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Research Paper

GEOCHEMICAL CORRELATION BETWEEN MAFIC AND FELSIC IGNEOUS ROCK FROM GODEAN, YOGYAKARTA, INDONESIA

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Godean is a as a part of Miocene Southern Mountain magmatisme range that occur in Yogyakarta, Indonesia. Godean is a hilly morphology that compose from several type of igneous rock occurs that are andesite and microdiorite intrusion, dacite subvolcanics to lava, and the latest is basalt subvolcanic. That's rock indicated there is completes differentiation of igneous rock in Godean, that's occurs as felsic rock to mafic rock that must have a correlation in between. This research was conduct from field geological mapping, petrographic analysis, and complete geochemistry. Geochemical correlation analysis was done using qualitative method and quantitative method. Both of the rock was origin from same magma source at normal differentiation of island arc magma, and from CIPW-normative mineralogy show decreasing of mafic and opaque mineral, and increasing of felsic mineral. Simple statistics method shows high positive correlation in major element and REE but low in trace element. Analysis with isocon method resulting Al_2O_3, Eu, Gd, and Sm as immobile element, and resulting that geochemical increasing at K_2O, SiO_2, NaO, Pb, Rb, La, Ce, Pr, while the other element was decreasing. Geochemical correlation between basalt and dacite, shows correlation from chemical data and genetic interpretation. This research perhaps can used to another type of igneous rock analysis, to interpretation the geological phenomena.

Keywords: Magmatism, Isocon, Mineral, REE, Java

INTRODUCTION

Location of this research is on Godean, Sleman District, in Yogyakarta. This location is only 20 kms west side from city of Yogyakarta.

Godean is a as a part of Miocene Southern Mountain magmatisme range that occur in Yogyakarta, Indonesia. Godean hills is locate on Yogyakarta basin, that bordered from Oligo-Miocene age of calc-alkaline magmatisme of Kulon Progo mountain on western side and several Miocene volcanics to Miocene Sediments on eastern side. Yogyakarta basins and the hilly morphology of Godean have lower elevation because of the graben system and covered by quarternary fluvio-volcaniclastic from Merapi Mountain.

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Godean is a hilly morphology that compose from several type of igneous rock occurs that are andesite and microdiorite intrusion, dacite subvolcanics to lava, and the latest is basalt subvocanic. That's rock indicated there is completes differentiation of igneous rock in Godean, that's occurs as felsic rock to mafic rock that must have a correlation in between.

