

Petrology of some clinopyroxene-bearing nodules and megacrysts from ancient Etnean lavas

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ABSTRACT. — Various types of clinopyroxenes represent the dominant modal constituent of most ultramafic nodules of «ancient» Etnean hawaiiite lavas, giving useful information on the origin of the inclusions. These may be divided into two main groups, *Cr-diopside-bearing* and *augite-bearing*. Poikilitic wehrlites belong to the first group, whereas the augite-bearing nodules may be split into two subgroups on the basis of the Ti and Al contents of their pyroxenes, relative to those of the augite phenocrysts of the host lavas. Hence there are «Low-Ti» augite megacrysts, kaersutite-bearing «Low-Ti» augite wehrlites and olivine-bearing «Al-augite» clinopyroxenites.

Textures of all the above-mentioned nodules suggest their magmatic (cumulate) origin. Plots of $(Al + Fe + Ti + Na)/(Mg + Cr)$ ratios (= F.I.) for these pyroxenes show a fractionation trend from *Cr-diopside* to *Low-Ti* augites and *Al-augites*. A pressure trend, inferred by the ratios $(Al^{IV} + Ti)/Si$ of the same pyroxenes is in good agreement with the above trend.

All the studied nodules may therefore derive from polystage polybaric fractionation of some primary magma, which first occupied a deep-seated position in the upper mantle and later migrated up to crustal levels.

Key words: Etna, Petrology, Ultramafic Nodules.

RIASSUNTO. — I caratteri composizionali dei clinopirosseni di noduli (s.l.) di alcune hawaiiiti antiche dell'Etna, vengono usati per operare discriminazioni tra tali inclusioni e forniscono indicazioni sull'origine degli stessi. Sono stati distinti noduli a *Cr-diopside* e ad *augite*. I primi sono costituiti da wehliti poikilitiche, gli altri sono stati ulteriormente suddivisi nei tipi ad *augite* bassa in titanio ed *augite* alluminifera, usando come termine di paragone il tenore in questi elementi nei fenocristalli augitici delle lave ospiti. Tra i tipi ad *augite* bassa in titanio si annoverano megacristalli isolati, mentre tutti gli altri sono frammenti di rocce cumulitiche (ad *augite* \pm olivina \pm kaersutite).

I caratteri composizionali dei pirosseni studiati suggeriscono che derivano dalla cristallizzazione frazionata polibarrica di un magma «primitivo» verosimilmente originatosi nel mantello superiore. I suddetti noduli ultramafici sono dunque frammenti di cumuliti comagmatiche con le lave ospiti.

Parole chiave: Etna, Petrologia, Noduli Ultramafici.

Introduction

Some hawaiiite lavas belonging to the «Ancient Alkaline Centres» of Mt. Etna show a number of xenocrysts and ultramafic nodules whose deep-origin has been already suggested (SACHS & SCRIBANO, 1985; AURISICCHIO & SCRIBANO, 1987; SCRIBANO, 1987). The first accounts on these nodules focussed on tectonic dunitic, giving information on the nature of upper mantle beneath Mt. Etna. On the contrary, this note deals with «magmatic» clinopyroxene-bearing nodules, attempting to recognize their accidental or cognate origin (hence their bearing on the origin of the host lavas).

Host rocks

Nodule-bearing rocks constitute lava flows discontinuously outcropping in some localities of the lowermost slopes of Mt. Etna (e.g. *eastern slope*: base of Acireale scarp, top of Mt. Vampolieri. *Western slope*: nearby villages of Paternò, Biancavilla, Bronte). Above-mentioned lavas represent the oldest alkaline

