RENDICONTI DELLA SOCIETÀ ITALIANA DI MINERALOGIA E PETROLOGIA, 1987, Vol. 42, pp. 83-94

The Basalts of M.te Guzzini (South-Central Sardinia)

LUCIANO MACCIONI, MARIA VITTORIA MURGIA
Dipartimento di Scienze della Terra, Università degli Studi, Via Trentino 51, 09100 Cagliari

ABSTRACT. — The Pliocene volcanites of M.te Guzzini consist of hawaiites and lati-basalts, both characterized by an olivine-clinopyroxene-feldspar-opaque oxide assemblage. Rare nephelines mark the groundmass of some doleritic hawaiites. Lati-basalts form the lower part of the lava sequence.

Microprobe analyses show compositions ranging from chrysolite to hyalosiderite for olivines; from labradorite to andesine for plagioclases; from diopside to salite or to Ca-augite for pyroxenes; and from anorthoclase to Na-sanidine for alkali feldspars. The presence of the pair ilmenite-magnetite in the groundmass provides information on the T (°C) — fO_2 conditions of crystallization for P = 1 atm: T = 978 °C $fO_2 = 10^{-11.6}$ (lati-basalts) and T = 985 °C $fO_2 = 10^{-12.4}$ (hawaiites). The geothermometry based on olivines gives temperatures of 1140 °C in the lati-basalts and 1175 °C in the hawaiites.

The complex genesis of M.te Guzzini volcanites is indicated both by the mineral chemistry, which shows a frequent Mg-rich olivine-host rock disequilibrium, and by the major and trace elements trends showing a marked enrichement of incompatible elements.

Key words: Italy, Sardinia, Pliocene, basalts, petrology.

RIASSUNTO. — Le vulcaniti plioceniche del M.te Guzzini sono rappresentate da hawaiiti e lati-basalti, entrambi caratterizzati da una paragenesi a olivina, clinopirosseno, feldspati e minerali opachi. Rare nefeline contraddistinguono la pasta di fondo di alcune hawaiiti doleritiche. I lati-basalti formano la parte inferiore della sequenza lavica.

Le analisi alla microsonda elettronica hanno rivelato composizioni varianti da crisolito a ialosiderite per le olivine; da labradorite ad andesina per i plagioclasi; da diopside a salite o a Ca-augite per i pirosseni; da anortoclasio a Na-sanidino per i feldspati alcalini. La presenza della coppia ilmenite-magnetite nella pasta di fondo ha fornito informazioni sui valori di T (°C) — fO_2 che hanno caratterizzato le condizioni di cristallizzazione per P = 1 atm: T = 978 °C $fO_2 = 10^{-11.6}$ (lati-basalti) e T = 985 °C $fO_2 = 10^{-12.4}$ (hawaiiti). La geotermometria basata sulle olivine indica temperature di 1140 °C per i lati-basalti e 1175 °C per le hawaiiti.

La genesi complessa delle vulcaniti del M.te Guzzini emerge sia dai caratteri chimici dei minerali essenziali che evidenziano frequenti disequilibri tra le olivine ricche in Mg e la roccia ospite, sia dai trends degli elementi maggiori e in tracce che mostrano un marcato arricchimento in elementi incompatibili.

Parole chiave: Italia, Sardegna, Pliocene, basalti, petrologia.

Introduction

This paper describes the ongoing research on the Pliocene basic volcanics of central southern Sardinia (CONTI L., MACCIONI L., 1974; MURGIA M.V., 1984) involving the study of the basalt flows (hawaiites and lati-basalts) of M.te Guzzini near Nurri. The Pliocene volcanics (2.62 m.y., ASSORGIA et al., 1983) rest directly on shallow marine Miocene sediments (conglomerates and sandstones with Ostrea and Echinids) and on marls with the typical foraminiferal fauna of the Trexenta - Marmilla basin (POMESANO CHERCHI A., 1967).

Geological notes

The basalt cover extends over about 10 sq. km and consists of a northern part (where at least five lava flows can be identified) with

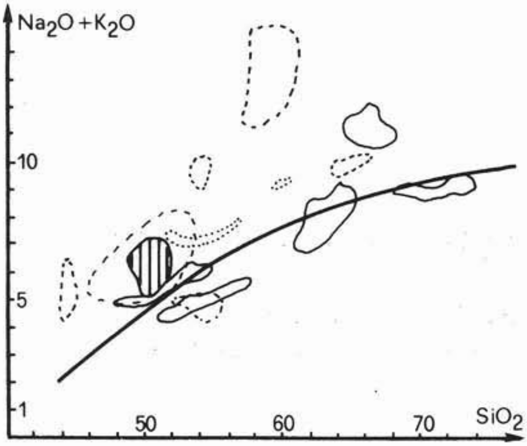

Fig. 1. — SiO_2 - ($Na_2O + K_2O$) diagram (IRVINE T.N., BARAGAR W.R.A., 1971): the volcanics of Mt. Guzzini (hatched area) are confronted with the coeval basalts of Mt. Arci (continuous line), the alkaline basalts of Montiferro (dashed line), the subalkaline basalts of Campeda and Montiferro (dash and point line) and the alkaline suite of Capo Ferrato district (pointed line).

a maximum thickness of 15-20 m and culminating at an altitude of 734 m on M.te Guzzini, and a southern part, which forms the tongue of Tacquara.

The earliest volcanic activity erupted tuffaceous breccias, cropping out in a morphological depression around the C.ru Casas dike.

Petrography

The lava flows are all dark grey in colour. The texture varies from aphanitic to microcrystalline. Microscopically, the volcanics are porphyric, varying from intersertal to pilotaxitic, with local tendencies towards a doleritic texture.

The predominant hawaiites can be subdivided into two types. The first type is characterized by prevalent olivine phenocrysts (18% volume), with rims that are often transformed into iddingsite, and with rare inclusions of opaque minerals, surrounded by a microlithic plagioclasic matrix of felt-like texture, subordinate alkali feldspars, and abundant opaque minerals. The second type of hawaiite, somewhat doleritic, has phenocrysts of olivine (8%), partially transformed into iddingsite and with opaque inclusions, subhedral phenocrysts of clinopyroxene (9%) that often show zonation and/or are grouped in cumuli, and phenocrysts of plagioclase (4%). Its matrix also contains plagioclases with a felt-like texture, isodiametric olivines (6%), and clinopyroxenes (6%), which are sometimes enclosed by alkali feldspars. The paragenesis is completed by abundant opaque minerals, rare subidiomorphic nephelines (1%), and microphenocrysts of apatite.

In lati-basalts, the phenocrysts consist of olivine (15%) and clinopyroxene (2%), sometimes in cumuli. The hypocrystalline matrix consists of plagioclases, alkali feldspars, olivines, clinopyroxenes, and many opaque minerals.

All the lithotypes described show the presence of quartz xenocrystals and, rarely, resorbed plagioclases.