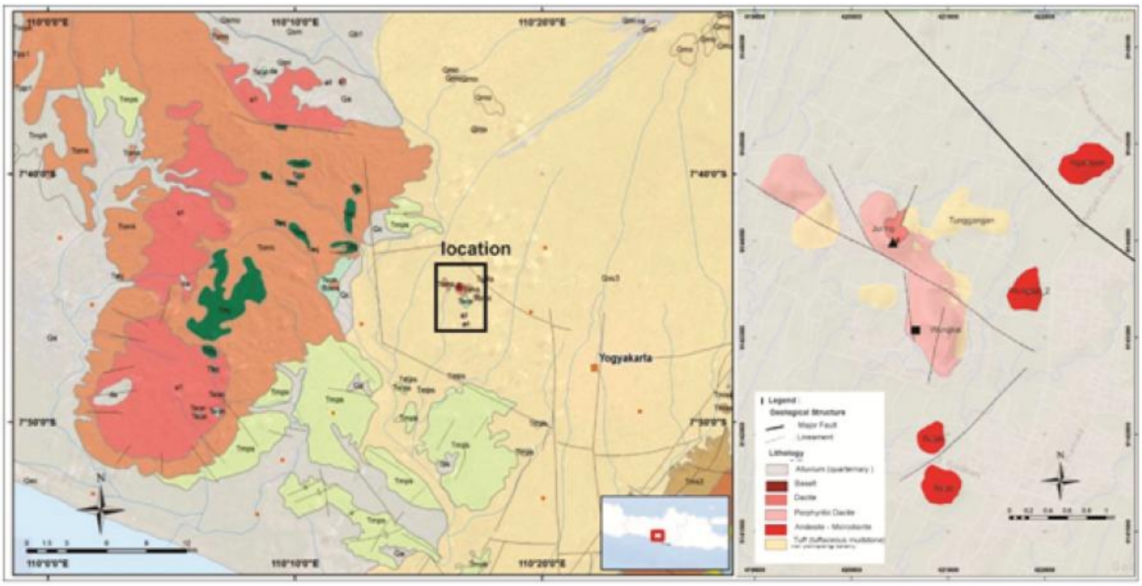
Geological Settings

In the middle area of Yogyakarta there hills morphology isolated in Godean formed under the influence of control denudational on igneous rocks and ancient volcanoes, as the rest of the weathering of surface erosion so that it appears as highs. The flat morphology at around Godean, produced by the deposition of sediment in the form of quarternary fluvio-vulcanics and gigantic avalanches from Young Merapi volcano (Bronto, 2014), which are locally visible terrain is a little bumpy due to deposition of material in a concentrated system.

Raharjo *et al.* (1997) mention that oldest rock in Godean is members of Nanggulan Formation, in Eocene age. This formation composed of lignite, sandy marlstone, claystone with limonitic concretion, marls, limestone, sandstone, and tuff. Above Nanggulan, there is Kebobutak Formation (Tmok), which is composed of andesite breccia, tuff, lapilli tuff, andesite lava flows aglomerat, in Oligo-Miocene age. Both of that lithologies were then intruded by diorite and andesite, the Lower Miocene. More to the south of Godean, namely in the area of Bantul, there Sentolo Formation (Tmps), which consists of limestones and sandstones napalan Miocene - Pliocene.

Geological structures interpetated in Paleogene aged, and mainly in Godean seemed to form a parallelogram pattern, as the combined of east – west trending structures and north-south that as part from the graben Yogyakarta - Bantul system (Sudarno, 1999; and Barianto, 2009), and the pattern of tectonic as fault trending south-

Figure 1: Location of Godean, in Regional Geology Map by Raharjo, et al. (1997) and Local Geological Map of Godean by Verdiansyah (2016a) and Location of Sample that Discuss in this Paper (Triangular Shape is for Basalt, Square Shape is for Dacite)



north-west and fault down trending east - west (Widyanto, 2013; and Syafri *et al.*, 2013) that affect the pattern of anomalies in Godean and Banguntapan the range of interpretation as bedding sediments influenced their intrusion (Verdiansyah, 2016a).

METHODES AND MATERIALS

Methode

This research was used geological mapping to determine type of rocks, rocks sampling, laboratory analysis, data analysis and interpretation using qualitative and quantitative method.

Quantitative analysis using simple statistics, isocon methods (Grant, 2005) in the software "EASYGRANT" by Lopez-moro (2012). Isocon method is method that usually used for calculated relative gain or loss of an element changes in metasomatisme process in altered rocks, in this paper, researcher try to using the isocon method to known the relative gain and loss of chemical changes of igneous rock that interpretated as product of continuous differentiations of same magma.

Qualitative analysis using CIPW-normative mineralogy and magmatic discrimant diagram.

Material

Material that used for interpretation is complete geochemically analysis of basalt and dacite. Chemical analysis was using XRF (X ray fluorences) and ICP-OES (Inductively Coupled Plasma optical emission spectrometry) analysis that conduct on PT. Intertek Utama Service on Jakarta. Result of geochemical analysis was 77 elements for each sample that resulting for major element, trace element, and rare earth element. This data is compiling from Verdiansyah (2016a) and Verdiansyah (2016b).

RESULTS AND ANALYSIS

Lithology of Godean consist of 5 type, that is igneous rocks, sediment, volcaniclastics, pyroclastic, and alluvium. For igneous rocks, there are porphyry andesite to microdiorite as intrusive, dacite as lava and subvolcanics, and basalt as subvolcanic intrusion.

