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ΠΡΟΕΔΡΙΑ ΠΕΤΡΟΥ ΧΑΡΗ

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ΓΕΩΧΗΜΕΙΑ.— **Geochemistry of high K-andesites from Polichnitos area (Lesvos island, Greece), by A. E. Kelepertsis\***. Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Ἰω. Τριγκαλινοῦ.

#### ABSTRACT

The distribution of rock forming ( $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{TiO}_2$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{FeO}$ ,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{MnO}$ ,  $\text{P}_2\text{O}_5$ ) and rare (V, Cr, Ni, Cu, Zn, Rb, Ba, Sc, Sr, Y, Zr, Nb, Th, U, lanthanides) elements from volcanites of Polichnitos area is reported. These volcanites belong to the high K-andesites. Total lanthanide rare earth elements for the whole collection appear to be related to the hydrothermal action. Geochemical and  $\text{Sr}^{87}/\text{Sr}^{86}$  isotopic data for the andesitic rocks are inconsistent with their derivation by fractional crystallization from a basaltic parent, or by direct mantle derivation involving a single stage process. It is suggested that the andesitic volcanics are products of a primary andesitic magma which originated by partial fusion of material of the lower crust.

#### INTRODUCTION

Mytilini is a mountainous island made up of cenozoic volcanic rocks, sedimentary rocks derived from the volcanics, and subordinate organic limestones and marls. Mytilini has a total area of  $1600 \text{ km}^2$ , with

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some 15-20% of its area occupied by two shallow water gulfs (lagoons), both situated in the southern part of the island (Fig. 1).

The work reported here forms the beginning of an investigation of the major and trace element geochemistry of the volcanic rocks in

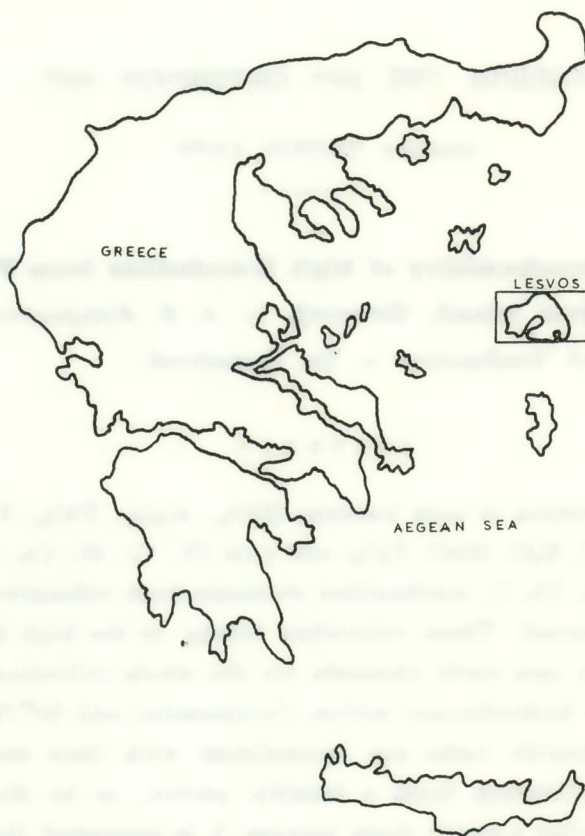


Fig. 1.

Mytilini island. The samples studied are representative rock types from the localities Nyfida and Apothika (Fig. 2) north-west of Polichnitos villa, and from the Agra area.

The geology and petrology of Mytilini has been described by Hecht (1971) who has carried out the geological mapping of the island. The extrusive rocks of Mytilini are mainly Pliocene in age. According to Borsi et al. (1972) the volcanism of Lesbos began in the lower Miocene (21 m. y.). The rocks described belong to the group described by Hecht



(1971) as upper lava unit. This large group comprises dacitic, latitic, latitandesitic and quartz-andesitic lavas.

#### PETROGRAPHY OF THE ROCKS

Thin section examinations showed the rocks to be composed of the following minerals:

- a) Plagioclase. X-ray diffraction of mechanically separated crystals was used to identify the plagioclase feldspar (andesine). In some cases the plagioclase have suffered a magmatic corrosion. The composition of plagioclase is between  $An_{65-75}$ , according to Brager (1966). Zoned plagioclase phenocrysts are abundant.
- b) Biotite is widespread showing a strong pleochroism from brown to light brown.
- c) Clinopyroxene (augite). This is the principal ferromagnesian mineral in the phenocrysts.
- d) A few olivine grains, as residues.
- e) Hematite - magnetite.
- f) Apatite.
- g) Amphibole rare (Hornblende).

