RENDICONTI DELLA SOCIETÀ ITALIANA DI MINERALOGIA E PETROLOGIA, 1987, Vol. 42, pp. 219-224

# Some ultramafic xenoliths from Etna

CARLO AURISICCHIO
Centro di Studio per la Mineralogia e Petrologia delle Formazioni Ignee del C.N.R., Città Universitaria, Piazzale Aldo Moro, 00185 Roma

VITTORIO SCRIBANO
Istituto di Scienze della Terra dell'Università, Corso Italia 55, 95125 Catania (Italy)

ABSTRACT. — The occurrence of deep-seated ultramafic nodules in some ancient alkaline lavas from Etna is here reported. Two *dunite* types were recognized, the former consisting of very coarse (up to 2 cm) equant olivine grains exhibiting kink bands and neoblastic olivine grains at their adges. The latter type consists of coarse tabular olivines exhibiting complex networks of polygonal subgrains, extreme kink banding and other deformation features, some fo them unique. $Fo_{86 \pm 1}$ olivine and scarce Cr-spinel and Cr-diopside constitute the modal occurrence for both the dunite types.

Green pyroexene bearing *poikilitic wehrlite* xenoliths also occur in the studied lavas, exhibiting a cumulate-like texture. Numerous of their mineral components consist of unmelted fragments of the above described dunites, whereas unstrained Cr-diopside and $Fo_{81-84}$ olivine should represent the magmatic ones.

The two dunite types are believed to represent fragments of a texturally complex upper-mantle, probably that is due to its diapiric upwelling from deeper levels. The wehrlite xenoliths, on the contrary, might represent cumulate materials at the bottom of a magmatic chamber in the upper mantle, probably within the dunite level.

*Key words:* Etna, xenolith, dunite, wehrlite, upper mantle.

RIASSUNTO. — In alcune nefelin-hawaiiti appartenenti ai «Centri Alcalini Antichi» dell'Etna, sono stati riconosciuti inclusi ultrafemici di origine profonda. Vi sono *duniti*, sia di tipo granulare che tabulare; le prime sono costituite da cristalli di olivina (fino a 2 cm) tendenzialmente equigranulari, incastonati secondo superfici curvilinee e caratterizzati da «kink bands» e subgrani neoblastici non deformati. Le seconde sono costituite da cristalli olivinici a grana media, allungati secondo l'asse «c», talora lenticolari, con vistose deformazioni lamellari ad andamento irregolare. La composizione dell'olivina è uguale per i due tipi di duniti ($Fo_{86 \pm 1}$), come pure gli scarsi minerali accessosi, Cr-spinello e Cr-diopside.

Sono state inoltre riconosciute *wehrliti* a pirosseno verde (Cr-diopside) «pecilitico», inglobante cristalli di olivina e anche frammenti policristallini delle suddette duniti «metamorfiche».

Duniti e wehrliti presentano somiglianze tessiturali e composizionali con quelle delle Hawaii e, anche sulla base di questo confronto, si può ipotizzare che esse rappresentino refrattari del mantello superiore, le cui deformazioni sarebbero conseguenti a flussi di tipo diapirico. Le wehrliti, invece, potrebbero rappresentare cumuliti al fondo di una «camera magmatica» profonda, forse ubicata all'interno del suddetto livello dunitico.

*Parole chiave:* Etna, xenoliti, duniti, wehrlite, mantello superiore.

## Introduction

Deep-seated olivine and diopside xenocrysts were recently found in some Etnean lavas belonging to the «Ancient Alkaline Centres» (SACHS & SCRIBANO, 1985). Further field investigations allowed to recognize in the same lavas rare ultramafic nodules related to those xenocrysts, constituting the argument of this note.

### *The host lavas*

The xenolith bearing rocks crop out in the Eastern and Western lowermost slopes of Mt. Etna, representing the oldest alkalic lava flows laying over the «Basal Tholeiites» or directly over the Etnean sedimentary basement rocks (Geologic Map of Etna, 1980) (Fig. 1). Several Authors (e.g. ROMANO, 1982) suggest that these Ancient Alkalic Lavas formed a

