Magmatic related to hydrothermal alteration in Kulon Progo, Central Java, Indonesia

by Agus Harjanto

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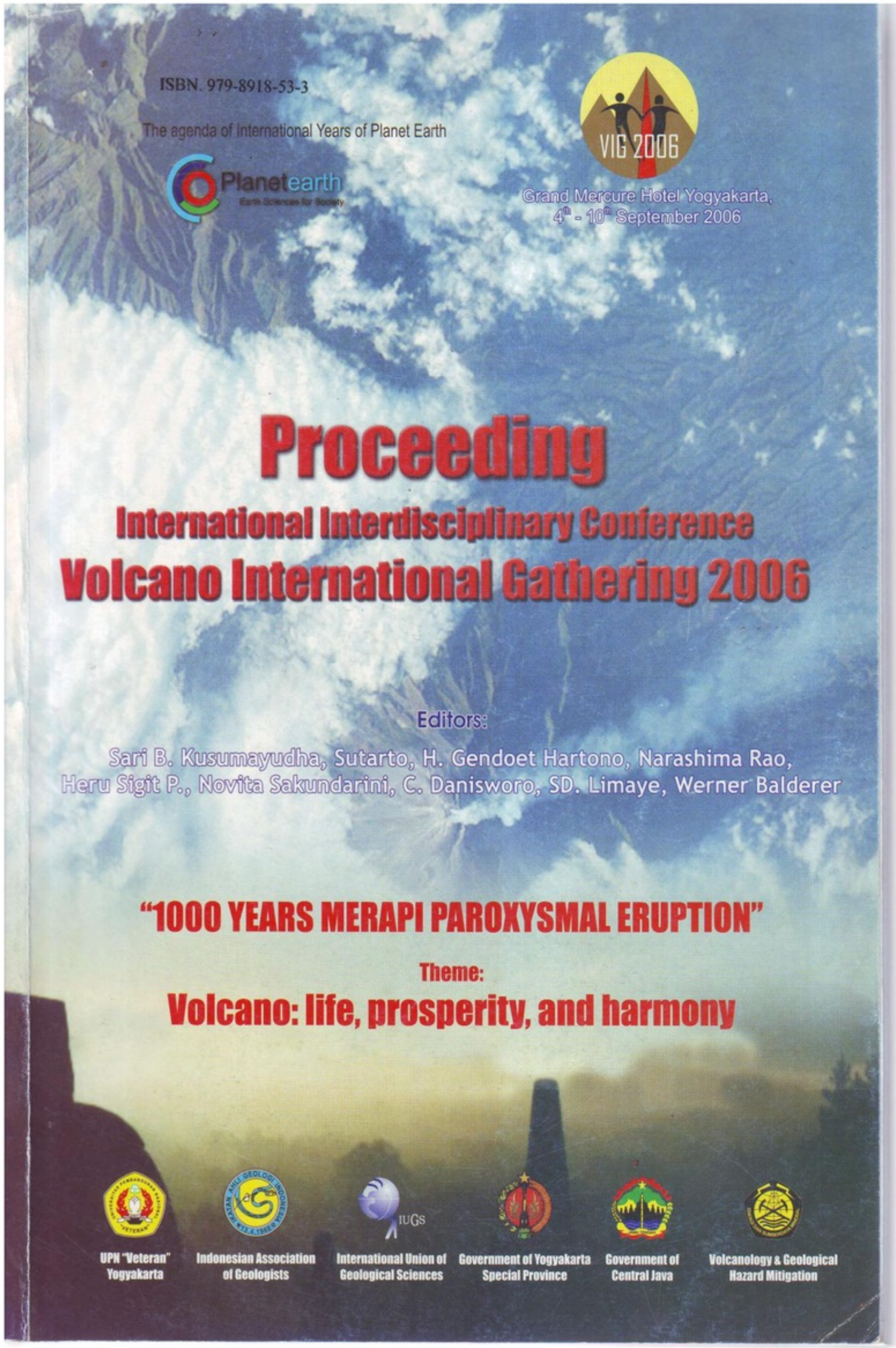

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Magmatic related to hydrothermal alteration in Kulon Progo, Central Java, Indonesia

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ABSTRACT

The volcanic rocks in Kulon Progo were formed during Oligocene-Miocene time and have undergone alteration since that time. They mostly form the Old Andesite Formation, which consists of interbedded volcanic breccia, tuff, andesite, dacite and diorite. They are part of the magmatic Sunda-Banda Arc.