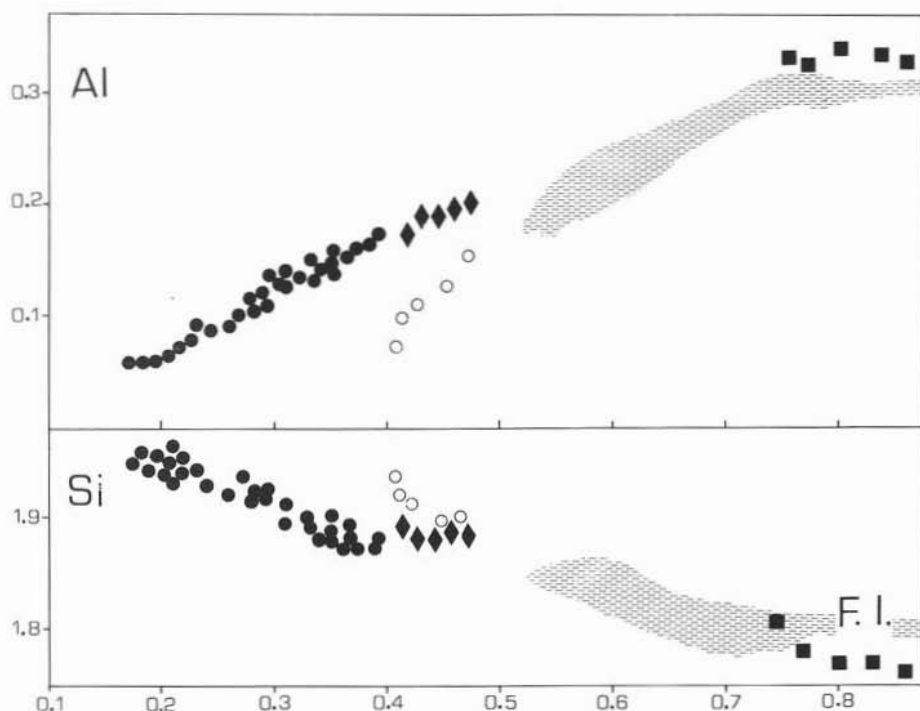


Fig. 1. — $(\text{Al} + \text{Fe}^* + \text{Ti} + \text{Na})/(\text{Mg} + \text{Cr})$ ratios ($= \text{F.I.}$) vs Si and Al (a.u.f.) for clinopyroxenes of studied nodules and phenocrysts of host lavas. Full circles: Cr-diopside of Cr-Di wehrlites. Double triangles: Low-Ti augite megacrysts. Open circles: Low-Ti augite nodules. Squares: Al-augite nodules. Shaded area: field of augite phenocrysts of host lavas and other hawaiiite lavas belonging to the Ancient Alkaline Centres (CRISTOFOLINI et al., 1981).

products of the Etnean area and lie directly on «Basal Tholeiites» (ROMANO, 1982; GEOLOGIC MAP OF MT. ETNA, 1979). Porphyritic ne-hawaiiites constitute the dominant lithotype, showing phenocrysts of labradoritic plagioclase, salite (see Table 1), crysolitic olivine and Ti-magnetite (e.g. CRISTOFOLINI & ROMANO, 1982).

Nodules, rarely exceeding 3 cm in size, only constitute 0.5-1% of the total volume of the host lava (the term nodule is here used in a broad sense, indicating all polycrystalline aggregates, except phenocryst clusters, whatever their origin).

Clinopyroxene-bearing ultramafic nodules

Apart from tectonic dunites, which are not considered in this paper, clinopyroxene is the dominant mineral phase in the Etnean ultramafic nodules, allowing us to divide them into two main groups: «Cr-diopside-bearing» and «augite-bearing». Neither type fits into

the division proposed by WILSHIRE & SHERVAIS (1975) because of the lack of orthopyroxene in the above-mentioned nodules.

1) Cr-diopside group

Poikilitic wehrlites belonging to Cr-diopside group (Cr-Di), consist of coarse diopside grains enclosing anhedral, eterogranular olivine. Macroscopically diopside has green colour. Under the microscope it shows either curvilinear grain boundaries or crystalline faces and, rarely, magmatic-type twinning. Wehrlite diopside is often unstrained, rarely it displays faint undulose extinction: unstrained and deformed diopside grains were never observed coexisting in the same nodule. Mineral chemistry of above-mentioned diopside is reported on Table 1: it must be emphasized that the weakly deformed diopside displays higher chromium content ($\text{Cr}_2\text{O}_3 = 1\text{-}1.5 \text{ wt\%}$) than the unstrained one

TABLE 1

Microprobe representative analyses of Cr-diopsides of wehrlite nodules. Formulae following PAPIKE et al. (1974)