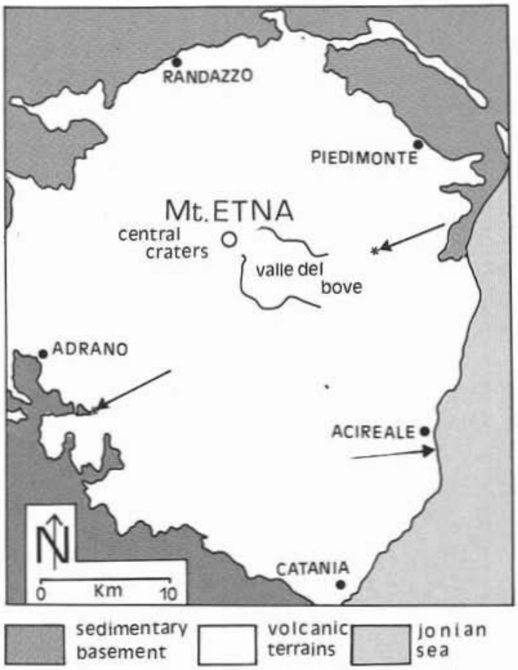


Fig. 1. — Approximate location of the xenolith bearing lavas (indicated by arrows).

shield volcano which later was covered by younger, more differentiated, volcanic products belonging to different eruptive axes.

These ancient lavas mostly consist of ne-normative porphyritic hawaiites, $An_{35-70}$ plagioclase, augite, $Fo_{56-80}$ olivine and Ti-magnetite consituting their modal occurrence. Mafic magmatic cumulate xenoliths were previously found in these lavas (Lo Giudice & Rittmann, 1974).

## Deep-seated ultramafic nodules

The nodule sizes rarely exceed the few cubic centimetres often being less than one; their volume percentage in the host lavas never exceeds 1 vol%, that is much less than xenocrysts (up to 15 vol%: Sachs & Scribano, 1985); the nodules are not homogeneously distributed in their host lavas but often being zonally concentrated, that suggests these derive from the fragmentation of previous larger xenoliths during the lava emplacement.

The nodules' green colour in hand specimen allows to distinguish them from shallow-depth magmatic xenoliths and phenocryst clusters (black in colour). Dunite and wehrlite xenoliths were thus recognized, the latter being more aboundant than the former.

### *Dunites*

Two types of metamorphic dunite were recognized on textural basis. The first consists of coarse equant olivine grains exhibiting green colour in hand specimen; the olivine grain size in some cases exceeds 25 mm, that is unusually large in comparison to the olivines in elsewhere occurring dunites, rarely exceeding 5 mm (Harte, 1970; Kirby & Green, 1980 etc.); they exhibit well developed kink bands, which appear as straight, parallel and regularly spaced lamellae. Up to 5 μm fluid inclusions also occur in these olivine crystals. Few, up to 30 μm large «drops» of Cr-spinel, often rimmed by Cr-diopside, constitute the only accessory minerals in these granular dunites, never exceeding the 0.5% of the modal percentage. One of these nodules consists of two or three

Table 1

*Representative microprobe analyses of olivines occurring in the studied dunite (A-C) and wehrlite (D-F) xenoliths*

| OLIVINE Wt% | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| $SiO_2$ | 40.23 | 41.23 | 40.39 | 38.48 | 39.38 | 40.93 |
| FeO | 13.79 | 12.85 | 12.87 | 16.85 | 17.01 | 12.81 |
| MgO | 45.54 | 46.80 | 46.54 | 42.84 | 43.69 | 46.42 |
| MnO | 0.25 | 0.00 | 0.00 | 0.37 | 0.32 | 0.00 |
| $TiO_2$ | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 |
| CaO | 0.23 | 0.21 | 0.00 | 0.23 | 0.24 | 0.21 |
| Total | 100.04 | 101.09 | 99.80 | 98.97 | 100.64 | 100.37 |
| Cations per formula unit (O=4) | | | | | | |
| Si | 1.004 | 1.006 | 0.999 | 0.983 | 0.999 | 1.006 |
| Fe | 0.287 | 0.265 | 0.269 | 0.364 | 0.359 | 0.266 |
| Mg | 1.692 | 1.719 | 1.733 | 1.648 | 1.641 | 1.717 |
| Mn | 0.005 | 0.000 | 0.000 | 0.008 | 0.007 | 0.000 |
| Ti | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 |
| Ca | 0.006 | 0.006 | 0.000 | 0.006 | 0.007 | 0.006 |
| Σ Cations | 2.994 | 2.996 | 3.001 | 3.013 | 3.013 | 2.995 |
| Fo (mol%) | 85.50 | 86.64 | 86.56 | 81.91 | 82.05 | 86.58 |