These volcanic rocks have chemical compositions that range from basalt andesite to dacite and from low potassium series to calc-alkaline series. Phenocrysts consist of pyroxene, hornblende, plagioclase, alkali feldspars and quartz.

The rocks have under gone hydrothermal alteration and based on mineral alteration assemblages, they can be divided into three alteration zones. These zones are : 1) A phyllic zone that is characterized by quartz-sericite-chlorite, 2) A prophyllitic zone that is characterized by chlorite-epidote-calcite, 3) An argillic zone characterized by illite-kaolinite-monmorilonite.

GEOLOGICAL SETTING

Almost half of the Yogyakarta quadrangle, mainly the south-southwestern and eastern parts, is occupied by a depression covered with alluvium and young merapi volcanic products. Westward i.e. Kulon Progo area, the depression gradually changes into a hilly morphology. Most of the western part (Kulon Progo Mountains) has a high relief. The Jonggrangan plateau which is the highest place in the antire area, reached an altitude of 750 meters above sea level. The hills are dissected by streams, forming valleys that radiate downsstream separated by elongate hills which represent local devides.

To the northeast, the landscape develops into a conical morphology of the Merapi volcano, except the western slope, where it was deformed due to faulting and the activities of the Merapi volcano itself. Valley which form on the slopes are filled with lava flows and other volcanic products.

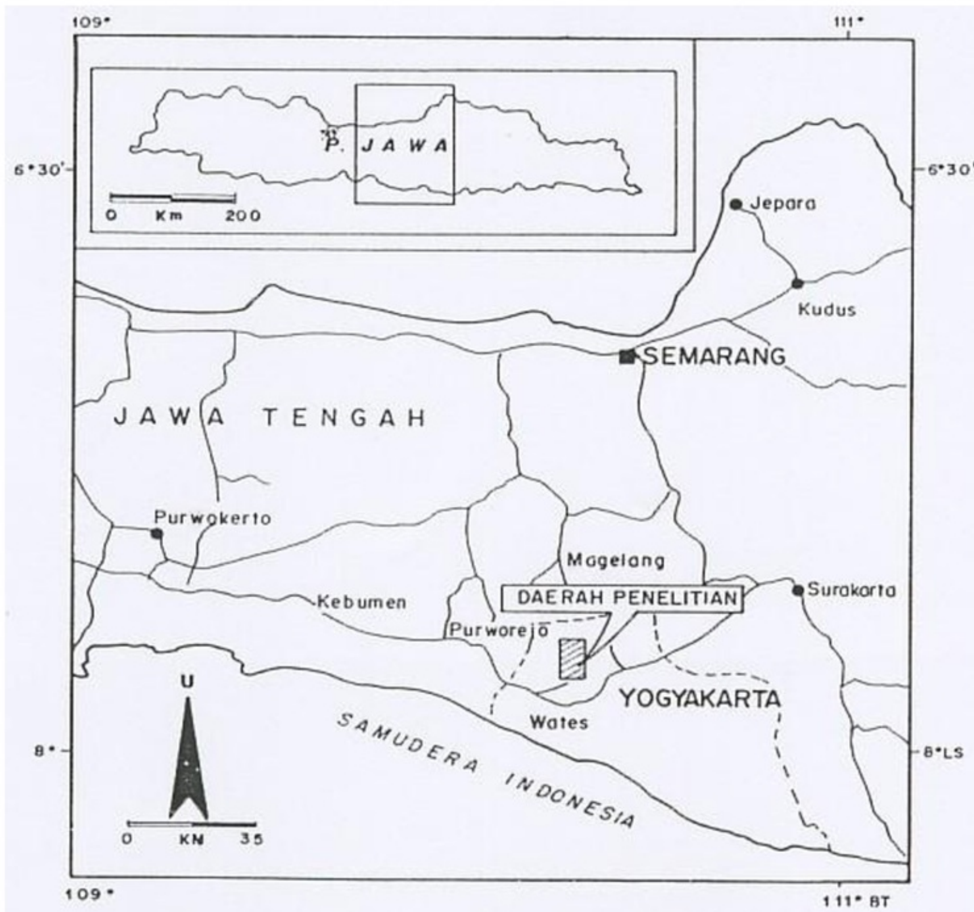

Figure 1. Location map of study area

Several faults are found beside the folds. Geophysical data reveal a major fault that runs northeast-southwest along the edge of Bantul graben (Untung et,al,1973) Based on these data and field observation, there are two fault systems. The major one has a southwest-northeast direction.