The rocks have a porphyritic texture the phenocrysts of plagioclase, clinopyroxene, biotite being set in a fine or medium-fine grained groundmass.

Xenocrysts of corroded quartz occur sporadically.

#### ANALYTICAL METHODS

Laboratory work was carried out at the Department of Geology, Manchester University. Whole rock analyses have been made by standard X. R. F. (Brown et al. 1973) and classical wet chemical methods. (FeO was determined using the method of Wilson 1955, 1960; H<sub>2</sub>O and CO<sub>2</sub> was determined gravimetrically). The trace elements V, Nd, Ce, Cr, Ni, Cu, Zn, Rb, Ba, Sc, Sr, Y, Zr, La, Nb were determined by X. R. F. analysis. U, Th and lanthanides were determined by using mass spectrographic analysis (Nicholls et al. 1967, and Nicholls 1970).

The results obtained are reported in tables 1 and 2.

T A B L E 1

Chemical composition of five representative rock types and comparison with average chemical compositions of a high K-andesite and dacite (Jakes and White, 1972).

O x i d e	P M 1	N R 2	Π' 3	N' G R' 4	N R' 5	High K-andesite	Andesite (Coulon, 1973)	D a c i t e
SiO <sub>2</sub>	60.75	61.22	57.39	60.83	58.36	58.52	61.23	66.80
Al <sub>2</sub> O <sub>3</sub>	14.79	15.33	15.77	15.69	16.15	16.20	17.43	18.24
(total)								
Fe <sub>2</sub> O <sub>3</sub>	6.19	5.45	6.44	5.43	6.55	6.58	—	2.38
FeO	2.42	0.65	2.16	0.66	0.39	—	1.48	—
MgO	2.02	2.96	3.99	2.31	2.55	4.14	1.37	1.50
CaO	5.28	5.86	7.19	6.84	8.16	5.59	5.66	3.17
Na <sub>2</sub> O	2.92	3.23	2.86	3.20	3.24	3.64	3.43	4.97
K <sub>2</sub> O	3.72	3.22	2.09	3.10	2.58	2.67	2.65	1.92
MnO	0.17	0.13	0.11	0.06	0.08	0.09	0.09	0.06
TiO <sub>2</sub>	0.92	0.69	0.73	0.65	0.70	0.76	0.60	0.23
P <sub>2</sub> O <sub>5</sub>	0.46	0.23	0.26	0.28	0.29	0.25	0.25	0.09
H <sub>2</sub> O <sup>+</sup>	2.49	1.41	2.75	1.10	0.98	—	1.55	—



T A B L E 2

Trace elements in the andesite formation under study  
(data in ppm by wt).

	P M 1	N R 2	Π' 3	N G R' 4	N R' 5
V	109	79	137	151	119
N D	39	26	21	28	28
C E	100	75	62	66	63
C R	236	178	480	354	527
N I	81	59	79	81	71
C U	40	41	52	41	51
Z N	119	61	69	64	48
R B	164	119	126	129	107
B A	1846	1550	1282	4459	1214
S C	20	15	19	22	27
S R	820	658	553	692	658
Y	30	21	19	17	12
Z R	218	167	146	146	123
L A	64	57	47	31	42
N B	23	16	20	17	19

## WHOLE ROCK GEOCHEMISTRY

## Discussion

The rock type was identified on the basis of the potassium-silica relationship (Fig. 3). The rocks plot in the field of high K-andesite (one of them in the field of andesite) as defined by Taylor (1969).

The FMA diagram (Fig. 4) indicates that there is no iron enrichment, relative to MgO and  $\text{Na}_2\text{O} + \text{K}_2\text{O}$ . On the same diagram

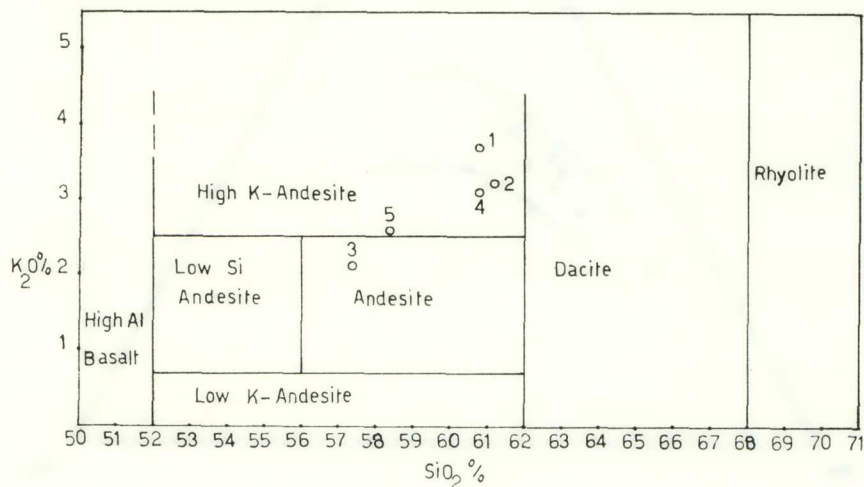


Fig. 3.

other high K-andesites and similar rocks are plotted for comparison. The rocks plot within the limits of Kuno's (1966) «hypersthenic rock series» and belong to the calc-alkaline rock series.

