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The harzburgite xenoliths in a quaternary basanitoid lava near Scordia (Hyblean Plateau, Sicily)

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ABSTRACT. — In a quaternary age basanitoid lava flow, cropping out in the Loddiero Valley (Scordia area, Hyblean Plateau), upper mantle derived ultramafic xenoliths occur; these mostly consist of harzburgites, which exhibit a coarse equant (rarely tabular) texture due to olivine ($Fo_{89.5}$) and orthopyroxene ($En_{90}Fs_9Wo_1$) grains, with scarce Cr-spinel (Cr/(Cr+Al)=0.4-0.7) and Cr-diopside ($En_{50}Fs_7Wo_{43}$) accessories. These minerals, particularly the coarse olivine grains, exhibit deformation features (mainly kink bands) and complex clusters of unstrained neogenetic subgrains.

The textural evidences and the rather low estimated equilibrium temperature values ($T < 730°$ C) suggest these ultramafic assemblages, prior their incorporation in the host magma, suffered a sort of retrograde metamorphism due to their transfer from deeper to shallower levels in the upper mantle, or as a consequence of a (temporary?) stepping down of the Hyblean geotherm.

The studied harzburgites also exhibit vitrophyric « blebs » due to minor partial melting episodes probably occurred after their incorporation into the host magma. In fact, the pressure release during the xenolith (rapid) ascent to the earth's surface and the thermal and metasomatizing effects exerted on them by the host liquid and its fluids, can largely account for these partial melting episodes.

Key words: Hyblean Plateau, lava flow, xenolith, harzburgite, upper mantle.

RIASSUNTO. — In una colata lavica a tendenza basanitica di età quaternaria, affiorante nella Valle del Loddiero tra Scordia e Militello (Altipiano Ibleo), sono stati riconosciuti numerosi xenoliti di diversa natura ove prevalgono largamente le *harzburgiti* di mantello; queste hanno struttura granulare data da cristalli di olivina ($Fo_{89.5}$) e ortopirosseno ($En_{90}Fs_9Wo_1$) le cui variazioni modali sono, rispettivamente, 70-85 % (Ol) e 15-30 % (Opx); gli accessori sono costituiti da Cr-spinelli (Cr/(Cr+Al) = 0,4-0,7) e Cr-diopside ($En_{50}Fs_7Wo_{43}$).

I più grossi cristalli di olivina (max. 0,4 mm) presentano evidenti deformazioni lamellari e complessi sistemi di « subgrani » neogenici privi di deformazioni, indicanti una complessa storia « metamorfica » di queste harzburgiti prima della loro incorporazione nel magma ospite. Ciò troverebbe riscontro nelle stime geotermometriche che indicano una ri-equilibrazione di queste rocce a temperature relativamente basse ($T < 730°$ C).

Questi inclusi harzburgitici presentano inoltre numerose plaghe vitrofiriche costituite da microcristalli di diopside e vetro; queste sono dovute a episodi minori di fusione parziale, forse avvenuti dopo l'incorporazione nel magma ospite anche in seguito all'azione termica di questo, alla penetrazione di fluidi magmatici lungo microclasi e, forse, alla decompressione durante la risalita a giorno.

Parole chiave: Altipiano Ibleo, colata lavica, xenolite, harzburgite, mantello superiore.

Introduction

The Hyblean Plateau (South Eastern Sicily) belongs to the Northern margin of the African Plate and consists of a platform carbonate interbedded with volcanic horizons, whose age ranges from the Cretaceous to the Pleistocene (e.g. BARBERI et al., 1974). These volcanic products are related with a fissural-type activity both in submarine and in subaerial environments, the alkaline and tholeiitic basalts representing the dominant lithotypes (e.g. CRISTOFOLINI and BATTAGLIA, 1974).

Some of the alkalic volcanic rocks exhibit mantle and crust derived xenoliths, whose study should contribute to the knowledge of the upper mantle and the lower crust beneath this region. This paper on the harzburgite xenoliths in a quaternary lava from the Northern margin of the Hyblean Plateau represents the first contribution.