The Nanggulan Formation is the oldest formation in the Yogyakarta, deposite during Middle Miocene to Upper Oligocene time. After the deposition of this formation, the whole area of Kulon Progo was uplifted. During this time volcanic activities produced the "Old Andesite Formation" of van Bemmelen, 1949. At the same time, in the Southern Mountain area, the Semilir, Nglanggran and Sambipitu Formation were deposited. In the subsequent volcanic phase, the andesites of Kulon Progo area were intruded by pyroxene-andesites which in turn were altered hydrothermally. During late Early Miocene, several transgressive-regressivent proceeded the submergence of the Kulon Progo area, resulted in the deposition of the Jonggrangan Formation. In the western part of southern Mountains, uplifting occurred during Midde Miocene, followed by the deposition of Wonosari Formation.

PETROGRAPHY

The study area contains a wide variaty of volcanic rock types including diorite, andesite, dasite, volcanic breccia and tuff. These rocks have certain differences in texture and mineral composition percentage. The diorite is dominated by pyroxene, hornbende, plagioclase and opaque minerals. It also has alteration products that include silica grains, clay minerals and opaque minerals. Andesite is differentiated from diorite on the basis of its grain size of minerals. The dacite is composed of plagioclase, quartz, potassium feldspar and small amounts of hornblende and alteration minerals. The volcanic breccias consist of andesite, dacite and diorite fragments. These rocks are invariably slightly to completely altered to sericite, chlorite, clay minerals, epidote, silica, actinolite, calcite and pyrophyllite.

GEOCHEMISTRY

Major Elements

Ten volcanic rock samples were analyzed by ICP(WRA.REV2) for the elements show in Table 1. These rocks have a silica content that ranges from 50-90 weight percent. The relationship between silica dioxide and potassium oxide or tholeiitic series and calc-alkaline series. In general, the Harker variation diagram shows a linier correlation between the major oxides and silica dioxide. It also shows a negative trend, except for potassium oxide and sodium oxide. These two oxides do not show a clear correlation. This blurred correlation could indicate an effect of alteration and/or crustal contamination (Rollinson,1993). This indicates that the volcanic rocks probably originated from partial melting or fractional crystallization (Wilson,1991: Rollison,1993).

These rocks generally show a high volatile content, having a mean loss on ignition of 3.5 percent and a 1 to 12 weight percent range. However, the present rock chemical composition must have been effected by total alteration. Those that form calc-alkaline series have moderate to hight loss on ignition values and are highly altered by phyllic alteration. It is known that phyllic alteration adds potassium and removes sodium, calcium and magnesium. Therefore, the high potassium content of these samples could be the result of this alteration. In contrast, the tholeiitic series has low to moderate loss on ignition values and is highly altered by propyllitic alteration. Rocks of the tholeiitic series are characterized by being highly porphyritic, with plagioclase forming most of the phenocrysts. The hydrous minerals amphibole and biotite, are almost entirely absent from the tholeiitic series. This suggests that the parental magma had a low volatile content (Wilson,1991)

Table1. Major element and Trace element whole rock ICP analyses (wt%) of the Kulon Progo volcanic rocks