CLINOPYROXENE OF Cr-DIOPSIDE GROUP

wt%	A	B	C	D	E	F	G	H
SiO ₂	53.37	53.53	53.64	53.69	52.42	52.04	51.92	52.22
Al ₂ O ₃	1.57	1.78	1.33	1.20	2.22	3.38	3.16	3.13
FeO ²⁺	3.45	3.58	3.24	3.53	4.34	4.22	4.30	4.10
MgO	17.88	17.19	18.02	17.17	16.67	16.65	16.69	16.46
MnO	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00
TiO ₂	0.21	0.13	0.15	0.33	0.37	0.47	0.39	0.28
Cr ₂ O ₃	1.37	1.45	1.29	1.19	0.67	0.61	0.61	0.52
CaO	22.01	22.53	22.15	22.07	22.56	22.17	22.23	22.37
Na ₂ O	0.43	0.32	0.15	0.41	0.38	0.70	0.48	0.69
Total	100.29	100.51	99.97	100.22	99.63	100.24	99.78	99.77
Cations in formula (O=6)								
Si	1.933	1.942	1.952	1.951	1.920	1.887	1.894	1.902
Al(iv)	0.067	0.058	0.048	0.049	0.080	0.113	0.106	0.098
Al(vi)	0.001	0.018	0.009	0.002	0.015	0.031	0.030	0.036
Fe ²⁺	0.059	0.095	0.094	0.077	0.096	0.040	0.060	0.044
Fe ³⁺	0.045	0.013	0.005	0.024	0.081	0.088	0.060	0.080
Mg	0.965	0.930	0.997	0.960	0.910	0.900	0.907	0.893
Mn	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000
Ti	0.006	0.004	0.004	0.009	0.010	0.010	0.013	0.007
Cr	0.039	0.042	0.037	0.034	0.019	0.017	0.020	0.015
Ca	0.854	0.876	0.864	0.859	0.885	0.861	0.869	0.873
Na	0.030	0.023	0.011	0.029	0.027	0.049	0.034	0.049
$\frac{\text{Mg}}{\text{Mg}+\text{Fe}^{2+}}$	0.903	0.895	0.907	0.905	0.872	0.875	0.873	0.877

(Cr₂O₃ = 0.8-0.4 wt%). The latter also shows some patchy zoning of chromium content, the former instead being quite unzoned. The atomic ratio Mg/(Mg + Fe_t) (= *mg* number) of wehrlite diopsides ranges from 0.85 to 0.90 ca., whereas the ratio (Al + Fe + Na + Ti)/(Mg + Cr) (= F.I.) varies from 0.18 to 0.40 (Fig. 1).

Poikilitic olivines display rounded edges and, in most cases, kink bands and patchy extinction. In some cases strained olivine form polycrystalline aggregates which appear as tectonic dunite nodules already described by AURISICCHIO & SCRIBANO (1987). Strained olivines from wehrlite and dunite even show close similar mineral chemistry (Fo₈₆₋₈₈:

Table 3, analyses A, B). Thus deformed olivine might represent fragments of dunites, giving the wehrlite a composite character. Unstrained, sub-euhedral cumulus olivine (Fo₈₂₋₈₄: Table 3, analyses C, D) also rarely occur in the wehrlite Cr-diopsides. Finally, anhedral Cr-spinel micrograins are rarely enclosed in our Cr-diopside (Table 3, analysis F).

2) Augite-bearing group

It must be first remarked that feldspar-bearing (gabbroic) nodules and phenocryst clusters are not considered in this paper, having previously been studied by LO GIUDICE

TABLE 2

Representative analyses of clinopyroxenes of studied augite-bearing nodules. Analyses A, B, C represent megacrysts of Low-Ti group; D, E, F represent other Low-Ti augites, G, H, J are Al-augites (see text for further explanation). Analyses K, I, L represent cores of augite phenocrysts of host lavas. Formulae calculated as in Table 1