Result of geochemically analysis of igneous rock in Godean, base on data of this research and combination with other data from previous researcher (Bakar, 1999; Bronto, 1999; Verdiansyah, 2016a; and Verdiansyah, 2016b) conclude Godean is the island arc volcanisme that have tholeiitic to calc-alkaline magmatic affinity.

Geochemically correlation between basalt and dacite of Godean, will be explained below.

Qualitative Analysis

Mineralogical Correlation

Mineralogy comparisons between basalt and dacite necessarily have significant differences, it is associated with differentiation. Basalt in Godean, has a main composition of plagioclase, clinopyroxene and less olivine, mainwhile the dacite has composition of plagioclase, quartz, hornblende and biotite. In this study, comparison and correlation using CIPW-normative mineralogy so mineralogical parameters can be clearly seen where the difference.

Base on CIPW-normative (Table 1), the change mineralogy from basalt to dacite seen from increase of quartz, K-feldspar and diopside, the increase mineralogy assumption of element increase in dacite such as SiO_2, K_2O in felsic minerals, and calcium in mafic mineral. Plagioclase as dominan mineralogy on both rocks, have decrease in dacite but other side has increase of K-felspar (sanidine). Acessory mineral, like magnetite and ilmenit have decrease follow differentiation.

The mineralogical correlation seen from several things:

- Mafic mineral from CIPW-normative seen decrease from 29.5% in basalt to 11.1% in dacite, and from petrographic data changes from 31% (pyroxenes, olivine, diagenetic minerals) in basalt to 15% (hornblende, biotite) in dacite.
- Felsic mineral from CIPW-normative seen increase from 66.7% in basalt to 83.9% in dacite, and from petrographic data changes from 60% in basalt to 75% in dacite.
- Opaque mineral from CIPW-normative seen decrease from 3.6% in basalt to 1.8% in dacite, and from petrographic data changes from 5% in basalt to 2% in dacite.

Magmatic Discriminant Diagram

In this subchapter, i want to determine the relationship between basalt and dacite using qualitative pattern of the existing geochemical discriminant diagrams. The relationship between basalt and dacite can be seen from relative continuity in magmatic affinity pattern, and the pattern of similarity in spider diagram for Rare Earth Element (REE).

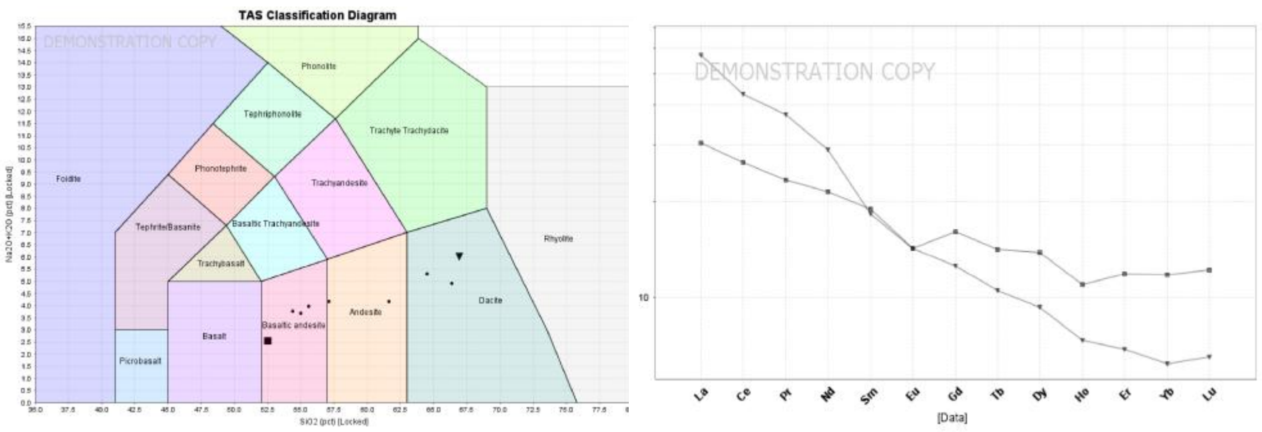
In the magmatic discriminant diagram, both rock was interpreted as same magmatic origin that form in calc-alkaline magma (in TAS diagram), or in one differentiation of magmatic trend from tholeitic basalt to calc-alkaline dacite (Figure 2) and its normally in island arc magma origin.