	KP. 06	KP. 07	KP. 17	KP. 19	KP. 20	KP. 23	KP. 24	KP. 40	KP. 43	KP. 50
Major el. (%)										
SiO_2	50.97	40.04	58.27	52.50	56.18	57.19	56.28	51.73	49.86	50.82
TiO_2	0.741	1.064	0.501	0.653	0.771	0.432	0.665	0.640	0.821	0.825
Al_2O_3	17.04	17.42	16.39	17.89	17.72	15.38	16.45	17.44	17.90	17.63
Fe_2O_3(Total)	8.68	12.47	6.24	8.99	7.37	5.14	7.39	8.41	9.54	10.52
MnO	0.156	0.169	0.145	0.153	0.135	0.153	0.131	0.169	0.149	0.168
MgO	2.89	4.09	2.42	3.29	2.07	2.80	3.99	2.91	4.04	3.11
CaO	10.04	8.21	6.44	8.66	8.33	6.83	6.55	8.81	8.70	9.85
Na_2O	2.69	1.84	3.30	2.80	3.52	2.49	3.49	2.76	2.11	2.68
K_2O	0.24	1.36	1.65	1.08	1.21	2.01	0.62	0.78	0.25	0.19
P_2O_5	0.17	0.14	0.13	0.16	0.18	0.12	0.21	0.19	0.16	0.19
LOI	5.54	12.31	3.30	2.94	2.07	6.90	3.82	5.34	5.99	3.72
TOTAL	99.15	99.12	98.76	99.11	99.55	99.44	99.59	99.19	99.52	99.70
Trace el. (ppm)										
Cr	30	20	20	<20	20	30	60	<20	<20	<20
Co	20	21	12	20	15	12	19	16	22	23
Ni	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Cu	20	650	<10	20	<10	<10	<10	10	10	30
Zn	50	90	30	60	60	30	60	70	100	80
V	177	270	107	167	154	91	136	139	202	184
Rb	4	35	50	26	32	56	10	24	7	3
Ba	130	274	285	324	260	325	140	199	298	157
Sr	325	157	281	310	305	276	289	332	286	370
Th	3.9	1.7	4.9	3.9	4.3	3.9	1.9	4.1	3.2	3.7
Ta	0.2	0.1	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2
Hf	2.5	1.8	2.8	2.3	3.3	2.8	2.8	2.6	2.4	2.5
Tb	0.6	0.6	0.5	0.5	0.7	0.4	0.5	0.6	0.6	0.6
Yb	1.9	1.9	1.7	1.8	2.5	1.4	1.9	1.9	2.1	2.2

Trace Elements

The major elements of the volcanic rocks in the study area have the chemical behavior of an oceanic island arc, with plagioclase and magnetite as the major fractionating phase in the evolution of magma. The variation diagrams of trace elements versus silica dioxide show that incompatible elements, such as thorium, uranium, zircon, hafnium, rubidium, strontium and barium, increase with increasing silica dioxide. The result of this is a distinct positive trend. Light rare earth elements, such as lanthanum and cerium, also increase with increasing silica dioxide but the rare earth elements show no increase and some, such as samarium, holmium and ytrium, actually decrease. Some data have a more scattered trend and, thus, suggest that the volcanic rocks are altered. This also indicates that alteration has produced some mobility of the elementa. Srontium and europium have been removed during feldspar alteration, whereas rubidium and cesium have been added during phyllic to argillic alteration.

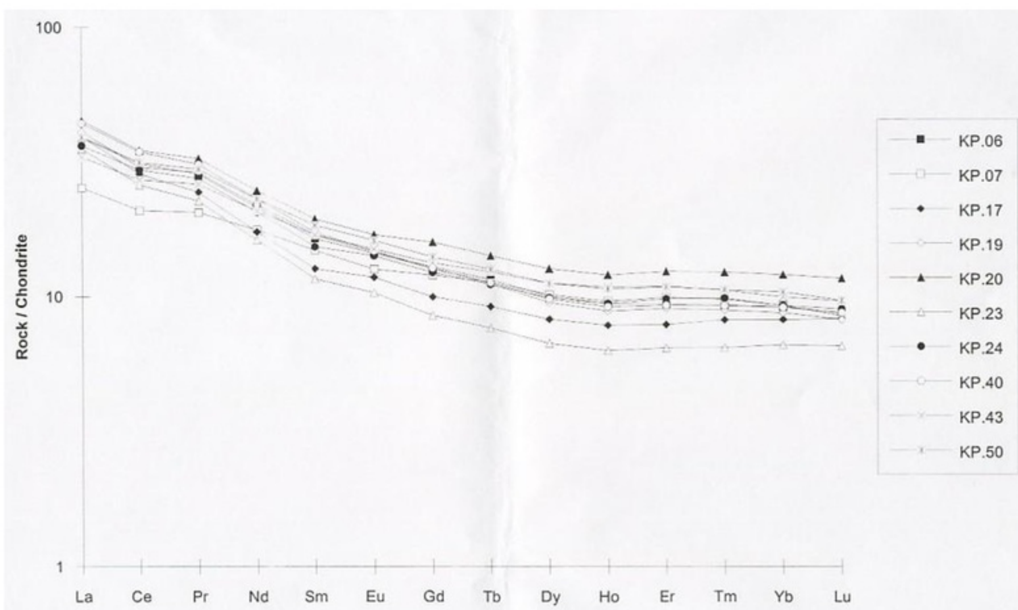

Figure 2. Trace elements versus rock/chondrite

HYDROTHERMAL ALTERATION

Corbett and Leach (1998) made a list of relationships between pH fluid with temperature in which mineral alteration formed in equilibrium conditions and pH degree as a function of chemical fluid characteristics. Morrison (1990) classified types of alteration.

