distribution. As a result of assay, 10 anomalous composition

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Acknowledgements

We wish to thank for Korea Resources Corporation for providing financial assistance during the exploration. This work was partially supported by the **Energy Efficiency & Resources** of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government Ministry of Knowledge Economy (**No. 2008RRD11P020000**). The authors thank the survey team members who participated in the Joint Mineral Exploration Project.

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2010년 12월 27일 원고접수, 2011년 2월 16일 게재승인