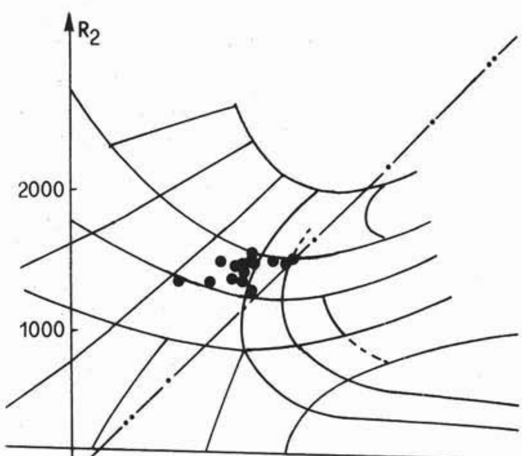

Fig. 2. — R1 - R2 diagram (DE LA ROCHE H. et al., 1980).

Chemistry

Chemical analysis was performed on fifteen selected samples (Table 1 and 2).

The basic alkaline nature of all the samples analyzed is shown in the SiO_2 — ($Na_2O + K_2O$) diagram in Fig. 1 (IRVINE T.N., BARAGAR W.R.A., 1971), while their

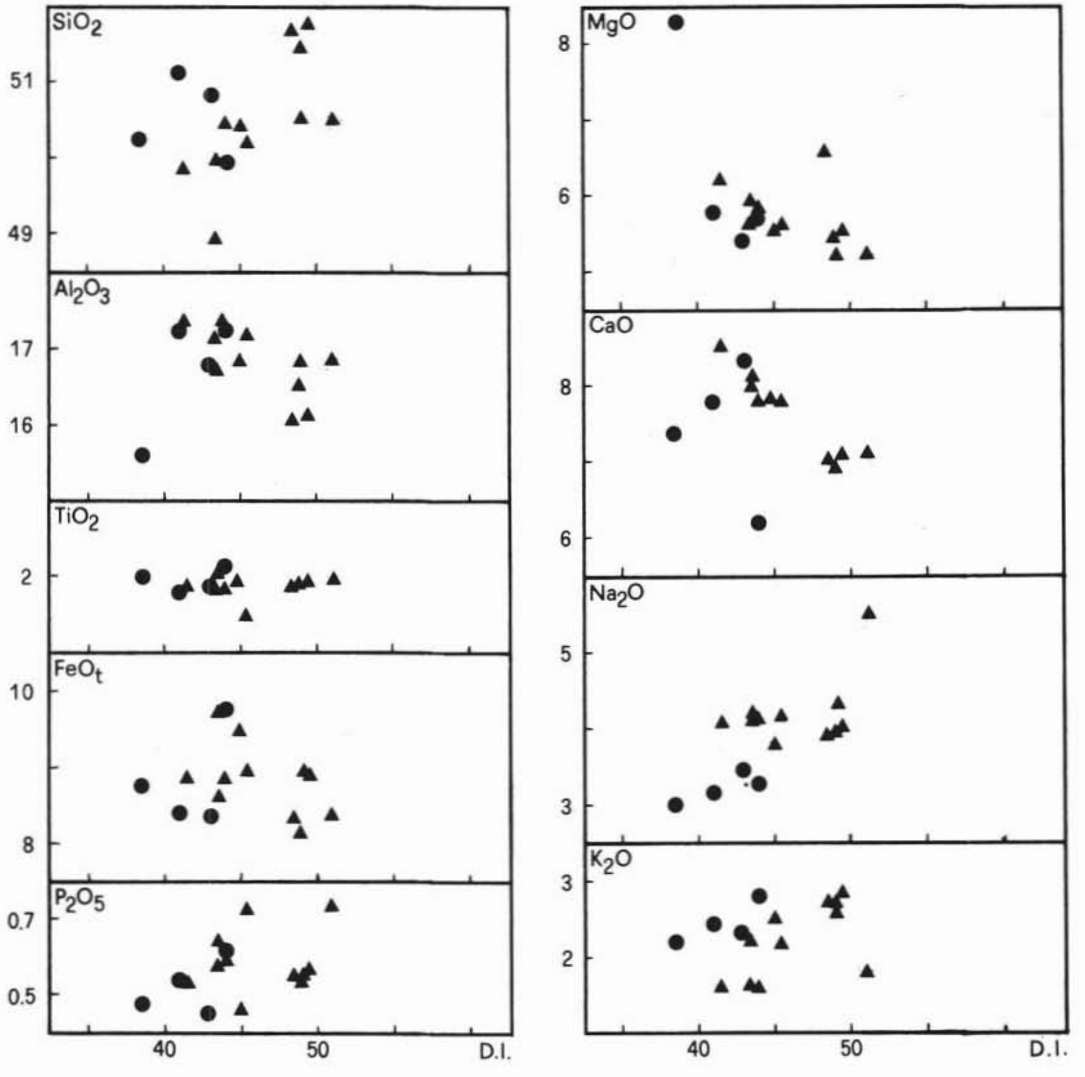

Fig. 3. — Major elements - DI diagrams; ● lati-basalts; ▲ hawaiites.

predominant hawaiitic character is shown by the R1-R2 diagram in Fig. 2 (DE LA ROCHE H. et al., 1980). Only four samples are in the lati-basalt field; these are situated in the basal part of the plateau (samples G4 and G13) and in the Tacquara tongue (G1), where a less differentiated facies was also found (G2). In the hawaiites, too, less evolved facies are present (G11), together with terms characterized by a mugearitic tendency (G5 and G3). Correspondingly, the solidification index (SI) attains the maximum value in G2 (37.5) and its minimum in G5 and G3 (24.5 and 25.0).

In the variation diagrams in Fig. 3, one may observe a relative dispersion of the values, probably due to the porphiricity of all samples and to the presence of cumulus enrichment processes, evidenced by diffuse glomerophyric aggregates.

The distribution of trace elements, particularly those with a low value in respect with the bulk solid/liquid distribution coeficient, also seems to confirm the complex genesis of the volcanics of M.te Guzzini. As is known,

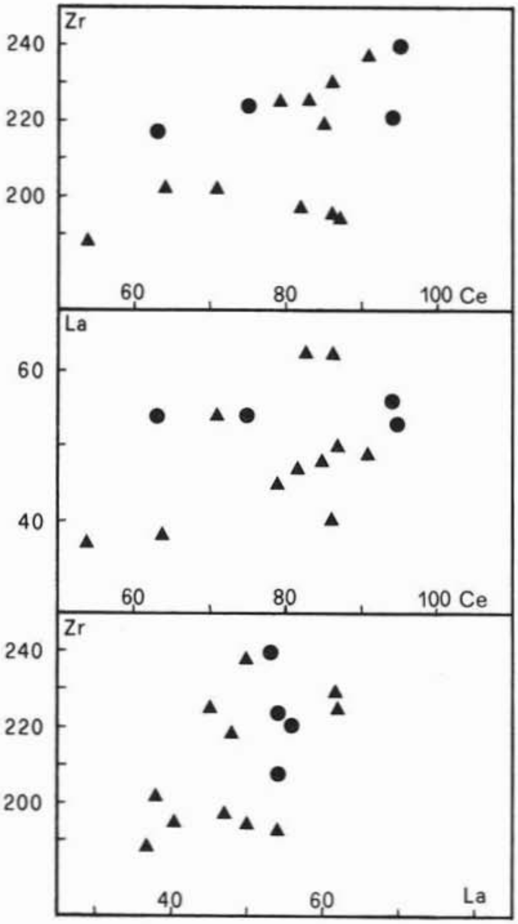

Fig. 4. — Zr - Ce, La - Ce, Zr - La diagrams; symbols as in Fig. 3.

the ratio of content of incompatible elements should remain constant in lithotypes formed by fractional crystallization. However, in the La — Ce, Zr — Ce, Zr — La diagrams, only lati-basalts are characterized by a linear correlation that contrasts with the irregular hawaiites distribution (Fig. 4).