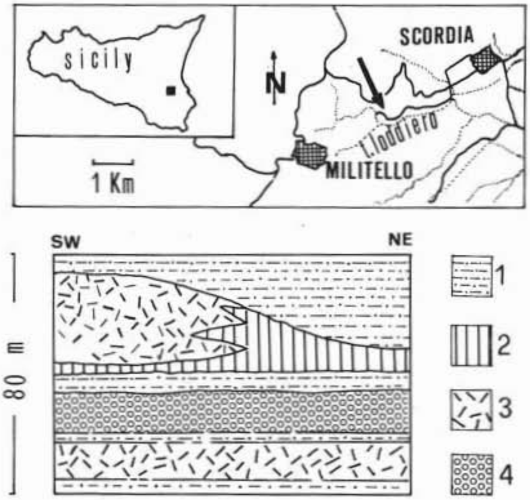


Fig. 1. — Location of the xenolith bearing lava and its stratigraphic relationships with the surrounding rocks. The full lines in the upper sketch, represent roads, the light dotted ones, streams. The arrow indicates the studied outcrop. Legend of the stratigraphic sketch: 1) quaternary calcarenites and marls; 2) massive basanitoid lava; 3) basanitoid pillow-fragment breccia; 4) tholeiite pillow lava. Both 2 and 3 are xenolith bearing.

Geological setting and petrological outlines of the host lava

In the Valley of the Loddiero river, between the villages of Scordia and Militello, 80 m thick alternating volcanic rocks and shallow water marine sediments crop out; their quaternary age was already suggested (CARTA GEOLOGICA DELLA SICILIA SUD-ORIENTALE, 1984). The xenolith bearing rocks belong to a 10 m thick lava sheet resting on white marls and interfingered with 40 m thick lens of pillow-fragment breccia (fig. 1).

This lava is a massive basanitoid, with ca. 7 % normative nepheline. This rock plots close to the boundary line between the basalts and the basanites fields in the total alkalies over silica diagram proposed by Cox et al. (1984) (tab. 1). This lava exhibits an oligo-microporphyritic texture (P.I. = 20) due to skeletal olivine microphenocrysts plunged into a vitrophyric groundmass, where acicular An_{65} plagioclase feldspar, purplish clinopyroxenes, olivine and opaque microlites can be distinguished within the glass patches.

The olivine phenocrysts are zoned from Fo_{85} to Fo_{73} with CaO ranging from 0.25 up to 0.45 (wt%). The pyroxene microlites plot in the salite field in the En-Fs-Wo quadrilateral and exhibit rather high Ti content (TiO_2 = 3.5 %) (tab. 5, analysis « *P* »; fig. 5). The opaque micrograins are Ti-magnetite ($X_{mt} = 0.4$) where a low vanadium content was found (V_2O_6 = 0.36 wt%). The glass is enriched in the feldspar components for some microprobe analyses indicate Na-sanidine compositions.

TABLE 1

Chemical analysis of the host lava and its CIPW normative composition. All elements were found by XRF, except FeO that was determined by Titration and MgO by AAS

Wt%	
SiO_2	42.93
TiO_2	3.45
Al_2O_3	14.29
Fe_2O_3	6.25
FeO	6.32
MnO	.24
MgO	8.19
CaO	11.01
Na_2O	3.02
K_2O	1.33
P_2O_5	.96
L.I.	2.01
Total	100.00
CIPW	
Ab	12.19
An	21.54
Or	7.85
Ne	7.23
Di	22.10
Ol	14.45
Il	6.56
Mt	4.21
Ap	2.27

(Analytical facilities at Istituto di Scienze della Terra, Catania).

It should be stressed this lava was mostly liquid when emplaced as indicated by the low P.I. and the skeletal character of the olivine microphenocrysts.

The xenoliths

Both mantle- and deep crust derived xenoliths occur in the considered lava, the former being the dominant type. The size of these inclusions varies from few centimetres down to the size of isolated xenocrysts; the largest ones exhibit rounded shapes, whereas the small ones generally angular edges. For these xenoliths are not uniformely distributed in the host lava, it is impossible to evaluate precisely their volume percentage, which somewhere is more than 15 vol.%.

The ultramafic assemblages are typified on mineralogic and textural basis following the IUGS recommendations (1973) and HARTE (1977). Coarse harzburgites and minor olivine-clinopyroxenites where thus recognized, the first constituting the subject of this paper.