In REE/Chondrite normalizing spider diagram, we can see the global pattern was same with pattern of HREE, such as La-Ce-Pr-Nd, was increase in dacite and slowly down to immobile point at Sm and Eu, and up again to make LREE pattern on Gd-Tb-Dy-Ho-Er-Yb-Lu. If we look carefully the pattern of up and down the plotting point of each REE, can assume both this geochemical data have same origin.

Table 1: Mineralogical Composition from CIPW-Normative and Petrography on Basalt and Dacite Sample

Normative	Basaltic Andesite	Dacite	Change		Petrografi	Basaltic Andesite	Dacite
Minerals	Volume %	Volume %	*Difference*	%	Minerals	Volume %	Volume %
Quartz	7.08	18.53	11.45	162	Quartz		15
Plagioclase	57.43	54.85	-2.58	-4	Plagioclase	60	45
Orthoclase	2.20	10.59	8.39	381	Sanidine		15
Diopside	7.51	11.07	3.56	47	Clinopyroxene	5	
Hypersthene	22.00		-22.00		Hornblende		10
Wollastonite		2.54	2.54		Biotite		5
Ilmenite	0.94	0.42	-0.52	-55	Magnetite	5	2
Magnetite	2.49	1.47	-1.02	-41	Olivin	2	
Apatite	0.30	0.30	0.00	0	Glass Volc	3	8
Zircon	0.01		-0.01		px/diagenetic	25	
Chromite	0.04		-0.04				

Figure 2: Ploting Geochemical Data of Basalt (Square), Dacite (Triangle) and Other References (Bakar, 1997; and Bronto, 1999). (a) Total Alkali Silika Diagram (i.e., Bas et al., 1986), Shows Pattern of Diferentiation of Same Magma, (b) Normalizing to Chondrite, REE Diagram (Sun and Mc Donough, 1995 in Rollinson, 1993)



Quantitative Analysis

Correlation

Correlation between basalt and dacite, have a high positive correlation in major oxides (R: 0.98) and rare earth element (R: 0.98) and low correlation in trace element (R: 0.42). For bulk data, both rock seens have possitively correlation that interpretated that both rocks have correlated because it's diagenetic factor. Gain or loss of element from basalt to dacite will be explained with *isocon method*.

Isocon Method

For the isocon methode calculation in this paper, we are using density of rocks is 2.98 gr/cc for basalt and 2.78 gr/cc for dacite base on normative geochemically calculation.

Gressens (1967) and Grant (2005) performs the calculation of changes in the elements - elements immobile and mobile with metasomatisme concept, where the addition and subtraction element (i) of the initial rock (o) towards the rocks after (a) that affect for Concentration (C). Mass balance calculation formula by Grant (2005) are as follows:

$$(\Delta C_a^i / C_0^i) = (C_a^i / C_0^i) - 1,$$

$$(\Delta C_a^i / C_0^i) = (\rho_a / \rho_0)(C_a^i / C_0^i) - 1$$

Slope analysis (Table 2), used to see changes in the elements of basalt rocks toward dacite. For example if the slope is 1.0 shows that no change in the numbers. Result from slope analysis, K_2O, Na_2O, Rb, Ta, Ba, Nb, Th, La have a significant change. While, element of Eu, Al_2O_3, and Sm was near no change (0.96 – 1.0), and this element used in isocon calculation for definition how much gain or loss of element becaused of change from basalt to dacite. From isocon calculation, with calculated slope was 0.98 seen the rock from basalt to dacite have been increasing 8.81% of volume and 1.73% of mass, this result is correlation with the density of basalt greater than dacite.