The high-strength field elements (HSFE) Ti, Zr, Y and Nb serve to confirm the geodynamic environment: the Ti — Zr — Y triangular diagram and that of the ratios Ti/Y — Nb/Y (Figg. 5, 6), indicate the interplate position of the volcanics of M.te Guzzini and their alkaline character (Pearce J.A., Cann J.R., 1973; Pearce J.A., Norry M.J., 1979).

Lastly, the diagram in Fig. 7 seems to be

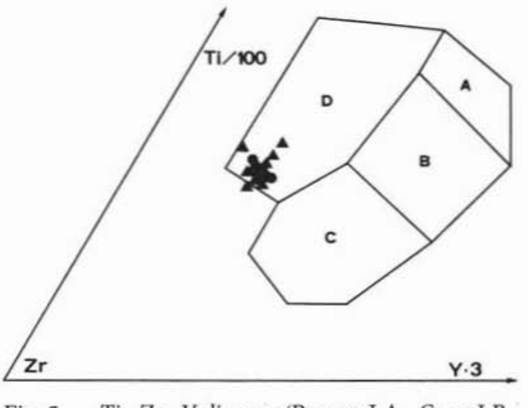

Fig. 5. — Ti - Zr - Y diagram (Pearce J.A., Cann J.R., 1973); A and B (LKT), B (OFB), C and B (CAB), D (WPB); symbols as in Fig. 3.

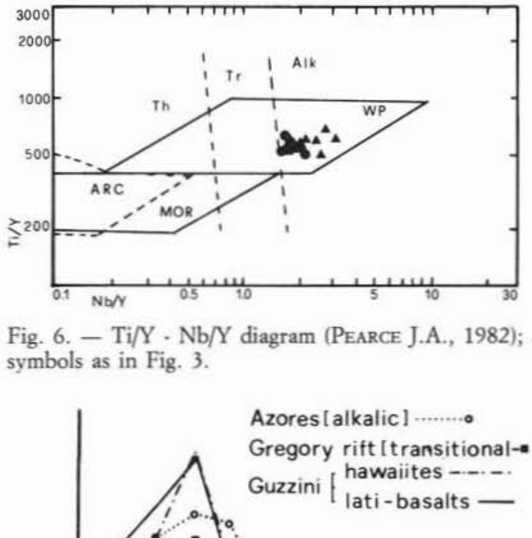

Fig. 6. — Ti/Y - Nb/Y diagram (Pearce J.A., 1982); symbols as in Fig. 3.

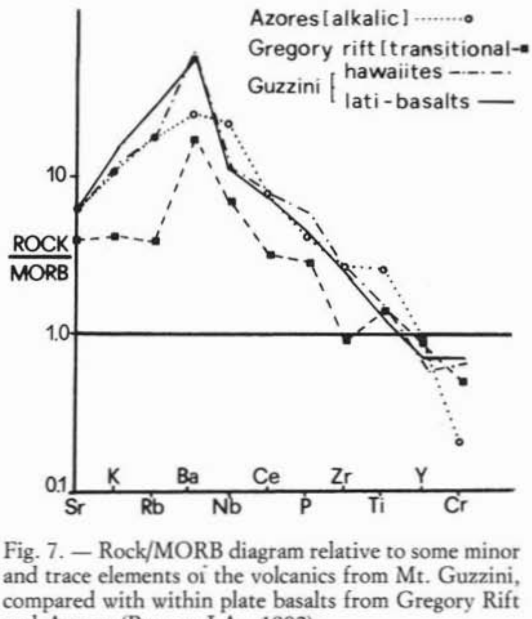

Fig. 7. — Rock/MORB diagram relative to some minor and trace elements of the volcanics from Mt. Guzzini, compared with within plate basalts from Gregory Rift and Azores (Pearce J.A., 1982).

TABLE 1

Major elements and CIPW norms of Mt. Guzzini volcanic rocks

Sample	G1	G2	G4	G13	G3	G5	G6	G7	G8	G9	G10	G11	G12	G14	G15
Rock type	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H
SiO_2	51.11	50.22	49.93	50.83	50.44	50.54	51.66	51.70	51.41	48.93	50.15	49.22	50.39	49.95	50.37
TiO_2	1.78	1.98	2.12	1.86	1.99	1.90	1.84	1.92	1.93	2.03	1.47	1.81	1.80	1.82	1.37
Al_2O_3	17.19	15.58	17.22	16.76	16.91	16.83	16.06	16.10	16.47	16.68	17.15	17.29	17.34	17.08	16.79
Fe_2O_3	1.21	3.85	4.43	4.33	1.81	3.42	2.74	3.40	3.20	3.06	1.50	2.10	3.01	4.68	4.63
FeO	7.30	5.32	5.77	4.47	6.74	5.84	5.91	5.81	5.24	6.94	7.60	6.95	6.03	4.40	5.21
MnO	0.12	0.12	0.13	0.11	0.12	0.12	0.13	0.13	0.13	0.15	0.10	0.13	0.13	0.13	0.12
MgO	5.77	8.32	5.68	5.42	5.21	5.17	6.54	5.54	5.38	5.89	5.60	6.19	5.82	5.57	5.48
CaO	7.78	7.36	6.23	8.33	7.10	6.94	7.06	7.12	6.91	8.00	7.82	8.53	7.77	8.14	7.80
Na_2O	3.16	3.01	3.25	3.46	5.49	4.29	3.88	4.01	3.96	4.08	4.14	4.05	4.09	4.14	3.74
K_2O	2.44	2.22	2.79	2.27	1.78	2.70	2.72	2.85	2.60	2.21	2,16	1.56	1.58	1.62	2.51
P_2O_5	0.54	0.48	0.61	0.45	0.74	0.55	0.54	0.56	0.54	0.57	0.72	0.53	0.59	0.64	0.46
L.O.I.	1.60	1.54	1.84	1.71	1.67	1.70	0.92	0.86	1.23	1.46	1.59	1.04	1.45	1.83	1.03
mg*	58	68	56	57	57	57	62	58	57	58	58	60	58	58	56
Or	14.4	13.1	16.5	13.4	10.5	15.9	16.1	16.8	15.4	13.0	12.8	9.2	9.3	9.6	14.8
Ab	26.7	25.5	27.5	29.3	33.6	29.9	31.6	31.4	33.5	25.6	30.1	30.1	34.6	32.9	28.4
An	25.5	22.4	24.1	23.5	16.2	18.7	18.4	17.5	19.5	20.7	21.8	24.4	24.3	23.2	21.6
Ne	---	---	---	---	7.0	3.5	0.7	1.3	---	4.8	2.7	2.2	---	1.1	1.7
Di	7.8	8.8	2.2	12.2	11.6	10.0	10.6	11.6	9.2	12.5	10.0	11.8	8.5	10.6	11.5
Hy	10.1	9.1	8.4	3.1	---	---	---	---	1.1	---	---	---	0.1	---	---
Ol	7.5	12.6	11.5	10.2	12.1	13.4	15.0	13.4	12.3	14.5	14.6	14.6	14.9	13.6	13.9
Mt	1.6	1.7	1.9	1.6	1.6	1.7	1.6	1.7	1.6	1.9	1.7	1.7	1.7	1.7	1.8
Il	3.4	3.8	4.0	3.5	3.8	3.6	3.5	3.6	3.7	3.8	21.8	3.4	3.4	3.4	3.5
Ap	1.3	1.1	1.4	1.1	1.7	1.3	1.3	1.3	1.3	1.3	1.7	1.2	1.4	1.5	1.1
DI	41.1	38.6	44.0	42.7	51.1	49.3	48.4	49.5	48.9	43.4	45.6	41.5	43.9	43.6	44.9