TABLE 2

*Analyses of spinels occurring in the considered xenoliths. Analyses G, H, I, K, represent spinel within the olivines, J, L, within the diopside. Formulae were computed imposing stoichiometry*

SPINEL

| Wt% | G | H | I | J | K | L |
|---|---|---|---|---|---|---|
| $Al_2O_3$ | 20.94 | 20.78 | 21.28 | 30.62 | 22.47 | 31.00 |
| FeO* | 26.44 | 26.58 | 26.69 | 27.40 | 25.76 | 27.52 |
| MgO | 12.48 | 12.36 | 12.66 | 14.82 | 12.79 | 14.87 |
| MnO | 0.30 | 0.00 | 0.00 | 0.00 | 0.62 | 0.00 |
| $TiO_2$ | 1.59 | 1.33 | 1.29 | 2.80 | 1.38 | 2.81 |
| $Cr_2O_3$ | 37.77 | 37.63 | 37.81 | 22.45 | 37.33 | 22.36 |
| Total | 99.52 | 98.68 | 99.73 | 98.09 | 100.35 | 98.56 |
| Cations in formula (O=32) | | | | | | |
| Al | 6.315 | 6.325 | 6.396 | 8.892 | 6.668 | 8.950 |
| Fe(3+) | 2.163 | 2.227 | 2.444 | 2.556 | 2.082 | 2.536 |
| Fe(2+) | 3.487 | 3.506 | 3.441 | 3.083 | 3.335 | 3.095 |
| Mg | 4.753 | 4.752 | 4.806 | 5.435 | 4.794 | 5.422 |
| Mn | 0.065 | 0.000 | 0.000 | 0.000 | 0.132 | 0.000 |
| Ti | 0.306 | 0.258 | 0.247 | 0.518 | 0.261 | 0.517 |
| Cr | 7.632 | 7.674 | 7.614 | 4.368 | 7.422 | 4.325 |
| $\frac{Cr}{(Cr + Al)}$ | 0.547 | 0.548 | 0.543 | 0.329 | 0.527 | 0.326 |

coarse olivine grains interlocked by curvilinear grain boundaires which are marked by lighter coloured, unstrained, equant olivine subgrains.

The second dunite type consists of coarse-tabular olivine grains strongly elongated according to their *c* axes; the crystals appear roughly isooriented, but their boundary surfaces often do not correspond to rational faces and sometimes they are marked by clusters of polygonal subgrains (also by infiltrating material from the host lava's groundmass).

These tabular olivines exhibit a number of dislocation features, the «hembricated» arrangement of the grains or «ribbon foliation» defined by interconnected lenticular crystals. Undulose extinction and kink bands are also ubiquitous, the latter appearing irregularly spaced, the lamellae being dislocated and somewhere «folded». That might indicate that stresses overimposed on previous «normally» kink banded olivine grains. This hypothesis is also supported by the rare occurrence of nodules where the tabular olivines laterally grade to large, granular crystal. Peraphs the small size of the studied dunite xenoliths might obliterate their true «composite» or porphyroclastic character.

