Central Java regional geochemistry: influence of environmental geology and mineral occurrences

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Abstract. Stream sediments geochemical surveys were undertaken in Central Java, Indonesia as a part of the Geological Agency’s geochemical mapping project with support from several universities. A total of 1583 stream sediment samples were collected from Central Java and analyzed using X-Ray Fluoresces for 29 elements. Geochemical maps were processed by the GIS software. Based on the overlay between geological and geochemical maps, there are several elemental anomalies, for example, the ultramafic formation from Kebumen showing distinctive Chromium (Cr), Cobalt (Co), and Magnesium (Mg) anomalies. Meanwhile, the potassic igneous rocks from Muria Mountain have Cerium (Ce), Lanthanum (La), and Zirconium (Zr) anomalies. Elemental anomalies related to mineral resources and mining areas such as Arsenic (As), Copper (Cu), and Lead (Pb) are found in Tenggalek, Pacitan, and Kebumen; while Barium (Ba), Iron (Fe), and Manganese (Mn) are scattered along the southern coast of Central Java. Anthropogenic elements (Chlorine (Cl), Ce, and As) spread along the north coast of Central Java probably because of pollution by industrial, farming, and urban areas. Heavy metals pollutions that were identified previously in the Bengawan Solo River flow can be seen on this geochemical map which can convincingly delineate elements anomalies due to geological and environmental conditions.

1. Introduction

A series of regional geochemical atlases were created by the Centre for Geological Survey for the Java Island as part of the technical report of the Java-Kalimantan geochemical survey project from 2011 to 2014. The West Java Geochemical Atlas was published in 2015. [1], while other atlases are still in progress.

Stream sediment sampling in the Central Java area was carried out in 2012 and 2013 involving students and researchers from Gadjah Mada University (UGM), Pembangunan Nasional University (UPN), and IST Akprind. Samples obtained in Central Java reach a total of 1583 samples, one sample represents the density of 25 km². The sampling guidelines followed the Geological Map Sheet with a scale of 1:100.00 and the topographic map with a scale of 1:50,000. Fourteen geochemical maps of the elements are shown in this paper. These geochemical maps constitute an unpublished report to complete the 20 geological maps that have been published locally in Central Java.

The Central Java’s geochemical maps are bounded by Longitude 108°00’E and 112°00’E; Latitude 6°00’ S and 8°00’S. The Quaternary and Tertiary Sediments, Tertiary Volcanic and Plutonic rocks are geological features on Central Java. Gold and base metal deposits are widespread in this region following the low and high epithermal mineralization zone (Figure 1). These geological conditions are
caused by subduction, volcanism, and deposition that have occurred since 90 Ma until recently. The deposition of sedimentary rocks since the Tertiary was much influenced by volcanic activity and sea-level changes which were characterized by thick sequences of volcanic and epiclastic rocks throughout the Late Oligocene to Early Miocene, followed by carbonate formation in the Early Miocene to Middle Miocene. There are no Pliocene or Quaternary deposits in the Southern Mountains zone due to uplift and erosion, different from the northern part of Java, the deposition of Pliocene and Quaternary sediments widespread in the offshore area [2]. This geochemical survey by using sediment streams method is expected to assist in the exploration of mineral resources and determine environmental influences after being overlaid with the geological region of Central Java and current conditions.

![Central Java Metallogenic map](image)

**Figure 1.** Central Java Metallogenic map (Modified from [3]).

2. Data and Method

Geochemical mapping survey activities included: taking samples of stream sediment in the field, laboratory analysis, and configuring geochemical map by GIS software (ArcGIS and Oasis Montaj). Stream sediment sampling activity followed the standard operating procedure document made by the Centre for Geological Survey and referred to the stream sediment sampling techniques which were commonly used in mineral exploration and the global standard of geochemical mapping [4].

The samples taken consisted of active river sediment that had been sieved through a #40 sieve, an #80 sieve and a grab sample. A total of 1583 sediment stream samples were collected, with sample density, one sample represents a 5x5 km grid cell (25km²) in Central Java region. These samples were dried and subsequently sieved to the <200 μm fraction. The dried and sieved material was placed in the plastic sample, labelled, and prepared into pellet samples. The pellet is the result of a pressed mixture of powder sample, polyvinyl alcohol, and borate acid. The ARL 9900 Thermo Scientific X-ray fluorescence was used for geochemical analysis. The instruments belonging to the Geological Laboratory of the Centre for Geological Survey could determine 29 elements.
The results of the analysis were then made by a geochemical map of the elements using Kriging method on Esri, ArcMap 10.0 software, concentration increases as indicated by the contour from blue to red. Statistical analysis and frequency diagram used Geosoft Oasis Montaj software [5]. Due to the large number of samples, only 14 geochemical maps are shown for further discussion.