Wt%	A	B	C	D	E	F	G	H	I	J	K	L
SiO ₂	51.62	52.69	51.32	51.67	52.27	51.00	47.74	47.82	48.76	49.75	49.41	48.79
Al ₂ O ₃	3.78	3.02	4.28	2.30	1.33	2.79	7.44	7.05	6.88	3.74	4.39	5.21
FeO*	4.68	4.57	5.50	6.87	7.40	6.95	7.74	7.33	7.10	8.27	7.41	7.49
MgO	16.22	16.34	15.66	15.38	15.43	14.89	13.35	13.50	13.78	13.46	14.09	13.69
MnO	0.12	0.11	0.14	0.29	0.47	0.63	0.17	0.12	0.14	0.27	0.18	0.18
TiO ₂	0.52	0.39	0.64	0.43	0.58	0.63	1.49	1.33	1.26	2.53	1.45	1.71
Cr ₂ O ₃	0.13	0.06	0.14	0.00	0.00	0.00	0.04	0.04	0.06	0.00	0.00	0.00
CaO	22.55	22.40	22.19	21.89	21.52	22.15	21.64	21.95	22.14	21.27	21.89	21.96
Na ₂ O	0.31	0.28	0.30	0.37	0.54	0.40	0.39	0.42	0.43	1.00	0.43	0.36
Total	99.93	99.86	100.17	99.20	99.54	99.05	100.00	99.56	100.55	100.29	99.25	99.39
Cations in formula (O=6)												
Si	1.885	1.927	1.877	1.918	1.937	1.898	1.766	1.774	1.789	1.843	1.842	1.819
Al(iv)	0.115	0.073	0.123	0.082	0.063	0.102	0.234	0.226	0.211	0.157	0.158	0.181
Al(vi)	0.048	0.057	0.062	0.018	0.000	0.021	0.091	0.082	0.087	0.006	0.035	0.049
Fe ²⁺	0.087	0.126	0.125	0.146	0.159	0.141	0.153	0.128	0.135	0.174	0.158	0.172
Fe ³⁺	0.056	0.013	0.043	0.067	0.070	0.075	0.087	0.099	0.083	0.082	0.073	0.062
Mg	0.883	0.890	0.853	0.851	0.852	0.826	0.736	0.746	0.753	0.743	0.783	0.761
Mn	0.004	0.003	0.004	0.009	0.015	0.008	0.005	0.004	0.004	0.008	0.006	0.006
Ti	0.014	0.011	0.018	0.012	0.016	0.018	0.041	0.037	0.035	0.070	0.041	0.048
Cr	0.004	0.002	0.004	0.000	0.000	0.000	0.001	0.001	0.002	0.000	0.000	0.000
Ca	0.882	0.877	0.869	0.870	0.854	0.883	0.858	0.872	0.870	0.844	0.874	0.877
Na	0.022	0.020	0.021	0.027	0.039	0.029	0.028	0.030	0.031	0.072	0.031	0.026
$\frac{Mg}{(Mg+Fe^*)}$	0.860	0.865	0.835	0.800	0.790	0.792	0.754	0.766	0.775	0.744	0.794	0.744

& RITTMANN (1975); CRISTOFOLINI & TRANCHINA (1980) and CRISTOFOLINI et al. (1980): however the mineral chemistry of the augites of gabbroic nodules is quite similar to the cores of augite phenocrysts of the host lavas, as demonstrated by the above-quoted authors and additional microprobe results obtained during this study.

Thus, augite-bearing ultramafic nodules of the studied lavas may be split into two sub-groups, using the titanium and aluminium contents of their augites as discriminatory factors. These are Low-Ti augite (TiO₂ = 0.4-0.6 wt%) and the Al-augite (Al₂O₃ = 6-7.5 wt%) groups, Ti and Al contents being relative to those of augite phenocrysts in the host lavas (TiO₂ = 1-2.5 wt%; Al₂O₃ = 3-5 wt%).

Low-Ti augite megacrysts (called LT-M) occur quite commonly in the studied lavas, either as isolated crystals often exceeding 5 cm in length, or as aggregates of a few (2-3) of those crystals joined by irregular impingement grain boundaries. In hand-specimens these pyroxenes are glassy in aspect and greenish-black in colour. Analytical results show some irregular compositional zoning (unrevealed by microscope study) in Low-Ti augite megacrysts, particularly for Al, Ti and Fe variations (Table 2): *mg* number also varies between 0.83 and 0.86 and F.I. between 0.4 and 0.48 (Table 2; Fig. 1).

Low-Ti augite nodules (LT-N), whose augite grains-size is several times less than that of megacrysts, were also found in the studied lavas. These nodules show a complex texture,

TABLE 3

Representative analyses of olivines and spinel of studied nodules. A, B: strained xenocumulus olivine of Cr-Di wehrlites. C: unstrained cumulus olivine of Cr-Di wehrlites. D: cumulus olivine from LT-N nodules. E: cumulus olivine of Al-Aug nodules. F: spinel enclosed in the strained olivines of Cr-Di wehrlites. G: spinel occurring in Cr-diopside of Cr-Di wehrlites. Formulae of spinels calculated on the basis of 4 oxygens, 3 cations