Correlation coefficient of both rocks was positively, but in *isocon* calculation we can knows how much gain/loss of each major oxide. Result of calculation shown in Table 3 and Figure 3.

Gain or loss of concentration of major oxide shows the significant increasing oxide is K_2O with

Table 2: Slope Analysis of Elements from Basalt to Dacite

Major Elemet		Trace Element				REE	
Element	Slope	Element	Slope	Element	Slope	Element	Slope
K2O	5.56	Rb	4.07	Ge	0.87	La	1.89
Na2O	1.96	Ta	2.93	Tm	0.67	Ce	1.64
SiO2	1.27	Ba	2.92	Y	0.59	Pr	1.61
P2O5	1.08	Nb	2.23	Cs	0.33	Nd	1.35
Al2O3	0.99	Th	2.12	V	0.27	Eu	1.00
MnO	0.58	U	1.83	Hf	0.26	Sm	0.96
Fe2O3	0.53	Tl	1.67	Sc	0.23	Gd	0.78
TiO2	0.49	Zn	1.40	Zr	0.23	Tb	0.75
CaO	0.35	Li	1.10	Ni	0.06	Dy	0.68
MgO	0.21	Sr	1.07	Cr	0.05	Ho	0.67
		Ga	0.98	Zr	0.23	Er	0.58
						Lu	0.53
						Yb	0.53

4.2 to 4.65 times in dacite, for SiO_2 and NaO increase 0.2 to 1.0 times, while the MnO, Fe_2O_3, TiO_2, CaO and MgO decrease 0.4 to 0.79 times. This changes, is positively correlation with the occurences of mineralogy in dacite, such as presence of sanidine and quartz in dacite.

In trace element, Pb and Rb, shows significant increasing 2.8 – 4.0 times in dacite, while another trace element such as Ta, Ba, As, Nb, Th, U, Tl, and Zn increase 0.56 – 1.9 times in dacite. Other element; Y, Cs, V, Hf, Sc, Zr, Ni, Cr; decreasing 0.4 – 0.9 times in dacite.

Table 3: Result of Element Gain / Loss Calculation from Basalt to Dacite

Sample	Mafic	Felsic	Constant mass		Constant volume		Isocon	
			Gain/Loss relative to C_i^0	Gain/Loss in wt.% or ppm	Gain/Loss relative to C_i^0	Gain/Loss in wt.% or ppm	Gain/Loss relative to C_i^0	Gain/Loss in wt.% or ppm
	BGD_01	GD09RO	$\Delta C_i/C_i^0$	ΔC_i	$\Delta C_i/C_i^0$	ΔC_i	$\Delta C_i/C_i^0$	ΔC_i
SiO2	52.51	66.94	0.27	14.43	0.19	10.07	0.30	15.59
TiO2	0.78	0.39	-0.51	-0.39	-0.54	-0.42	-0.50	-0.39
Al2O3	15.89	15.74	-0.01	-0.15	-0.07	-1.18	0.01	0.12
Fe2O3	9.03	4.76	-0.47	-4.27	-0.51	-4.58	-0.46	-4.19
MnO	0.16	0.09	-0.42	-0.07	-0.45	-0.07	-0.41	-0.06
MgO	8.26	1.76	-0.79	-6.50	-0.80	-6.62	-0.78	-6.47
CaO	8.73	3.05	-0.65	-5.68	-0.67	-5.88	-0.64	-5.63
Na2O	2.24	4.39	0.96	2.15	0.83	1.87	1.00	2.23
K2O	0.31	1.72	4.56	1.41	4.20	1.30	4.65	1.44
P2O5	0.13	0.14	0.08	0.01	0.01	0.00	0.10	0.01
As	3.00	7.00	1.33	4.00	1.18	3.54	1.37	4.12
Cs	3.90	1.30	-0.67	-2.60	-0.69	-2.68	-0.66	-2.58
Li	23.30	25.70	0.10	2.40	0.03	0.73	0.12	2.85
Rb	6.80	27.70	3.07	20.90	2.81	19.10	3.14	21.38
Ba	135.00	394.00	1.92	259.00	1.73	233.36	1.97	265.82
Sr	231.00	247.00	0.07	16.00	0.00	-0.07	0.09	20.28
Pb	3.00	15.00	4.00	12.00	3.67	11.02	4.09	12.26
Cr	354.00	19.00	-0.95	-335.00	-0.95	-336.24	-0.95	-334.67
Ni	171.00	10.00	-0.94	-161.00	-0.95	-161.65	-0.94	-160.83
V	178.00	48.00	-0.73	-130.00	-0.75	-133.12	-0.73	-129.17
Sc	26.00	6.00	-0.77	-20.00	-0.78	-20.39	-0.77	-19.90
Ga	17.90	17.50	-0.02	-0.40	-0.09	-1.54	-0.01	-0.10
Ge	1.50	1.30	-0.13	-0.20	-0.19	-0.28	-0.12	-0.18