In the study area, the level of hydrothermal alteration ranges from selected individual phases to that of composite rock mineralogy. The rocks instudy area are variably altered, with three overprinted, but distinct, styles of hydrothermal alteration assemblages. These alteration assemblages were definited by field mapping and thin section and x-ray diffraction studies. They are quartz-serisite-chlorite, chlorite-epidote-calcite and illite-kaoline-monmorillonite.

Table 2. Rock Chemistry by AAS of the Kulon Progo volcanic rocks.

Ore minerals	KP.12 (ppm)	KP.1C (ppm)
Au	0.170	0.090
Ag	8.8	3.7
Cu	9.2	11.5
Pb	14.0	25.0
Zn	9.4	25.1
As	18.7	12.4
Sb	10.9	2.6
Mo	0.45	0.35

Quartz-Sericite-Chlorite (Phyllic Zone)

The host rocks are porphyritic andesite/dacite, diorite and brecciated rocks. The brecciated rocks include hydrothermally brecciated and volcanic brecciated. This alteration type is texturally destructive and pervasive in character. It preferentially attacks the feldspar phenocrysts have been entirely replaced by sericite and silica. At times, chlorite has partially replaced these phenocrysts. The silica alteration is the most destructive in the assemblage. It has replaced the plagioclase phenocrysts and matrix and often occur as fine-grained aggregates. In general, this alteration is the resut of adding potassium and removing sodium, calcium and magnesium. The increase in potassium oxide and the decrease in sodium oxide in the andesite rocks could be due to sericitization of plagioclase. Quartz is a secondary product of this sericitization and , as such, may be the reason the porphyritic andesite is saturated with silica dioxide.

Chlorite-Epidote-Calcite (Prophyllitic Zone)

They occur throughtout the dacite and andesite rocks. The chlorite occurs mostly in brecciated rocks. It occurs as a replacement mineral and is especially intense around clast boundaries. It is confined to breccia matrix and to rims clasts. It indicates a temperature less than 120 degrees Celsius and nerly neutral pH. It may have resulted from condensation of magmatic volatiles. However, the epidote and actinolite indicate a hight temperature and hight PH. This suggests that the rocks are overprinted.

Illite-Kaolinite-Monmorillonite (Argillic Zone)

These rocks are generally composed of clay minerals, plagioclase, and pyroxene. The alteration is texturally tentativeThin sections reveal that mineral boundaries are slightly fuzzy and the usual sharp interlocking texture is blurred. This is primarily so with plagioclase and the dark minerals. This alteration assemblage is predominantly a replacement type with chlorite replaced the mafic minerals and plagioclase. The matrix of these rocks has been mostly replaced by kaolinite. Four volcanic rocks samples were analyzed by x-ray diffraction for the clay minerals shown illite, kaolinite and monmorillonite. Kaolinite indicates low temperature and neutral pH.

CONCLUSION

The volcanic rocks in Kulon Progo are located in the Sunda-Banda magmatic arc that was formed during the Oligosen-Miocene. They have the chemical make up of an oceanic island arc. These rocks are dominated by the Old Andesite Formation. This Formation consists of interbedded volcanic breccia, tuff, diorit, andesite and dacite. The volcanic breccia has fragments of andesite, dacite and diorite. These rocks have tholeiitic series and a calc-alkaline series that has loss on ignition values ranging from 1 to 12 weigh percent. The percence og these minerals indicates that the volcanic rocks in Kulon Progo have undergone hydrothermal alteration. These mineral series from three assemblages : a quartz-sericite-chlorite assemblage (phyllic zone), a chlorite-epidote-calcite assemblage (prophyllitic zone) and a illite-kaolinite-monmorillonite assemblage (argillic zone).

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