	O L I V I N E					S P I N E L	
	A	B	C	D	E	F	G
SiO ₂	40.43	40.71	39.38	38.86	38.12	0.00	0.00
Al ₂ O ₃	0.00	0.00	0.00	0.00	0.00	30.62	22.47
FeO*	11.70	11.49	17.01	19.09	22.84	27.40	25.76
MgO	47.58	46.53	43.69	41.79	38.39	14.82	12.79
MnO	0.12	0.30	0.32	0.18	0.61	0.00	0.62
TiO ₂	0.00	0.00	0.00	0.03	0.03	2.80	1.38
Cr ₂ O ₃	0.00	0.00	0.00	0.00	0.00	22.45	37.33
CaO	0.22	0.26	0.24	0.18	0.17	0.00	0.00
TOTAL	100.05	100.53	100.64	100.13	100.16	98.09	100.16
Cations in formula	(0=4)						
Si	0.999	1.001	0.999	0.994	0.995	---	---
Al	---	---	---	---	---	1.073	0.810
Fe ²⁺	0.241	0.236	0.359	0.409	0.489	0.406	0.433
Fe ³⁺	---	---	---	---	---	0.274	0.225
Mg	1.749	1.750	1.641	1.595	1.493	0.657	0.583
Mn	0.003	0.006	0.007	0.003	0.013	---	0.016
Ti	---	---	---	0.001	0.001	0.063	0.032
Cr	---	---	---	---	---	0.528	0.902
Ca	0.006	0.007	0.007	0.005	0.005	---	---
$\frac{\text{Mg}}{(\text{Mg} + \text{Fe}^{2+})}$	0.879	0.881	0.820	0.790	0.750	0.618	0.573
$\frac{\text{Cr}}{(\text{Cr} + \text{Al})}$	---	---	---	---	---	0.329	0.527

consisting of fragments of cumulitic olivine-bearing clinopyroxenites, enclosed in, or enfolded between, coarse (1-3 cm) kaersutite grains (Table 4). These are widely replaced by Ti-magnetite and subordinate plagioclase micrograins, resembling the «black-type» amphibole breakdown products described by

GARCIA & JACOBSON (1979). LT-N augite shows lower Al and higher Fe contents than the above megacrysts, F.I. values instead being similar, between both Low-Ti augite types (Table 2; Fig. 1).

Al-augite nodules (AL-N) consist of equant pyroxene grains (3-5 cm in size) with

TABLE 4

Representative microprobe analyses of kaersutite of LT-N nodules. Formulae following ROSS et al., 1969.

AMPHIBOLE

SiO ₂	40.44	40.11
Al ₂ O ₃	12.53	13.76
FeO*	10.81	10.71
MgO	13.66	13.51
MnO	0.19	0.16
TiO ₂	4.35	4.73
CaO	11.68	11.96
Na ₂ O	2.93	2.66
K ₂ O	0.52	0.74
TOTAL	97.11	98.34

Number of cations in formula (O=23)

Si	6.007	8	5.884	8
Al(iv)	1.993		2.116	
Al(vi)	0.203		0.266	
Ti	0.486		0.522	
Mg	3.024	5	2.954	5
Fe	1.265		1.238	
Mn	0.022		0.020	
Fe(M4)	0.078		0.076	
Ca	1.859	2	1.880	2
Na(M4)	0.063		0.044	
Na(A)	0.781	0.880	0.713	0.851
K(A)	0.099		0.138	

accumulitic texture, enclosing subordinate anhedral Fo₇₅ olivine grains. The mineral chemistry of AL-N augite is characterized by its elevated Al content (Al₂O₃ = 6-7.5 wt%) in comparison with all the above-reported pyroxenes and the host lava phenocrysts which show close compositional similarities with the Al-augites. The latter display elevated F.I. values (F.I. = 0.75-0.88: cf. Fig. 1) (which strongly depend on pyroxene Al contents).

Discussion

The mineral chemistry of Cr-diopside of Cr-

Di wehrlites well fit those of clinopyroxene of word-wide peridotite nodules (e.g. CARSWELL, 1980 and references therein; NIXON, 1987 and references therein; for nodules from Italy, see MORTEN, 1987). On the other hand, textures of our wehrlites may indicate a cumulitic origin. AURISICCHIO & SCRIBANO (1987) therefore suggest that a magmatic chamber was located in the uppermost part of the Etnean mantle, within a tectonic-dunite body: fragments of dunite wall rocks probably fell into the crystallizing magma, forming composite cumulates. The texture of some of our Cr-Di wehrlites correspond to the «modified igneous textures» of WASS (1979) indicating that the original impingement grain boundaries were modified by some degree of annealing.