Table 3 (Cont.)

Zn	50.00	70.00	0.40	20.00	0.31	15.45	0.42	21.21
U	0.29	0.53	0.83	0.24	0.71	0.21	0.86	0.25
Zr	69.10	15.90	-0.77	-53.20	-0.78	-54.23	-0.77	-52.92
Hf	2.30	0.60	-0.74	-1.70	-0.76	-1.74	-0.73	-1.69
Y	19.60	11.60	-0.41	-8.00	-0.45	-8.75	-0.40	-7.80
Nb	3.00	6.70	1.23	3.70	1.09	3.26	1.27	3.82
Ta	0.27	0.79	1.93	0.52	1.74	0.47	1.98	0.53
Th	1.33	2.82	1.12	1.49	0.98	1.31	1.16	1.54
Tl	0.06	0.10	0.67	0.04	0.56	0.03	0.70	0.04
La	7.20	13.60	0.89	6.40	0.77	5.52	0.92	6.64
Ce	16.20	26.60	0.64	10.40	0.54	8.67	0.67	10.86
Pr	2.16	3.47	0.61	1.31	0.50	1.08	0.63	1.37
Nd	9.80	13.20	0.35	3.40	0.26	2.54	0.37	3.63
Sm	2.80	2.70	-0.04	-0.10	-0.10	-0.28	-0.02	-0.05
Eu	0.80	0.80	0.00	0.00	-0.07	-0.05	0.02	0.01
Gd	3.20	2.50	-0.22	-0.70	-0.27	-0.86	-0.21	-0.66
Tb	0.51	0.38	-0.25	-0.13	-0.30	-0.15	-0.24	-0.12
Dy	3.40	2.30	-0.32	-1.10	-0.37	-1.25	-0.31	-1.06
Ho	0.60	0.40	-0.33	-0.20	-0.38	-0.23	-0.32	-0.19
Er	1.90	1.10	-0.42	-0.80	-0.46	-0.87	-0.41	-0.78
Tm	0.30	0.20	-0.33	-0.10	-0.38	-0.11	-0.32	-0.10
Yb	1.9	1	-0.47	-0.90	-0.51	-0.97	-0.46	-0.88
Lu	0.3	0.16	-0.47	-0.14	-0.50	-0.15	-0.46	-0.14

Figure 3: Graphic of Calculation Gain / Loss Element, with Isocon Method, Calculation Using Factor of Constant Mass, Constant Volume, and Immobile Element (Isocon Line)