The  $\text{K}/\text{SiO}_2$  ratio is high (5.09, 4.37, 3.02, 4.23, 3.67) similar to those values of the northern group of Aegean sea volcanoes (PE, 1975).

The average chemical composition of the analysed rocks and the average composition of the crust are given in the table 3). A high degree of similarity is evident, especially when comparing the Mytilini rocks with the average chemical composition of the crust. Assuming that these

andesites are derived directly from the upper mantle, higher Fe, Mg, Ca and Ti average values than in the crust would be expected. These

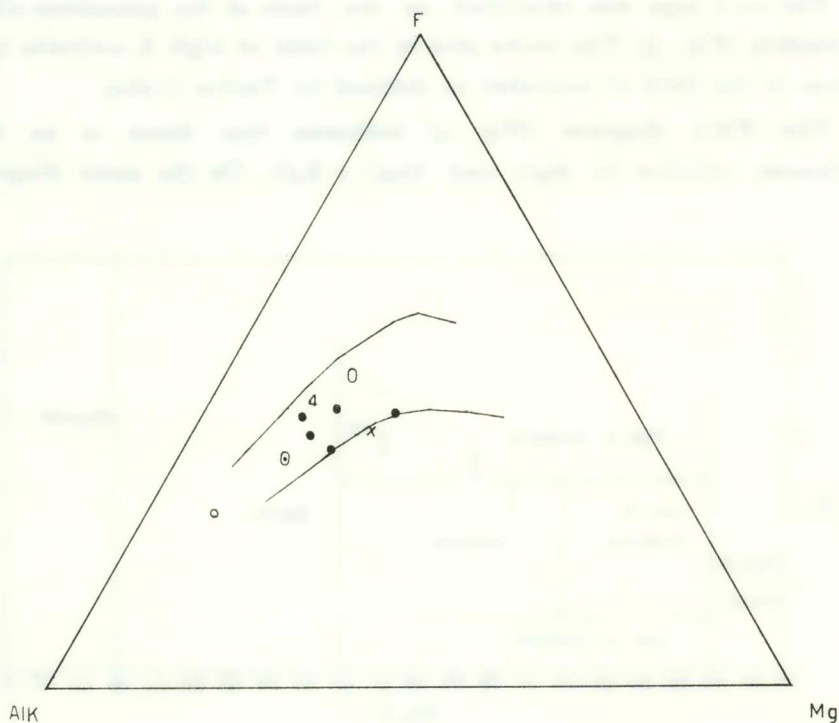


Fig. 4.

values, however, are either approximately equal to or lower than those of the crust.

The following trace elements have been determined in the andesites under study: V, Cr, Ni, Cu, Zn, Rb, Ba, Sc, Sr, Y, Zr, Nb.

#### MASS SPECTROGRAPHIC DETERMINATIONS OF U, Th AND RARE EARTHS

Table 4 shows the contents of U, Th and lanthanides in three andesites under study. The total lanthanide contents range between 140 and 175 ppm. For all samples analysed the light rare earths, La, Ce, Pr and Nd contribute the greater part to the total lanthanide content.



T A B L E 3

Average major element chemistry of volcanic rocks,  
in comparison with those of the crust, and of the  
detrital fraction of bottom sediments.

	Average vol- canic rock (5 analyses)	Average detrital fraction *	1	2	3
SiO <sub>2</sub>	59.71	56.21	59.4	60.3	60.18
Al <sub>2</sub> O <sub>3</sub>	15.55	15.57	15.6	15.6	15.61
(total)					
Fe <sub>2</sub> O <sub>3</sub>	6.01	6.39	—	7.2	—
FeO	1.26	—	5.0	7.2	3.88
MgO	2.77	3.33	4.2	3.9	3.56
CaO	6.67	1.35	6.6	5.8	5.17
Na <sub>2</sub> O	3.09	1.06	3.1	3.2	3.91
K <sub>2</sub> O	2.94	3.07	2.3	2.5	3.19
TiO <sub>2</sub>	0.74	0.79	1.2	1.0	1.06
MnO	0.11	0.08	0.2	—	—
P <sub>2</sub> O <sub>5</sub>	0.30	0.10	0.3	—	—
I. L.	1.75	—	—	—	—
C	—	5.30	—	—	—
H <sub>2</sub> O	—	6.33	—	—	—

1 = Continental crust, average of continental shield and young folded belt regions (Poldervart, 1955); corresponds to quartz-bearing latite-andesite.