mg* = 100xMg/(Mg+Fe^{+2}); Fe^{+2} = 0.85 FeOtot
L = lati-basalts; H = hawaiites

TABLE 2

Trace elements of Mt. Guzzini volcanic rocks

Sample	G1	G2	G4	G13	G3	G5	G6	G7	G8	G9	G10	G11	G12	G14	G15
Rock type	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H
Zn ppm	91	102	106	70	90	102	95	98	97	107	71	95	73	84	89
Cu	45	16	22	9	20	16	17	19	20	19	67	30	23	26	19
Ni	137	110	130	120	128	134	114	131	121	95	85	114	112	141	141
Co	30	29	32	30	28	30	28	27	29	24	27	35	28	28	32
Cr	181	193	184	185	175	202	203	187	186	201	175	163	160	176	173
Ce	63	75	95	94	86	83	85	79	91	71	86	64	54	82	87
V	178	190	186	179	178	160	180	175	113	181	139	191	185	190	172
Ba	1115	780	1442	1005	1186	1407	1142	1041	1021	1491	1252	1210	983	1026	1074
La	54	54	53	56	62	62	48	45	49	54	40	38	37	47	50
Nb	46	29	43	34	37	37	34	32	41	45	47	42	39	55	38
Zr	208	224	240	221	230	225	219	225	238	192	195	202	188	197	194
Y	21	18	22	22	22	22	21	19	22	20	17	17	14	18	19
Sr	692	618	674	702	724	724	732	731	751	853	837	819	784	832	716
Rb	54	48	52	53	36	56	53	55	57	48	31	23	22	37	54
Pb	8	13	10	12	13	13	16	18	15	14	7	9	18	12	12
Y/Nb	0.46	0.62	0.51	0.65	0.59	0.59	0.62	0.59	0.54	0.44	0.36	0.40	0.36	0.33	0.50
Rb/Sr	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.06	0.04	0.03	0.03	0.04	0.08
Ce/Sr	0.09	0.12	0.14	0.13	0.12	0.11	0.12	0.11	0.12	0.08	0.10	0.08	0.07	0.10	0.12

significant: here, the lati-basalts and hawaiites trends show a marked enrichment of incompatible elements up to Ti, with a positive anomaly of Ba peculiar of some alkaline rocks, while there is relative depletion of Y in relation to Ti, which is characteristic of interplate basalts (PEARCE J.A., 1982).

Mineral chemistry

The minerals of the hawaiites and lati-basalts were analysed with the SEMQ-ARL electron microprobe at the «Centro studi geominerari e mineralurgici», CNR-Cagliari. The standards applied were natural silicates and oxydes; the data reduction was made with a ZAF correction (COLBY J.W., 1971).

Olivines

Selected analyses of olivines are shown in Table 3.

The percentage of Fo varies from 82 to 67 in the lati-basalts, and from 84 to 51 in the hawaiites. This reflects the separate phases of segregation of the olivines, already noted during the optical examination; the latest phase is represented by microphenocrysts in the groundmass (Fig. 8).

Assuming that K_D (ol-liq/Fe-Mg) = 0.33

TABLE 3 — *Olivines*

Sample	* G 1	*	G4	*	G5	*	G6	*	G 7	*	G10	*
SiO_2	38.26	37.03	39.50	38.43	39.80	36.51	38.65	37.12	40.02	39.15	39.74	34.93
Al_2O_3	0.13	0.44	0.06	---	---	---	---	---	---	0.05	---	---
TiO_2	0.02	0.02	0.03	0.01	0.02	0.20	0.01	0.11	0.03	0.02	0.02	0.06
Cr_2O_3	---	0.01	---	0.02	0.03	---	---	0.02	0.03	0.01	0.01	0.02
FeO	24.85	28.61	17.15	20.90	14.84	30.75	22.12	30.18	15.26	16.30	17.22	40.83
MnO	0.48	0.56	0.27	0.31	0.21	0.55	0.33	0.61	0.22	0.26	0.25	0.83
MgO	36.96	33.31	43.55	40.12	44.24	31.64	39.08	32.00	45.11	43.46	43.63	23.59
CaO	0.24	0.31	0.19	0.24	0.17	0.36	0.18	0.29	0.19	0.23	0.22	0.45
Sum	100.94	100.29	100.75	100.03	99.48	100.01	100.38	100.33	100.86	99.48	101.14	100.71
Numbers of ions on the basis of 4 oxygens												
Si	0.998	0.993	0.995	0.994	1.004	0.994	1.000	0.998	0.997	0.996	0.998	0.995
Al	0.004	0.014	0.002	---	---	---	---	---	---	0.001	---	---
Ti	---	---	0.001	---	---	0.004	---	0.002	---	---	---	0.001
Cr	---	---	---	---	0.001	---	---	---	0.001	---	---	0.001
Fe^{+2}	0.542	0.641	0.361	0.452	0.313	0.700	0.479	0.681	0.318	0.347	0.361	0.972
Mn	0.011	0.013	0.006	0.007	0.004	0.013	0.007	0.014	0.005	0.006	0.005	0.020
Mg	1.437	1.330	1.635	1.546	1.669	1.283	1.508	1.288	1.676	1.647	1.631	1.001
Ca	0.007	0.009	0.005	0.007	0.005	0.010	0.005	0.008	0.005	0.006	0.006	0.014
Fo	72.6	67.5	81.9	77.4	84.2	64.7	75.9	65.4	84.1	82.6	81.9	50.7