The early appearance of Cr-diopside from primary liquids is demonstrated by the well-known occurrence of Cr-diopside-bearing dikes and «pods» in peridotite bodies of alpine-type ultramafic massifs, these intrusions

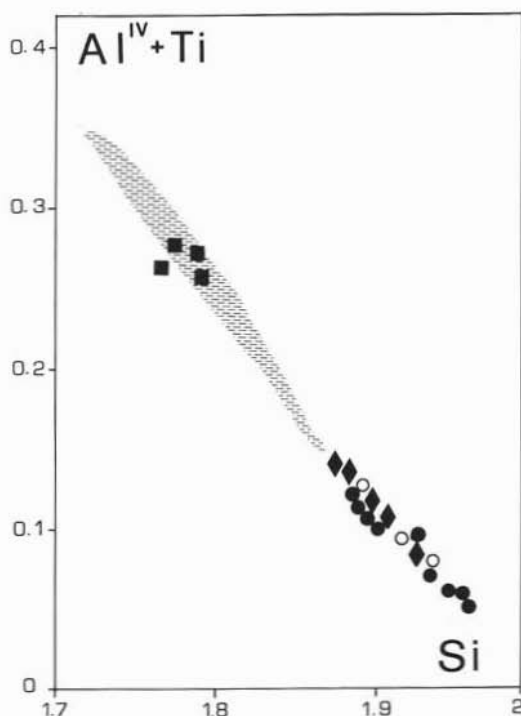


Fig. 2. — (Al^{IV} + Ti)/Si (a.u.f.) ratios for pyroxenes of studied nodules and phenocrysts of host lavas. Same symbols as in Fig. 1.

having been widely interpreted as products of fractionating primary liquid originating from partial melting of fertile peridotites (e.g. SINIGOI *et al.*, 1983). Additionally, Cr-diopside microcrysts constitute the most common quench minerals in «vitrophyric» patches of some peridotite nodule affected by small scale partial melting episodes (MAALØE &

increasing pressure. The same authors also show that, at 1 GPa of pressure, for liquid compositions corresponding to the «piercing point» through the Di-Fo-An plane, a reaction relationship exists in which olivine dissolves as diopside and spinel crystallize.

Chromium content in primary liquids originating from partial melting of peridotites

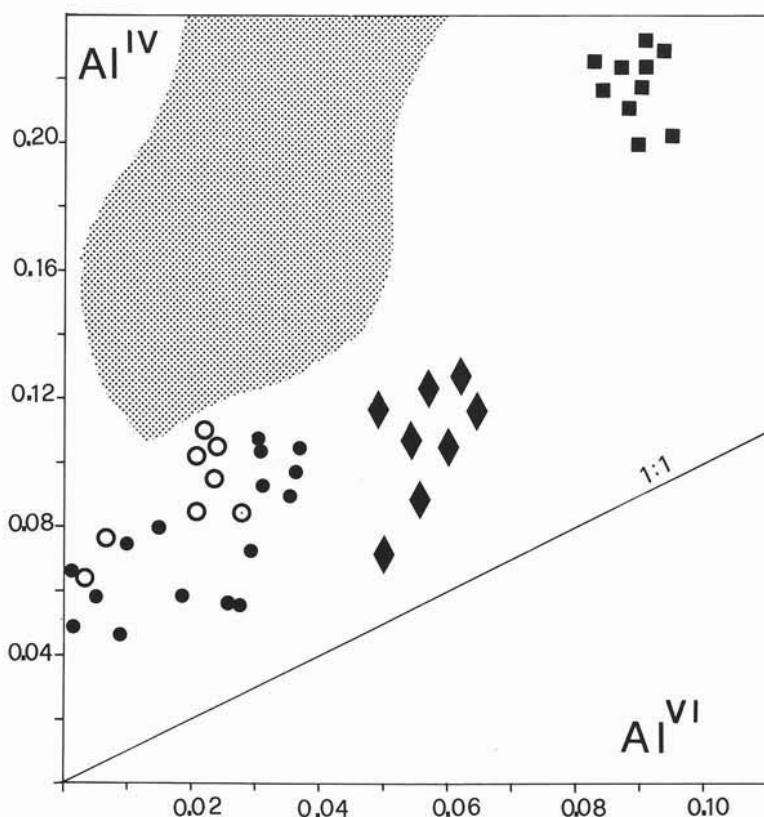


Fig. 3. — Plots of $Al^{IV}:Al^{VI}$ ratios for pyroxenes of studied nodules and phenocrysts of host lavas. Same symbols as in Fig. 1. Dotted area: field of augite phenocrysts of host lavas and other hawaiite lavas belonging to Ancient Alkaline Centres of Mt. Etna.