*Mineral chemistry of the dunite xenoliths*

Both granular and tabular dunite types ex-

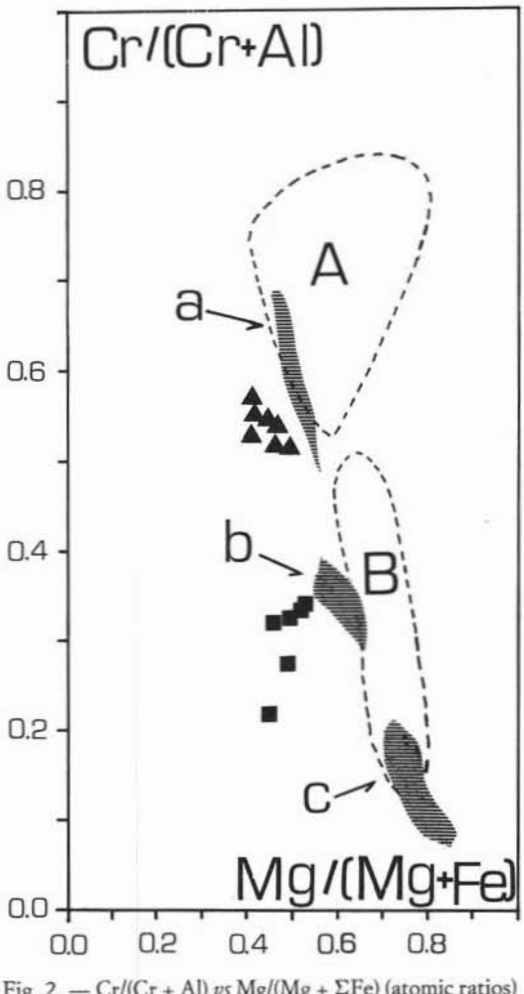


Fig. 2. — Cr/(Cr + Al) *vs* Mg/(Mg + ΣFe) (atomic ratios) for the studied spinels. The square symbols represent the spinel enclosed in the olivine, whereas those in the diopside are represented by triangles. The field A encloses the spinels in the «ocean-type» peridotite xenolithis, the field B those occurring in the «alpine-type» ones. (DICK & FISHER, 1984). The fields indicate as «a», «b», «c» represent spinels in harzburgite, lherzolite and websterite xenoliths from the Hyblean area (SCRIBANO, 1986).

hibit the same mineral chemistry. The *olivine* exhibits homogeneous $Fo_{86 \pm 1}$ composition (Tab. 1). The *spinel* is a chromian variety whose Cr/(Cr + Al) atomic ratio equals 0.2-0.3 in those cases where the spinel directly touches the olivine host, the same value being 0.5-0.55 where the spinel is rimmed by a thin sheath of diopside. Both spinels exhibit the same value of Mg/(Mg + ΣFe) ratio (Tab. 2; Fig. 2). The *diopside* exhibits a $Cr_2O_3$ = 0.5-1.5 (wt%) and $Al_2O_3$ = 3 (± 0.2) (wt%) contents (Tab. 3; Figs. 3, 4).

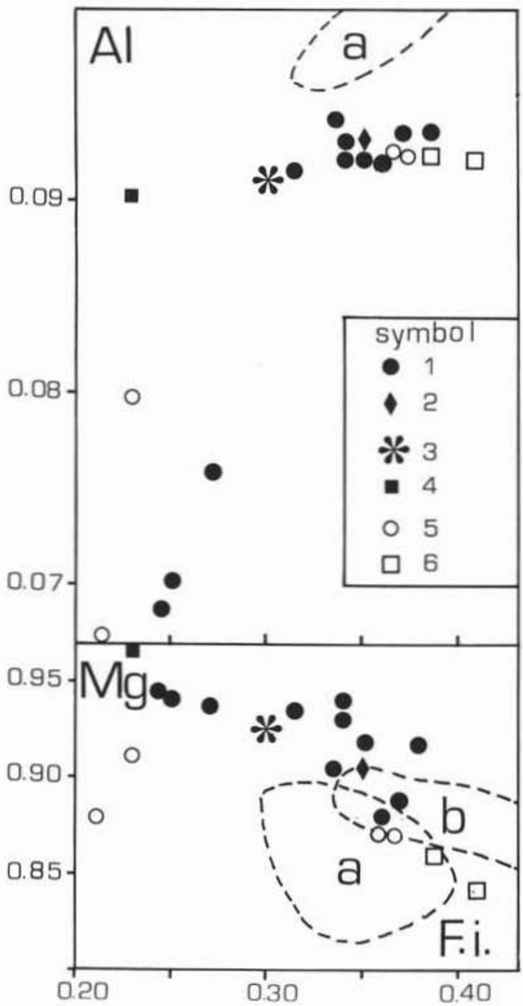


Fig. 3. — F.I. (= Al + Fe + Na + Ti)/(Mg + Cr) *vs* Al and Mg in diopside occurring in the studied and other xenoliths. Symbols: 1) diopside in Etnean weherlite; 2) diopside in Etnean dunites; 3) diospide xenocrysts in Etnean lavas reported by SACHS & SCRIBANO (1985); 4) diopside microcrysts in the vitrophyric blebs in Hyblean harzburgite xenoliths; 5) diopside in wehrlite and 6) in dunite xenoliths from Hawaii (WHITE, 1966). The field a encloses pyroxene occurring in the Hyblean lherzolites, b in the websterites.