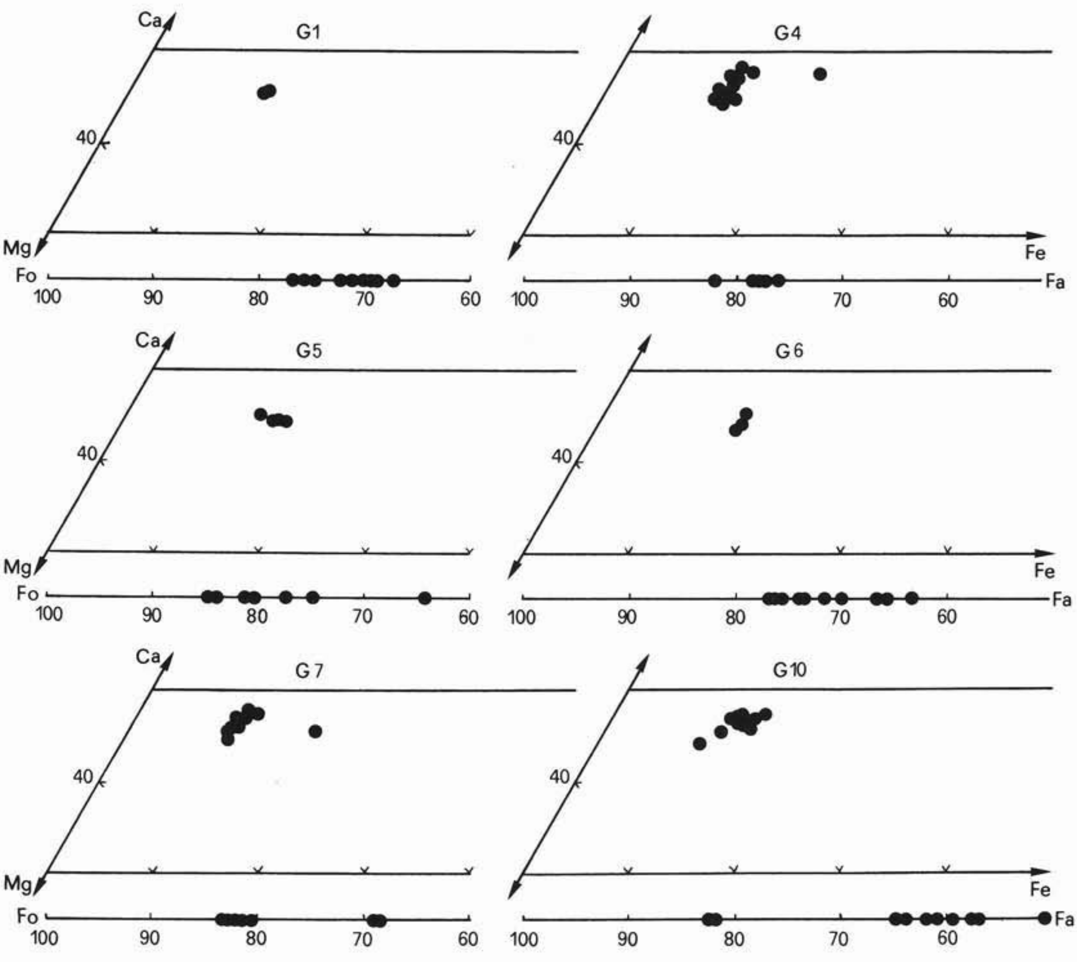

Fig. 8. — Composition of olivines and pyroxenes of some lati-basalts (G1 and G4) and hawaiites (G5, G6, G7 and G10).

and Fe_2O_3/FeO = 0.15 (ROEDER P.L., EMSLIE R.F., 1970; WILKINSON J.F.G., 1977) it may be concluded that both in the lati-basalts and in the hawaiites, the olivines in equilibrium with the host rock are not always the richest in Mg (in the lati-basalts, Fo obs 77 Fo calc 76; in the hawaiites, Fo obs 81 Fo calc 80, Fo obs 82 Fo calc 82). The olivines that are not in equilibrium show a composition varying from Fo 82 to 79 in the lati-basalts (which would be in equilibrium with a melt characterized by M = Mg/(Mg + Fe) = 0.60), thus implying more oxydising conditions (JOHNSON R.W. et al., 1985) or hereditary characters (xenocrysts); and Fo 84 (M = 0.64) in the hawaiites, where they seem to be xenocrysts like those, of similar composition, observed in the nearby flows of M.te Pizziogu (Fo 90-85) (MURGIA M.V., 1984).

For the olivines in equilibrium with the host rock, the following average crystallization temperatures were established: in the lati-basalts 1140 °C, and in the hawaiites, 1175 °C (LEEMAN W.P., SCHEIDEGGER K.S., 1977).

Pyroxenes

Selected analyses of pyroxenes are shown in Table 4.

Most of the pyroxenes examined consists of salite; the others have a diopsidic or augitic composition (Fig. 8). On the whole, the pyroxenes analysed show a short crystallization trend typical of alkaline basic rocks: an increase in Ca, together with a more or less marked increase in Σ Fe, is linked with progressive crystallization.

The alkalinity of pyroxenes is confirmed by the general decrease in Si and the resulting increase in Al, most of which has a tetrahedral co-ordination, and by the steady increase in Ti and Na during crystallization.

The compositional variation between core and rim of some pyroxenes is typical in this respect, both in the lati-basalts and in the hawaiites. Only rare crystals present the opposite character, with a core richer in Al(IV) and Ti and poor in Si, together with inverted Fe/Mg zonation. In this case, the exocity of the core, or more oxydising conditions during the final stage of crystallization might be assumed (JOHNSON R.W. et al., 1985).

Feldspars

Selected analyses of feldspars are shown in Table 5.

The plot in the An-Ab-Or diagram (Fig. 9)