PRINTZLAU, 1979; for nodules from Sicily, see SCRIBANO, 1986; 1987a).

Experimental results on the $CaO-MgO-Al_2O_3-SiO_2$ system provide additional evidence of Cr-diopside appearing early from primary liquids at elevated pressures. PRESSNALL *et al.* (1978) have, in fact, demonstrated that, in the $CaMgSi_2O_6-MgSiO_4-CaAl_2Si_2O_8$ join, the fields of diopside and spinel expand and those of anorthite and forsterite contract with

must also be taken into account. The experimental results of ONUMA & THOARA (1983) show that, in the $MgSiO_4-CaAl_2Si_2O_8-CaMgSi_2O_6-MgCr_2O_4$ join, the field of anorthite dramatically contracts with increasing Cr-spinel content: for 0.5 wt% of Cr-spinel the field of anorthite disappears even at low pressure, while forsterite reacts with liquid producing diopside and spinel. On the other hand, ONUMA & THOARA (1983) demonstrated that,

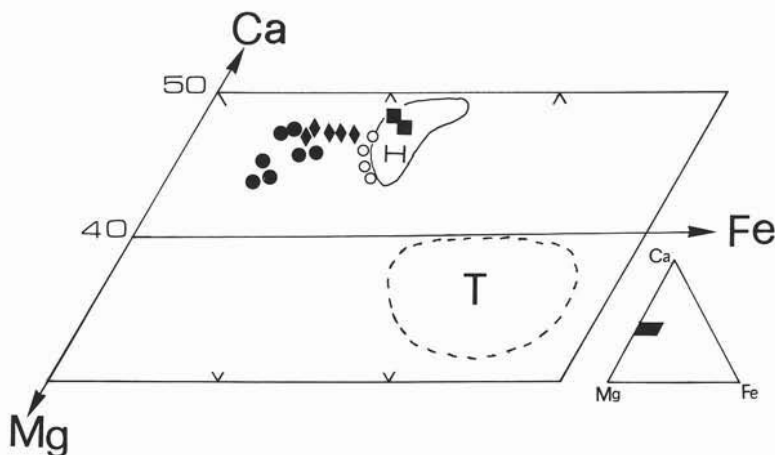


Fig. 4. — Plots of Ca:Mg:Fe^* (a.u.f.) for pyroxenes of studied nodules. Same symbols as in Fig. 1. Field T encloses clinopyroxene phenocrysts from Etnean *thoeliite* lavas; field H: pyroxenes of Etnean *alkaline* lavas.

in the MgCr_2O_4 - $\text{CaMgSi}_2\text{O}_6$ - $\text{CaAl}_2\text{Si}_2\text{O}_8$ join, the $\text{Di} + \text{An} + \text{Sp} + \text{Liq}$ field is located in a very narrow temperature interval (1280 - 1285°C): this may explain the occurrence of Cr-spinel relics only in some diopside grains of the studied wehrlites (see also AURISICCHIO & SCRIBANO, 1987).

The atomic ratio $(\text{Al} + \text{Fe}_t + \text{Ti} + \text{Na}) / (\text{Cr} + \text{Mg})$ (= F.I.) is a suitable fractionation index for our pyroxenes, because of their rather narrow *mg* range. Fig. 1 shows that F.I. value increases from Cr-diopsides to Low-Ti augites and Al-augites. F.I. values are also positively correlated with Al and negatively with Si in the same pyroxenes. The above results suggest that Cr-diopsides (lower F.I. values) represent early separates from some «primary» magma, whose further fractionation yielded Low-Ti augites and Al-augites (higher F.I. values). This trend also suggests the alkaline affinity of the postulated primary magma, since fractionation of alkali-basalt magma results in a decrease in SiO_2 activity and an increase of Al^{3+} in the tetrahedral site of clinopyroxenes (e.g. KUSHIRO, 1960; GUPTA et al., 1973). The alkaline affinity of our pyroxenes is even suggested by their Ca:Mg:Fe (atomic) proportions which do not fit those of clinopyroxenes from Etnean *thoeliite* lavas. The nodule pyroxenes instead trend towards the field of salite phenocrysts of the Etnean alkaline suite (Fig. 4).