3. Result and Discussion
Figures 2 to 15 show the map of the distribution of elements in alphabetical order. The geology of Central Java which consists of several zones such as sedimentary, volcanic, plutonic and metamorphic could create a distinctive pattern of elemental anomalies.

![Figure 2. Arsenic (As) geochemical map.](image1)

![Figure 3. Barium (Ba) geochemical map.](image2)

![Figure 4. Cerium (Ce) geochemical map.](image3)

![Figure 5. Chlorine (Cl) geochemical map.](image4)
Figure 6. Cobalt (Co) geochemical map.

Figure 7. Chromium (Cr) geochemical map.

Figure 8. Copper (Cu) geochemical map.

Figure 9. Iron (Fe) geochemical map.

Figure 10. Lanthanum (La) geochemical map.

Figure 11. Magnesium (Mg) geochemical map.
Figure 12. Manganese (Mn) geochemical map.

Figure 13. Lead (Pb) geochemical map.

Figure 14. Zinc (Zn) geochemical map.

Figure 15. Zirconium (Zr) geochemical map.

As clearly shown by the ultramafic rocks from Kebumen. Enrichment with Cobalt (Co), Chromium (Cr), and Magnesium (Mg) (Figure 6, Figure 7, and Figure 11, respectively) was found in stream sediments collected from Karangsambung ophiolite, which is underlain mainly by the Luk Ulo Melange Complex [6]. Meanwhile, the potassic igneous rocks from the Muria volcano have contrast anomalies of Cerium (Ce), Lanthanum (La) and Zirconium (Zr) (Figure 4, Figure 10, and Figure 15, respectively). Muria volcano is different from other active volcanoes in Central Java, located north of the present volcanic arc in Central Java [7, 8].

Some commodities of mineralization are found in this area; which belongs to several types of mineralization: low & high sulphidation epithermal in the west part of Central Java, and low sulphidation epithermal & porphyry in the east (Figure 1). Elemental anomalies related to mineral resources and mining areas such as Arsenic (As), Copper (Cu) and Lead (Pb) (Figure 2, Figure 8, and Figure 13, respectively) are found in Trenggalek, Pacitan, and Kebumen. The anomalies in Trenggalek may be correlated with gold-mineralized quartz veins, in volcanic rocks of oligo-miocene age close to
andesite plug in to the northern of the prospect area [9]. While the elements Ba, Fe, and Mn (Figure 3, Figure 9, and Figure 12, respectively) are scattered along the southern coast of Central Java. The southern coast is part of the Southern Mountains Range formed from the Old Andesite formation which has many mineral discoveries of iron, manganese, and gold deposits.

Initially, geochemical maps were only for mineral exploration, but in its development, it can also be used for environmental assessments [10]. In this case in Central Java, it can be seen that the segment of Wonogiri-Sragen, some industries (textile, plastic, metals, and chemical) disposed their wastewater to Bengawan Solo River. These industries cause an increase in heavy minerals pollution in water and sediments [11]. This phenomenon can be seen on the stream sediment geochemical anomaly map for the elements Cr, Cu, and Zinc (Zn) in the Bengawan Solo River flow between Wonogiri and Sragen city. Anthropogenic elements such as Chlorine (Cl), Ce, and As were spread along the north coast of Central Java probably because of pollution by industrial, farming, and urban locations. The area of cities such as Semarang, Yogjakarta, Purworejo, Wonosari, and Kebumen have increased concentrations of Ce, Cl, and Pb (Figure 4, Figure 5 and Figure 13, respectively).

Commonly, the elemental concentration pattern of the stream sediments reflects faithfully the distribution of geology and mineral deposits. However, the exception is limestone, which insignificantly influences the elemental concentrations of stream sediments [12]. The geochemical map of Fe, Mn, and Zn may be an example of this situation. However, the elements have a lower concentration than the surrounding area, exception for the element of Zirconium (Zr). These patterns are caused by the presence of carbonate or limestone from the Rembang zone in the south of the alkaline Muria volcano.

4. Conclusions

Regional geochemical surveys that have been carried out on the island of Java provide a typical pattern of elemental anomalies as a result of geological and environmental conditions. In this central part of Java, the geological products of alkaline igneous rocks are clearly shown by Ce and La anomalies, the Karangsambung Ophiolite may consider in Cr and Co pattern. While the consequences of human activities are shown from the Cl, Cu, and Pb patterns. The pattern is random and scattered close to the city, farming, and industrial areas. This stream sediment geochemical map can convincingly delineate elements due to geological and environmental conditions. The elemental anomalies shown are crucial for environmental pollution assessment or as preliminary exploration for mineral resources.

5. References

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