TABLE 4 — *Pyroxenes*

Sample	• G1	•	G 4	•	G 5	•	G 6	•	G 7	•	G10	•
SiO_2	49.43	50.48	50.54	47.13	49.90	48.35	50.75	49.45	51.51	48.84	51.06	47.56
Al_2O_3	3.92	3.96	3.37	4.53	3.26	4.45	2.63	4.25	3.39	3.01	3.39	6.96
TiO_2	1.78	1.19	1.67	3.09	1.50	2.08	1.34	1.97	0.98	2.34	0.97	1.70
Cr_2O_3	0.19	0.10	0.23	---	0.26	0.07	0.02	0.09	0.20	---	0.20	0.10
Fe_2O_3	2.58	1.90	1.37	1.41	2.04	2.24	2.14	1.76	1.17	2.25	1.77	3.08
FeO	5.28	5.08	5.99	9.44	5.77	6.47	6.17	6.40	4.90	8.46	4.42	4.35
MnO	0.14	0.19	0.15	0.24	0.20	0.16	0.19	0.19	0.16	0.28	0.14	0.13
MgO	14.30	15.27	14.79	10.87	14.45	13.75	14.82	14.00	15.68	12.37	15.92	13.54
CaO	21.53	21.15	21.65	21.23	21.06	20.50	21.23	21.42	21.45	21.27	21.22	21.48
Na_2O	0.44	0.40	0.36	0.59	0.35	0.46	0.41	0.40	0.43	0.52	0.39	0.49
K_2O	0.06	---	0.01	0.05	0.03	0.05	0.01	0.02	---	---	---	---
Sum	99.65	99.72	100.13	98.58	98.32	98.58	99.71	99.95	99.87	99.34	99.48	99.39
Numbers of ions on the basis of 6 oxygens												
Si	1.842	1.867	1.871	1.811	1.865	1.827	1.890	1.841	1.896	1.853	1.886	1.773
Al (IV)	0.158	0.133	0.129	0.189	0.134	0.173	0.110	0.159	0.104	0.135	0.114	0.227
Al (VI)	0.015	0.400	0.018	0.016	0.011	0.025	0.005	0.027	0.043	---	0.033	0.078
Ti	0.050	0.033	0.046	0.089	0.043	0.059	0.038	0.055	0.027	0.067	0.027	0.048
Cr	0.006	0.003	0.007	---	0.008	0.002	0.006	0.003	0.006	---	0.006	0.003
Fe^{+3}	0.072	0.053	0.038	0.041	0.058	0.064	0.060	0.049	0.032	0.064	0.049	0.086
Fe^{+2}	0.164	0.157	0.185	0.303	0.182	0.204	0.192	0.199	0.151	0.268	0.137	0.135
Mn	0.004	0.006	0.005	0.008	0.006	0.005	0.006	0.006	0.005	0.009	0.004	0.004
Mg	0.794	0.842	0.816	0.623	0.813	0.774	0.822	0.777	0.860	0.700	0.876	0.752
Ca	0.860	0.838	0.859	0.874	0.852	0.830	0.847	0.854	0.846	0.865	0.840	0.858
Na	0.032	0.029	0.026	0.044	0.026	0.034	0.030	0.029	0.031	0.038	0.028	0.035
K	0.003	---	---	0.002	0.001	0..02	---	0.001	---	---	---	---
Ca	45.4	44.2	45.1	47.3	44.6	44.2	43.9	45.3	44.7	45.4	44.1	46.7
Mg	41.9	44.4	42.9	33.7	42.5	41.2	42.7	41.2	45.4	36.7	46.0	41.0
ΣFe	12.7	11.4	12.0	19.0	12.9	14.6	13.4	13.5	9.9	17.9	9.9	12.3

TABLE 5 — *Feldspars*

Sample	*	G 1	*		G 4	*		G 5	*
SiO_2	54.24	55.57	64.88	54.17	59.11	63.89	54.30	59.08	62.18
Al_2O_3	29.08	25.45	20.13	28.40	23.57	19.26	27.92	23.92	20.84
TiO_2	0.15	0.20	0.44	0.17	0.18	0.22	0.11	0.21	0.44
FeO	0.83	0.67	0.46	0.53	0.50	0.45	0.62	0.55	0.48
MnO	---	0.01	0.01	0.01	0.03	---	0.01	---	0.02
MgO	0.04	---	---	0.12	0.01	0.03	0.013	0.02	0.03
CaO	10.78	8.86	1.60	11.14	6.03	1.21	10.64	6.18	2.46
Na_2O	4.55	5.30	4.67	4.52	6.21	4.99	4.75	6.84	6.18
K_2O	0.53	2.07	8.17	0.68	3.27	8.90	0.67	1.52	5.96
Sum	100.13	98.13	100.37	99.75	98.91	98.95	99.15	98.32	98.59
An	55.2	42.4	8.1	55.4	28.5	5.8	53.1	30.3	11.9
Ab	42.2	45.8	42.7	40.6	53.1	43.3	42.9	60.8	53.9
Or	2.6	11.8	49.2	4.0	18.4	50.9	4.0	8.9	34.2

Sample	*	G 6	*	G7	*		G10		*
SiO_2	53.21	57.39	64.55	53.64	58.05	53.65	57.26	62.48	66.43
Al_2O_3	29.33	26.67	18.94	28.57	27.87	29.26	26.57	21.53	20.08
TiO_2	0.11	0.15	0.27	0.17	0.17	0.09	0.14	0.18	0.17
FeO	0.76	0.61	0.27	0.58	0.54	0.59	0.58	0.20	0.13
MnO	---	0.03	0.01	---	---	---	0.02	---	---
MgO	---	0.01	---	0.10	0.04	0.03	---	---	---
CaO	11.41	8.57	0.73	11.68	8.40	11.63	8.19	3.94	0.70
Na_2O	4.38	5.95	4.88	4.39	5.23	4.55	6.23	7.00	6.08
K_2O	0.21	0.64	9.38	0.55	0.75	0.29	0.51	4.58	7.58
Sum	99.41	100.02	99.03	99.68	101.05	100.10	99.50	99.91	101.17
An	58.2	42.6	3.5	57.6	44.8	57.5	40.8	17.9	3.4
Ab	40.5	53.6	42.6	39.2	50.4	40.8	56.2	57.4	53.1
Or	1.3	3.8	53.9	3.2	4.8	1.7	3.0	24.7	43.5

illustrates the contemporaneous presence in all samples of plagioclases and alkali feldspars, the latter occuring only in the groundmass. Plagioclases are always represented by labradorites and andesines, the latter noteworthy for their high Or content (12) in one lati-basalt of Tacquara. The alkali feldspars vary from Na-sanidine to anorthoclase, not always occurring together in the same rock.

The detailed variation of the plagioclases expressed in anorthite is: An 55 to 35, for lati-basalts: An 58 to 39, for hawaiites.

The variation in the Or percentage for the alkali feldspars is: Or 49 to 18 for lati-basalts; Or 54 to 25 for hawaiites.

The highest potassium content of the alkali feldspars is reached in the lati-basalts, as can be seen in Fig. 9; only one sample of the hawaiites has a similar high value.

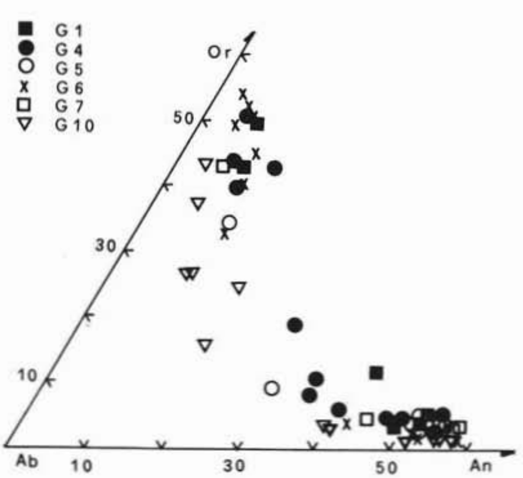

Fig. 9. — An - Ab - Or diagram. Samples as in Fig. 8.

Nephelines

Selected analyses of nephelines are shown in Table 6.