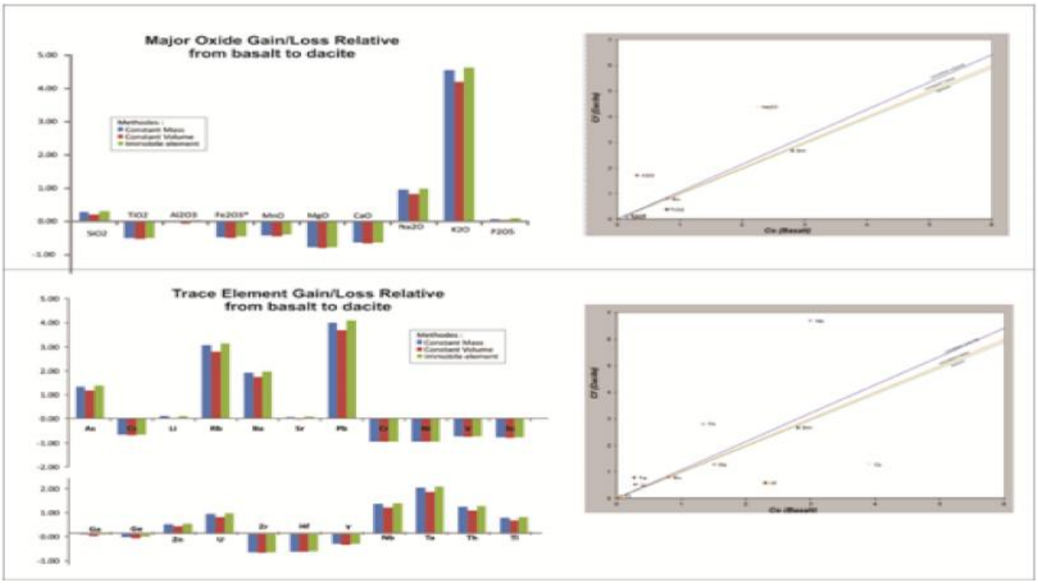
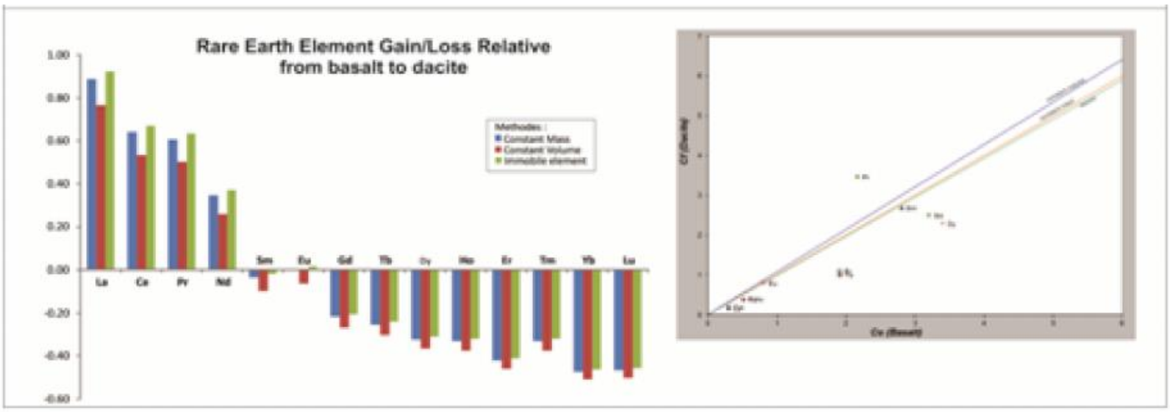


Figure 3 (Cont.)



In rare earth element, La, Ce, and Pr, increasing 0.6 – 0.992 times in dacite, with Eu and Sm are relatively stable as immobile element. While, Gd, Tb, Dy, Ho, Tm, Er, Lu, and Yb decrease 0.22 – 0.46 times in dacite.

CONCLUSION

Basalt as mafic rocks, and dacite as felsic rock in Godean have positive correlation in geochemistry, this conclude the magmatic of both rock was same base on qualitative and quantitative analysis. High positive correlation of both rocks, with Al_2O_3, Eu, Gd, and Sm as immobile element, and resulting that geochemical increasing at K_2O, SiO_2, NaO, Pb, Rb, La, Ce, Pr, while the other element was decreasing. Another method is needed to interpreted more detail in mineralogy changes, and magmatic changes in this case. This research perhaps can used to another type of igneous rock analysis, to interpretation the geological phenomena.

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