### *Wehrlite xenoliths*

The wehrlite xenoliths exhibit an inequigranular «poikilitic» texture, due to Cr-diopside oikocrysts (up to 10 mm) enclosing olivine grains. In hand specimen the pyroxene exhibits green colour, darker than the coexisting olivine. The diopside grains are unstrained and often exhibit irregular empty pathces probably representing decrepitated fluid (or melt) inclusions which somewhere give the pyroxene a spongy character; magmatic corrosion and brownish augite overgrowths are rather common where the diospide contacts the host lava (see SACHS & SCRIBANO, 1985).

The mineral chemistry of this pyroxene does not differ very much from the diospide rarely occurring in the dunite xenoliths (Tab.

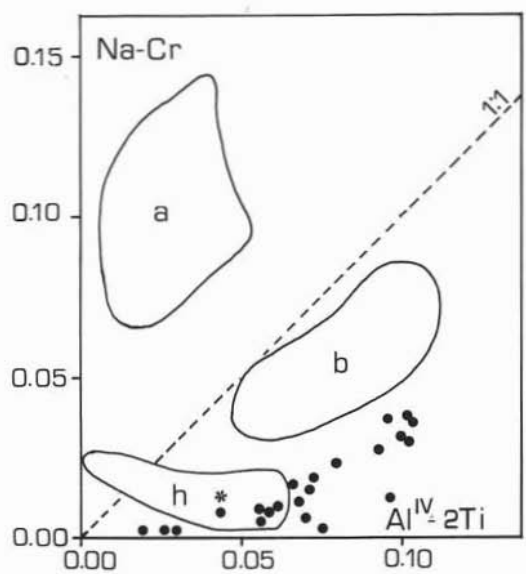


Fig. 4. — Na-Cr (Jadeite) *vs* $Al^{iv}$-2Ti (Tschermakite) variations in the studied dunite and wehrlite pyroxenes (dots). The asterisk indicates diopside xenocrysts reported by SACHS & SCRIBANO (1985). The fields «a» and «b» enclose pyroxenes occurring in the Hyblean lherzolite and websterite xenoliths, whereas the field «h» ecloses those occurring in the dunites and wehrlites from Hawaii (WHITE, 1966).

TABLE 3

*Analyses of pyroxenes occurring in the studied inclusions. P, Q represent accessory diopside in the dunites. Formulae were calculated following* PAPIKE *et al., 1974*

CLINOPYROXENE

| Wt% | M | N | O | P | Q | R | S | T | U | V | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 52.75 | 52.60 | 52.37 | 53.19 | 51.86 | 51.53 | 51.45 | 51.75 | 51.44 | 51.79 | 52.28 |
| $Al_2O_3$ | 1.91 | 1.53 | 1.79 | 2.68 | 3.24 | 3.14 | 2.79 | 2.75 | 2.86 | 2.70 | 2.88 |
| FeO* | 4.11 | 4.08 | 4.00 | 4.74 | 5.17 | 4.85 | 4.18 | 5.16 | 4.78 | 5.05 | 5.07 |
| MgO | 17.36 | 17.23 | 16.90 | 17.38 | 17.01 | 16.64 | 16.69 | 16.53 | 15.86 | 17.31 | 17.23 |
| $TiO_2$ | 0.40 | 0.44 | 0.21 | 0.59 | 0.48 | 0.50 | 0.58 | 0.48 | 0.49 | 0.53 | 0.61 |
| $Cr_2O_3$ | 0.63 | 0.61 | 0.54 | 0.68 | 0.67 | 0.42 | 1.37 | 1.01 | 0.40 | 0.73 | 0.99 |
| CaO | 22.55 | 22.06 | 22.14 | 21.10 | 21.16 | 22.80 | 22.37 | 20.79 | 22.69 | 20.48 | 20.30 |
| $Na_2O$ | 0.49 | 0.30 | 0.37 | 0.38 | 0.76 | 0.57 | 0.79 | 0.56 | 0.41 | 0.95 | 0.51 |
| Total | 100.20 | 98.85 | 98.62 | 100.74 | 100.35 | 100.45 | 100.22 | 99.03 | 98.93 | 99.54 | 99.87 |
| Cations per formula unit (O=6) | | | | | | | | | | | |
| Si | 1.914 | 1.948 | 1.930 | 1.923 | 1.879 | 1.867 | 1.869 | 1.909 | 1.901 | 1.887 | 1.908 |
| Al(iv) | 0.086 | 0.052 | 0.070 | 0.077 | 0.121 | 0.133 | 0.131 | 0.091 | 0.099 | 0.113 | 0.092 |
| Al(vi) | 0.000 | 0.014 | 0.008 | 0.038 | 0.017 | 0.002 | 0.000 | 0.028 | 0.026 | 0.003 | 0.032 |
| Fe(2+) | 0.044 | 0.110 | 0.063 | 0.129 | 0.044 | 0.016 | 0.011 | 0.112 | 0.086 | 0.027 | 0.122 |
| Fe(3+) | 0.081 | 0.017 | 0.061 | 0.014 | 0.113 | 0.132 | 0.115 | 0.048 | 0.062 | 0.127 | 0.033 |
| Mg | 0.938 | 0.933 | 0.945 | 0.936 | 0.919 | 0.899 | 0.904 | 0.909 | 0.873 | 0.940 | 0.939 |
| Ti | 0.011 | 0.012 | 0.006 | 0.016 | 0.013 | 0.014 | 0.016 | 0.013 | 0.014 | 0.015 | 0.017 |
| Cr | 0.018 | 0.018 | 0.016 | 0.020 | 0.019 | 0.012 | 0.040 | 0.029 | 0.012 | 0.021 | 0.029 |
| Ca | 0.877 | 0.875 | 0.874 | 0.819 | 0.822 | 0.885 | 0.870 | 0.821 | 0.898 | 0.800 | 0.794 |
| Na | 0.035 | 0.021 | 0.027 | 0.027 | 0.054 | 0.041 | 0.055 | 0.040 | 0.029 | 0.067 | 0.036 |
| $\frac{Mg}{(Mg + \Sigma Fe)}$ | 0.88 | 0.88 | 0.88 | 0.86 | 0.85 | 0.86 | 0.87 | 0.85 | 0.85 | 0.86 | 0.85 |