Equilibration pressure and temperature may also account for the variations in clinopyroxene mineral chemistry. In particular, a few experimental results on

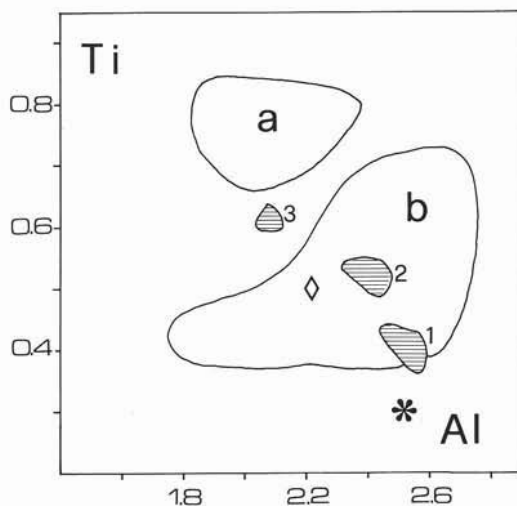


Fig. 5. — Al vs Ti (a.u.f.) for kaersutite of LT-N nodules (double triangle) and other Etnean amphiboles. Shaded areas: 1) kaersutite megacrysts from Ancient Alkaline Lavas, 2) cumulus kaersutite in gabbroic nodules of Ancient Alkaline Lavas and other hawaiite and mugearite volcanics, 3) Kaersutite phenocrysts from mygæarite and benmoreite volcanics of Trifoglietto II and Leone Units of Mt. Etna. Asterisk: pargasite from mantle-derived spinel-websterite nodules from Hyblean volcanic rocks (SCRIBANO 1987a; SCRIBANO 1985-87: unpublished analyses). Field b: amphiboles from mantle-derived magmas and mantle-xenoliths. Field a: crustal amphiboles (after GAMBLE & KYLE, 1987).

simplified systems (e.g. GUPTA et al., 1973) and several studies on natural clinopyroxene series from alkaline igneous rocks suggest that the $(\text{Ti} + \text{Al}^{\text{IV}})/\text{Si}$ ratio in igneous clinopyroxene increases with decreasing pressure (emphasizing the effect of the fractionation trend) (KUSHIRO, 1960; THOMPSON, 1974; WASS, 1979). Thus, plots of these ratios for pyroxenes of the studied nodules (Fig. 2) show a trend of decreasing pressure from Cr-diopsides to Al-augites, according to the fractionation trend (Fig. 1). In detail, most Cr-diopsides are located at the end of the high-pressure side of the point-distribution area, while Low-Ti augites and Al-augites follow a trend of decreasing pressure.

For clinopyroxene crystallized from a given magma, the $\text{Al}^{\text{IV}}/\text{Al}^{\text{VI}}$ ratio is reported to decrease with increasing pressure (e.g. WASS, 1979; MUNOZ & SAGREDO, 1974). The diagram of Fig. 3 may therefore indicate that the combined effects of pressure and composition of the parent liquid on the mineral chemistry of xenolithic clinopyroxenes cause serious difficulties in performing genetic models.

Texture of LT-N nodules (see previous section) is a clear evidence of late stage crystallization of kaersutite. Its mineral chemistry, compared to other Etnean kaersutites (Fig. 5), suggests the mildly-evolute and hydrous character of the nodule-bearing, kaersutite parent magma (a study of amphybole-rich xenoliths from Etna is now in progress).

Concluding remarks

This study on clinopyroxenes of some Etnean nodules indicates polybaric polystage crystallization for these nodules. The Cr-diopside series represent early precipitates from some primary magma, shifting its composition towards normative nepheline enrichment (see also SCRIBANO 1987b). Low-Ti augite megacrysts and cumulate nodules both derive from further polybaric fractionation of the above magma. Since high-pressure nodules are not found in recent Etnean lavas, one may hypothesize that the nodule-bearing «ancient» hawaiites were

erupted when the main magma chamber (in the upper mantle) had not yet well developed and had therefore not yet reached a steady state: this was later attained when the magma chamber migrated up to lower crustal levels, where the pressure and temperature conditions were more favourable for complete resorption of any deep-seated nodules (SCARFE et al., 1980).

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