2 = Continental crust, average of one part basic and one part felsic rock (Taylor, 1964); corresponds to quartz-bearing latite-andesite.

3 = Continental crust (Clarke and Washington, 1924); corresponds to quartz-bearing latite.

\* Average of 12 detrital fractions of bottom sediments from the Kalloni gulf. (Kelepertsis, 1977).

TABLE 4

Mass spectrographic determinations of U, Th and lanthanides (data in ppm wt) of unaltered and hydrothermally altered andesites.

	3	4	5	A*
U	13.40	14.3	1.01	—
Th	34	69.5	10	—
La	47	31	42	0.30
Ce	62	66	63	0.84
Pr	11.6	16	1.8	0.12
Nd	21	28	28	0.58
Sm	8.3	6.3	1.0	0.21
Eu	2.1	1.8	0.26	0.074
Gd	7.8	6.2	0.91	0.32
Tb	1.43	1.6	0.17	0.058
Dy	5.4	4.3	0.75	0.31
Ho	0.92	0.75	0.12	0.073
Er	3.3	3.8	0.77	0.21
Tm	0.47	0.59	0.16	0.033
Yb	3.4	3.5	0.56	0.17
Lu	0.58	0.86	0.25	0.031

A\* = Average of chondritic meteorite analyses given by Has-  
kin et al. 1966.

In any graphical representation of abundances of the rare earth elements a simple plot of log concentration against atomic number results in a zig-zag pattern due to the natural predominance of elements having an even mass number over those of odd mass number. Coryell et al. (1963) suggested removal of the figure by dividing the element contents in one population by the corresponding ones in a second. I have followed

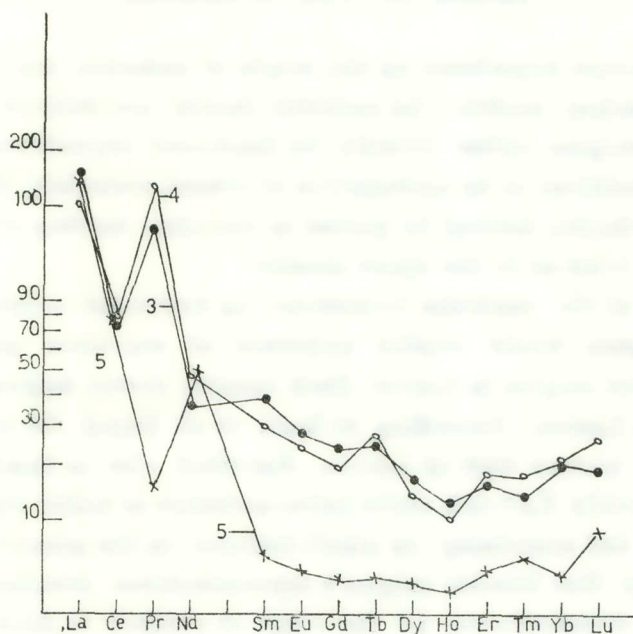


Fig. 5.

previous practice in using figures for the average rare earth contents of chondritic meteorites as the second population. For each rare earth in each of the andesite sample the ratio (content in andesite) / (average content in chondritic meteorites) was calculated and in the text figure in this paper these ratios have been plotted on a log scale against atomic number (fig. 5).

The two samples (No 3, No 4) represent grey coloured andesites which show no signs of hydrothermal alteration. The sample No 5 is a red coloured andesite which has been altered hydrothermally. Comparison of the total rare earths of the hydrothermally altered andesite with those of the unaltered andesite showed that the red andesite is depleted

in rare earths. Inspection on the fig. 5 shows that this depletion is mainly due to the lower Pr (light earth) content and the lower heavy rare earth contents of the red andesite. La, Ce and Nd contents are approximately the same in both the grey and red andesite. On the other hand, the two unaltered grey andesites show similar RE patterns.

#### ORIGIN OF THE ANDESITES

The current hypotheses on the origin of andesites can be grouped into two principal models: (a) andesitic liquids are derived from high Al-basaltic magma either directly by fractional crystallization under oxidizing conditions or by assimilation of crustal materials; (b) andesites are primary liquids derived by partial or complete melting of host rocks in the lower crust or in the upper mantle.