3; Figs. 3, 4) except the F.I. interval which is narrover in the dunite pyroxene (Fig. 3). (That however might depend on the low amount of pyroxene in the dunites, that implyes less statistical representativity of the microprobe analyses).

Two pyroxene groups can be recognized by plotting their F.I. values *versus* the atomic Mg and Al contents (Fig. 3), the one exhibits lower F.I. and Al but more elevated Mg contents than the other group; it must be remarked that only large (up to 10 mm) pyroxene in wehrlites belong to the first group whereas both dunite and wehrlite pyroxenes belong to the other one. The same diagram also shows that the pyroxene with lower F.I. values plot close to the «magmatic» diospide occurring in the «vitrophyric blebs» within the Hyblean harzburgite xenoliths (SCRIBANO, 1986 a) whereas the rest plots close to the pyroxenes occurring in the Hyblean lherzolite and websterite xenoliths (SCRIBANO, 1986 b).

Most of the poikilitically enclosed olivine grains exhibit the same composition and textural features as the previously described dunite olivines; moreover, not only isolated olivine grains but also policrystalline dunite fragments are often enclosed by the pyroxenes. $Fo_{81-84}$ unstrained ehuedral olivine grains also occur in the studied wehrlites.

## Concluding remarks

The studied dunite xenoliths have been strongly deformed and recrystallized and their microtextures are believed to represent evidence for mantle diapir flow (KIRBY & GREEN, 1980). These nodules could be interpreted as recrystallized cumulates related to a magmatic liquid: this is consistent with the rather low forsterite content of their olivines (see the mineral chemistry section) compared to those occurring in the «alpine type» dunites and in other peridotite types (as well as spinel-lherzolites and harzburgites: WHITE, 1966; CARSWELL, 1980; HERVIG et al., 1980; DICK & FISHER, 1984; for peridotite xenoliths from Sicily see SCRIBANO, 1986).

On the contrary, the olivine occurring in some *garnet*-lherzolite nodules from Hawaii (KIRBY & GREEN, 1980) exhibit a forsterite content almost similiar to that of the studied ones. Therefore it seems also worthwhile to consider these nodules refractory residua from garnet-lherzolite which yielded large amounts of magmatic liquid (WILKINSON, 1985).

The «poikilitic» character of the Etnean wehrlite xenoliths suggests these represent magmatic cumulates (WHITE, 1966). This hypothesis would imply the existence of a deep-seated magmatic chamber beneath volcano, where the cumulates originated from some primary liquid, because the mineral chemistry of these rocks suggests these formed at elevated pressure and temperature, probably within the spinel-peridotite field. The occurrence of dunite in the studied wehrlites could indicate that the postulated magmatic chamber was located within the dunite level.