Nephelines occur only in the groundmass of doleritic hawaiites, and show remarkable compositional uniformity: they also have a high silicon content, as is shown by the high Q value. The representative values in the Ne-Ks-SiO_2 diagram are a little outside the field of solid solution as determined by HAMILTON D.C., 1961; this suggests crystallization

TABLE 6

Nephelines - Opaque minerals

Sample	• G10	•
SiO_2	50.82	51.52
Al_2O_3	30.88	30.71
TiO_2	0.05	0.08
FeO	0.50	0.49
MgO	----	0.02
CaO	0.33	0.36
Na_2O	16.30	16.28
K_2O	2.37	2.22
Sum	101.25	101.68
Numbers of ions on the basis of 32 oxygens		
Si	9.324	9.396
Al	6.678	6.601
Ti	0.006	0.011
Fe	0.076	0.074
Mg	----	0.005
Ca	0.065	0.071
Na	5.800	5.755
K	0.555	0.515
Ne	75.8	75.6
Ks	8.1	7.5
Q	16.1	16.9

Sample	• G 1	•	G 2	•
	SP	RP	SP	RP
SiO_2	0.18	----	4.27	0.66
TiO_2	22.89	49.04	24.08	49.32
Al_2O_3	2.15	----	0.75	0.01
Cr_2O_3	0.06	0.03	----	----
FeO	66.39	42.04	67.13	44.14
MnO	0.65	0.75	0.71	0.91
NiO	0.03	0.02	----	----
MgO	3.35	4.16	0.98	1.06
CaO	0.06	0.17	0.15	0.07
Sum	95.76	96.21	98.07	96.05
Ilmenite basis				
Fe_2O_3	37.6	7.0	31.5	2.1
FeO	32.6	35.7	38.8	42.2
Sum	99.5	96.9	101.2	96.6
Ulvospinel basis				
Fe_2O_3	22.2		11.7	
FeO	46.4		56.6	
Sum	98.0		99.2	
Mol%				
USP	66		82	
R_2O_3		7		2.2
T°C	978°C		985°C	
fO_2	$10^{-11.4}$		$10^{-12.4}$	

temperatures above 1068 °C (for a dry system at 1 atm). However, this temperature seems high when related to the petrographic observations and to the equilibration temperatures of the opaque minerals in the groundmass. Some crystals with an incipient alteration show a marked decrease in Na content and, less marked, in Al.

Opaque minerals

In the petrographic section, the presence of two generations of opaque minerals has been described: one enclosed in olivine phenocrysts, the other as crystals in the groundmass. The former consists of more or less chromium-bearing titanium-magnetite (Cr_2O_3 up to 6.73, not shown in Table 6); the latter, which occurs in all the lithotypes examined, consists of more or less titanium-bearing magnetite, or of the pair titaniferous magnetite and ilmenite (Table 6). In the second case, it was possible to obtain information on the temperature and the fO_2 that determined the equilibration conditions of the opaque minerals in the groundmass. In particular, the following was established: for P = 1 atm: T = 978 °C, $fO_2 = 10^{-11.6}$ in the lati-basalt G1; T = 985 °C $fO_2 = 10^{-12.4}$ in the hawaiite G7 (BUDDINGTON A.F., LINDSLEY D.H., 1964; CARMICHAEL I.S.E., 1967).

Summary and conclusions

The basaltic flows of M.te Guzzini consist mainly of hawaiites and, subordinately, of lati-basalts, which form the lower part of the lava sequence. The Tacquara of tongue consists almost entirely lati-basalts.

In the lati-basalts, the distribution of major and trace elements suggests an evolutionary trend, even in the limited number of lithotypes; in contrast, the distribution in hawaiites is irregular. This points to a complex genesis, in accordance with data obtained from other lava covers of the same age in Sardinia (CIONI R. et al., 1982; MACCIOTTA et al., 1984). The origin of these basalts could be attributed to different degrees of partial melting of a garnet to spinel peridotite mantle source, enriched with incompatible elements, (particularly K and Rb acquired from the Oligo-Miocene magmatic cycle) and/or to differentiation within the continental crust by fractional crystallization and reactions with the surrounding rocks. The latter process is important in the volcanics of M.te Guzzini, as shown by common femic aggregates, expecially pyroxenes, and by the quartz xenoclasts. The mineral chemistry also suggests the interplay of several processes, expecially for olivines, whose composition varies between Fo 82 - 67 in the lati-basalts and between Fo 84 - 51 in the hawaiites. Both in the lati-basalts and in the hawaiites, the olivines in equilibrium with the melt (Fo obs 77 Fo calc 76 for lati-basalts; Fo obs 81 Fo calc 80, and Fo obs 82 Fo calc 82 for hawaiites) are not the richest in Mg. The Fo-richest olivines, whose composition varies between Fo 82 and 79 in the lati-basalts and Fo 84 in the hawaiites, could have crystallized under more oxidizing conditions, or could have been inherited. The geothermometry of the olivines in equilibrium with the host rock have the following average crystallization temperatures: in the lati-basalts, 1140 °C; in the hawaiites, 1175 °C. The pyroxenes have mainly a salitic composition and, subordinately, a diopsidic and augitic one; generally, they show a brief crystallization trend typical of alkaline basic rocks, which is characterized by enrichment in Ca, together with a more or less marked increase in Fe. The alkaline character of both lithotypes is also indicated by the simultaneous occurrence of plagioclases and alkali feldspars which, on the whole, show gradual enrichment in Na. Plagioclases are always labradorite-andesine with, generally, a higher proportion of Or in the lati-basalts; the alkali feldspars vary between Na-sanidine and anorthoclase, but these two do not always coexist. Rare nephelines with a high Q content occur in the groundmass of some hawaiites. All the lithotypes contain, in the groundmass, opaque minerals consisting of titaniferous magnetite or of the pair titaniferous magnetite and ilmenite, which made it possible to determine the equilibration conditions: $T = 978\ °C\ fO_2 = 10^{-11.6}$ for lati-basalts; $T = 985\ °C\ fO_2 = 10^{-12.4}$ for hawaiites.

The research was financed by a grant from the MPI.

REFERENCES

ASSORGIA A., MACCIONI L., MACCIOTTA G., SAVELLI C. (1983) - *Carta geopetrografica del vulcanismo pliocenico della Sardegna centro-meridionale*. S.E.L.C.A., Firenze

BAXTER A.N. (1975) - *Petrology of the older series lavas from Mauritius, Indian Ocean*. Geol. Soc. Am. Bull., 86, 1449-1458.

BECCALUVA L., MACCIONI L., MACCIOTTA G., VENTURELLI G. (1974) - *Dati geologici e petrochimici sul massiccio vulcanico di Monte Arci (Sardegna)*. Mem. Soc. Geol. It., 13/2, 387-405.

BECCALUVA L., MACCIOTTA G., VENTURELLI G. (1975) - *Dati geochimici e petrografici sulle vulcaniti plio-quaternarie della Sardegna centro-occidentale*. Boll. Soc. Geol. It., 94, 1437-1457.

BROOKS C.K. (1976) - *The Fe_2O_3/FeO ratio of basalt analyses: an appeal for a standardized procedure*. Bull. Geol. Soc. Denmark, 25, 117-120.