Origin of the «andesite formation» by fractional crystallization of basaltic magma would require existence of enormous quantities of basaltic parent magma in Lesvos. Such basaltic parent magma, however, is lacking in Lesvos. According to Borsi et al. (1972) the recent basic rocks of the eastern part of Lesvos, described also as basalts (Prager, 1966) are actually  $K_2O$ -rich mafic latite-andesites or latites rich in augite and olivine and containing an alkali-feldspar in the ground mass. It is very unlikely that basaltic magma's representatives remained at depth, whereas the differentiates, i.e. the range of andesite to dacites, reached the surface. Also the trace element abundances are inconsistent with a derivation of the magma of the andesite formation by fractional crystallization of basaltic parent. The  $Sr^{87}/Sr^{86}$  isotopic composition (Borsi et al. 1972) shows relatively high values. Magmatic rocks of upper mantle derivation show  $Sr^{87}/Sr^{86}$  ratios generally between 0.702 and 0.705 the andesites having a maximum frequency around 0.704 (Pushkar, 1968). Compared to this all values are too high (mean value 0.708) and therefore not consistent with a derivation of the andesitic magmas directly from the mantle. The data available for the andesites under study are inconsistent with their derivation by fractional crystallization of a basaltic parent or by direct mantle derivation involving a single stage process. The andesitic rocks are products of a primary andesitic magma originated by widespread partial fusion of material in the lower crust.



This suggestion is based both on major and trace element characteristics and on  $\text{Sr}^{87}/\text{Sr}^{86}$  compositions. An origin of the andesitic magmas by mixing of basaltic magmas of the upper mantle with acidic melts, formed by fusion of upper crustal rocks, does not seem plausible, because of the high contents of some large ionic radius elements (Ba, Th, U, Sr, Rb, K) which are approximately equal to or lower than those of the crust.

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#### Π Ε Ρ Ι Λ Η Ψ Ι Σ

Εἰς τὴν παροῦσαν ἐργασίαν μελετᾶται ἡ κατανομὴ τῶν ὀρυκτολογικῶν συστατικῶν καὶ ὀξειδίων ( $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{TiO}_2$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{FeO}$ ,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{MnO}$ ,  $\text{P}_2\text{O}_5$ ) καθὼς ἐπίσης ἡ κατανομὴ ἱχνοστοιχείων (V, Cr, Ni, Cu, Zn, Rb, Ba, Sc, Sr, Y, Zr, Nb, Th, U, σπάνιαι γαῖαι) εἰς ἡφαιστίτας ἀπὸ τὴν περιοχὴν Πολιχνίτου καὶ Ἄγρας τῆς νήσου Λέσβου. Τὰ κύρια ὀρυκτολογικὰ συστατικὰ τῶν ἀνωτέρω ἡφαιστιτῶν εἶναι πλαγιόκλαστον (ἀνδεσίνης), βιοτίτης, αὐγίτης, ἐνῶ δευτερευόντως ἀπαντοῦν ὀλιβίνης, αἱματίτης, μαγνητίτης, ἀπατίτης, κερροσίλβη.

Τὰ μελετηθέντα πετρώματα ἀνήκουν εἰς τὴν κατηγορίαν τῶν ἀνδεσιτῶν μὲ ὑψηλὸν ποσοστὸν καλίου (K). Τὸ σύνολον τῶν σπανίων γαιῶν ἀπεδείχθη ὅτι συνδέεται μὲ τὴν ὑδροθερμικὴν δρασιν.

Τὰ γεωχημικὰ δεδομένα καὶ τὰ ἀποτελέσματα τοῦ λόγου τῶν ἰσοτόπων στρόντιου  $\text{Sr}^{87}/\text{Sr}^{86}$  τῶν ἀνωτέρω ἀνδεσιτῶν δὲν συμβιβάζονται μὲ μία προέλευσιν ἀπὸ κλασματικὴν κρυστάλλωσιν ἐνδὸς βασालτικοῦ μάγματος ἢ ἀπὸ ἀπ' εὐθείας προέλευσιν ἀπὸ τὸν μανδύαν. Εἶναι πιθανὸν ὅτι τὰ μελετηθέντα πετρώματα προῆλθον ἀπὸ ἓνα πρωταρχικὸν ἀνδεσιτικὸν μάγμα, τὸ ὁποῖον ἐσχηματίσθη ἀπὸ μερικὴν τῆξιν ὑλικοῦ τοῦ κατωτέρου φλοιοῦ.



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