The crustal profile beneath Mt. Etna (CRISTOFOLINI et al., 1979; COSENTINO et al., 1982) shows the boundary surface where the «P» waves velocity increases from 7 Km/s to 8 Km/s, varies from a depth of 28.8 Km to 38 Km going from South-East to North-West beneath Mt. Etna. This can be accounted for a lateral variation of lithology which might be related to a «fossil» magmatic chamber, since the «P» waves' velocity equals 8 Km/s through the «metamorphic» dunites (e.g. JACKSON & WRIGHT, 1970).

This paper is part of an ongoing program to study the ultramafic nodules in the volcanic rocks from Mt. Etna and Hyblean Plateau. (Grant n. 87.00696.62 by CNR-GNV).

## REFERENCES

CARSWELL D.A. (1980) - *Mantle derived lherzolite nodules associated with kimberlite, carbonatite and basalt magmatism: a review*. Lithos, 13, 121-138.

CRISTOFOLINI R., LENTINI F., PATANÈ G. & RASÀ R. (1979) - *Integrazione di dati geologici, geofisici e petrologici per la stesura di un profilo crostale in corrispondenza dell'Etna*. Boll. Soc. Geol. It., 98, 239-247.

COSENTINO M., LOMBARDO G., PATANÈ G., SCHICK R. & SHARP A.D.L. (1982) - *Seismological researches on Mount Etna: state of art and recent trends*. Mem. Soc. Geol. It., 23, 159-202.

DICK H.J.B. & FISHER R.L. (1984) - *Mineralogic studies of the residues of mantle melting: abyssal and alpine-type peridotites*. In: Kornprobst J. (Editor), Kimberlite II: The Mantle and Crust-Mantle Relationships, Elsevier, Amsterdam, 393 p.

HERVIG R.L., SMITH J.V., STEELE I.M., DAWSON J.B. (1980) - *Fertile and barren Al-Cr spinel harzburgites from the upper mantle: ion and electron probe analyses of trace elements in olivine and orthopyroxene: relation to lherzolites*. Earth Planet. Sci. Lett. 50, 41-58.

JACKSON E.D. & WRIGHT T.L. (1970) - *Xenoliths in the Honolulu Volcanic Series, Hawaii*. Jour. Petr. 11, 405-450.

KIRBY S.H. & GREEN H.W. (1980) - *Dunite xenoliths from Hualalai Volcano: evidence for mantle diapiric flow beneath the Island of Hawaii*. Am. Jour. of Sci., 280, 550-575.

LO GIUDICE A. & RITTMANN L. (1974) - *Su alcune accumuliti etnee: aspetti mineralogici e genetici*. Rivista Mineraria Siciliana, 151, 20-36.

PAPIKE J.J., CAMERON K. & BALDWIN K. (1974) - *Amphiboles and pyroxenes: characterization of the other than quadrilater components and estimates of ferric iron from microprobe data*. Geol. Soc. of Am. Abstr., 6, 1053-1064.

ROMANO R., STURIALE C., LENTINI F. et alii (1980) - *Geologic Map of Mount Etna*. C.N.R., Istituto Intern. Vulc., P.F. Geodinamica. Scala 1:50.000.

ROMANO R. (1982) - *Succession of the volcanic activity in the etnean area*. Mem. Soc. Geol. It., 23, 27-48.

SACHS P.M. & SCRIBANO V. (1985) - *Mantle derived xenocrysts in ancient Etnean lavas*. Per. Mineral., 54, 53-60.

SCRIBANO V. (1986 a) - *The harzburgite xenoliths in a quanternary basanitoid lava near Scordia (Hyblean Plateau, Sicily)*. Rend. SIMP. 41, 2, 245-255.

SCRIBANO V. (1986 b) - *The ultramafic and mafic nodule suite in a tuff-breccia pipe from Cozzo Molino (Hyblean Pleteau, South-Eastern Sicily)*. Rend. SIMP, this volume.

WHITE R.W. (1966) - *Ultramafic inclusions in basaltic rocks from Hawaii*. Contr. Miner. Petr., 12, 245-314.

WILKINSON J.F.C. (1985) - *Undepleted Mantle Compostion beneath Hawaii*. Earth Planet. Sci. Lett. 75, 129-138.

MANUSCRIPT ACCEPTED MAY 1987