BROTZU P., DI SABATINO B., MORBIDELLI L. (1970) - *Contributo alla conoscenza delle vulcaniti post-elveziane del Montiferru. Nota IV. Distribuzione di alcuni elementi minori nella serie fonoliti-alcalibasalti del settore centrale del Montiferru (Sardegna centro-occidentale)*. Per. Min., 39, 19-49.

BROTZU P., FERRINI V., MORBIDELLI L., TRAVERSA G. (1975) - *Il distretto vulcanico di Capo Ferrato (Sardegna sud-orientale)*. Rend. Sem. Fac. Sc. Univ. Cagliari, 45, III-IV, 119-144.

BUDDINGTON A.F., LINDSLEY D.H. (1964) - *Iron-titanium oxide minerals and synthetic equivalents*. J. Petrology, 5, II, 310-357.

CARMICHAEL I.S.E. (1967) - *The iron-titanium oxides of salic-volcanic rocks and their associated ferromagnesian silicates*. Contrib. Mineral. Petrol., 14, 36-64.

CIONI R., CLOCCHIATTI R., DI PAOLA G.M., SANTACROCE R., TONARINI S. (1982) - *Miocene calc-alkaline heritage in the Pliocene post-collisional volcanism of Monte Arci (Sardinia, Italy)*. J. Volcanol. Geoth. Research, 14, 133-167.

COLBY J.W. (1971) - *Magic IV: a Computer program for quantitative electron microprobe analysis*. Bell Telephone Laboratories Inc., Allentown, Pennsylvania.

CONTI L., MACCIONI L. (1974) - *Le coltri basaltiche della piana di Siddi (Sardegna centro-meridionale)*. Quaderni C.N.R., Ist. Min. e Petr., Univ. Roma, 10.

COOMBS D.S., WILKINSON J.F.G. (1969) - *Lineages and fractionation trends in undersaturated volcanic rocks from East Otago volcanic province (New Zealand) and related types*. J. Petrology, 10, 440-501.

DE LA ROCHE H., LETERRIER J., GRAND CLAUDE P., MARCHAL M. (1980) - *A classification of volcanic and plutonic rocks using R1-R2 diagram and major element analyses - its relationship with current nomenclature*. Chem. Geology, 29, 183-210.

FLOYD P.A., WINCHESTER J.A. (1975) - *Magma type and tectonic setting discrimination using immobile elements*. Earth Plan. Sci. Lett., 27, 211-218.

FRANZINI M., LEONI L., SAITTA M. (1975) - *Revisione di una metodologia analitica per fluorescenza X, basata sulla correzione completa degli effetti di matrice*. Rend. Soc. It. Min. e Petr., 31, II, 365-378.

GREEN D.H., RINGWOOD A.E. (1967) - *The genesis of basaltic magmas*. Contrib. Mineral. Petrol., 15, 1057-10896.

HAMILTON D.L. (1961) - *Nepheline as crystallization temperature indicators*. J. Geol., 69,321-329.

IRVINE T.N., BARAGAR W.R.A. (1971) - *A guide to the chemical classification of common volcanic rocks*. Canad. J. Earth Sci., 8, 523-548.

JOHNSON R.W., JAQUES A.L., HICKEY R.L., MCKEE C.O., CHAPPEL B.W. (1985) - *Manam Island, Papua,* *New Guinea: petrology and geochemistry of a low TiO2 basaltic island-arc volcano.* J. Petrology, 26, II, 283-323.

KUDO A.M., WEIL D.F. (1970) - *An igneous plagioclase thermometer.* Contrib. Mineral. Petrol., 26, 52-65.

KUNO H. (1968) - *Differentiation of basalt magmas.* In «Basalts: The Poldervaart Treatise on Rocks of Basaltic Composition», 2, 623-688.

LEEMAN W.P., SCHEIDEGGER K.S. (1977) - *Olivine/liquid distribution coeficients and a test for crystal-liquid equilibrium.* Earth Plan. Sci. Lett., 35, 247-257.

LEONI L., SAITTA M. (1976) - *X-Ray fluorescence analysis of 29 trace elements in rock and mineral standard.* Rend. Soc. It. Min. Petr., 32, II, 497-510.

MACCIOTTA G., VENTURELLI G., BECCALUVA L. (1978) - *Geochemistry of mafic Cainozoic volcanic rocks from Sardinia (Western Mediterranean).* Bull. Volcanol., 41, 56-78.

MACCIOTTA G., SAVELLI C. (1984) - *Petrology and K/Ar ages of Pliocene Quaternary volcanics from North Western Sardinia.* Grafiche STEP, Parma.

MATHEZ E.A. (1973) - *Refinement of the Kudo-Weil plagioclase thermometer and its application to basaltic rocks.* Contrib. Mineral. Petrol., 41, 61-72.

MURGIA M.V. (1984) - *Le vulcaniti basiche recenti di Nurri-Orroli (Sardegna centro-meridionale).* Rend. Sem. Fac. Sc. Univ. Cagliari, 54, II, 241-261.

PEARCE J.A., CANN J.R. (1973) - *Tectonic setting of basic volcanic rocks determined using trace elements analyses.*. Earth Plan. Sci. Lett., 19, 290-300.

PEARCE J.A., NORRY M.J. (1979) - *Petrogenetic implications of Ti, Zr, Y and Nb variations in volcanic rocks.* Contrib. Mineral. Petrol., 69, 33-47.

PEARCE J.A. (1982) - *Trace elements characteristics of lavas from destructive plate boundaries.* Thorpe R.S., Andesites, John Wiley & Sons Ltd, New York, 527-548.

POMESANO CHERCHI A. (1967) - *Studio biostratigrafico del Miocene della Sardegna centro-meridionale (Campidano - Marmilla orientale - Sarcidano).* Atti IV Convegno Neogene Mediterraneo, Giorn. Geol., 35, Bologna.

ROEDER P.L., EMSLIE R.F. (1970) - *Olivine liquid equilibrium.* Contrib. Mineral. Petrol., 29, 275-289.

SIMBOLI G. (1963) - *I basalti di S. Pietro (Baunei) F 208 Dorgali (Sardegna).* Min. Petr. Acta, 9, 19-29.

STORMER G.C. (1973) - *Calcium zoning in olivine and its relationship to silica activity and pressure.* Geochim. Cosmochim. Acta, 37, 1815-1821.

THORTON C.P., TUTTLE O.F. (1960) - *Chemistry of igneous rocks. I. Differentiation Index.* Am. J. Sci., 258, 664-684.

WILKINSON J.F.J. (1977) - *Petrogenetic aspects of some alkali volcanic rocks.* J. Proc. R. Soc. New South Wales, 110, 117-138.

WOOD D.A., TARNEY J., VARNET J., SAUNDERS A.D., BOUGAULT H., JORON J.L., TREVIL M., CANN J.R. (1979) - *Geochemistry of basalts drilled in the North Atlantic by IPOD Leg 49: implications for mantle heterogeneity.* Earth Plan. Sci. Lett., 42, 77-97.

MANUSCRIPT ACCEPTED JANUARY 20, 1987