TABLE 2

Representative microprobe analyses of coarse olivine grains in the studied harzburgite xenoliths

OLIVINE

wt%	A	B	C	D	E
SiO_2	41.67	41.09	41.70	41.81	41.69
FeO	9.43	9.61	9.58	9.28	9.43
MgO	48.46	48.19	48.37	48.76	48.46
MnO	.00	.23	.17	.21	.00
CaO	.00	.00	.00	.00	.00
NiO	.30	.36	.36	.50	.00
TOTAL	99.86	99.88	100.18	100.56	99.58
cations in formula (O=4)					
Si	1.017	1.008	1.016	1.013	1.016
Fe	.192	.197	.195	.188	.192
Mg	1.763	1.761	1.757	1.763	1.761
Mn	.000	.005	.004	.004	.000
Ca	.000	.000	.000	.000	.000
Ni	.006	.007	.007	.010	.000
$Mg/(Mg+Fe^t)$	89.9	89.7	89.8	90.1	90.1

(Microprobe facilities at Centro di Studio delle Formazioni Ignee dell'Italia Centrale, CNR, Roma).

The harzburgite xenoliths

Petrography

The harzburgite xenoliths here found exhibit a coarse (both equant and tabular) « granoblastic » texture due to olivine grains whose modal percentage ranges from 70 up to 85 %, and enstatite (15-30 %) with less coarse spinel and diopside as accessory minerals, which never exceed 5 % of the total assemblages (fig. 2 *a, b*).

The coarse grained (up to 4 mm) olivine often exhibits undulatory extinction and deformation lamellae which in every grain appear sub-parallel to (001) and (100), but the various grains in the same mineral aggregate exhibit random attitudes. The deformation lamellae in some large olivine grains appear truncated by rather wide mosaics of unstrained neoblastic subgrains; that could be taken in account for the complex metamorphic history these minerals suffered in their source region.

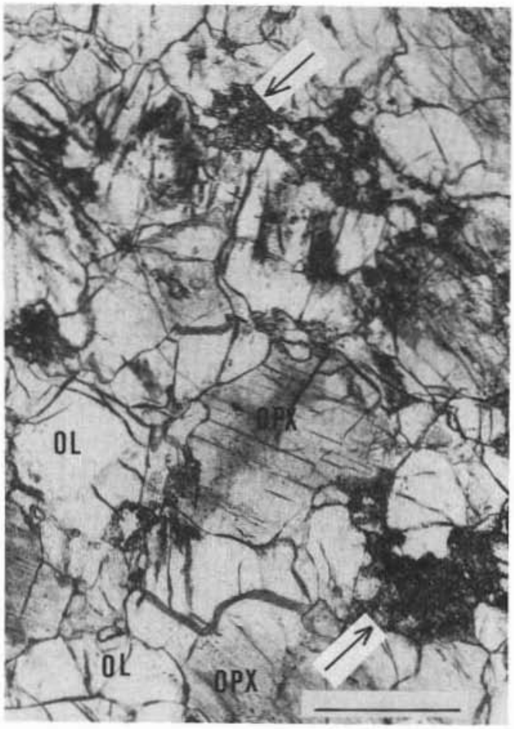
All the minerals occurring in these harzburgites exhibit straight trails of tiny, either ovoidal or spherical fluid inclusions, which often crosscut the deformation lamellae; these fluids (CO_2?) probably exsolved and migrated along discontinuties of the crystalline structures because of pressure release during the xenolith ascent to the earth's surface (ROEDDER, 1965; CARSWELL, 1975; MITCHELL, 1984) (fig. 2 *c*).

It must be remarked the enstatite often appears more clouded by fluid inclusions than the coexisting olivine; on the contrary the former shows less pronounced deformation features (mostly kink bands); blades of exsolved calcic pyroxene have also commonly found, often zonally arranged next to the rims of the orthorombic host.

Spinel and clinopyroxene are generally finer grained than the major minerals; the first exhibits a very deep reddish colour (it appears opaque when the thin section is a trifle thicker than normal) and often is corroded or even disrupted by incipient melting, as it will be stressed later. The clinopyroxene, which occur more rarely than spinel, sometime appears interfingered with it, and always exhibits « porous » rims and other features testifying its incipient melting.

Mineral chemistry

The *olivine* ([1, 2]) varies slightly in its forsterite content from $Fo_{89.6}$ to $Fo_{90.3}$ ($\bar{x} = Fo_{89.8}$) with NiO ranging from 0.30 up to 0.50 (wt%) ($\bar{x} = 0.36$); the other minor element concentrations are generally



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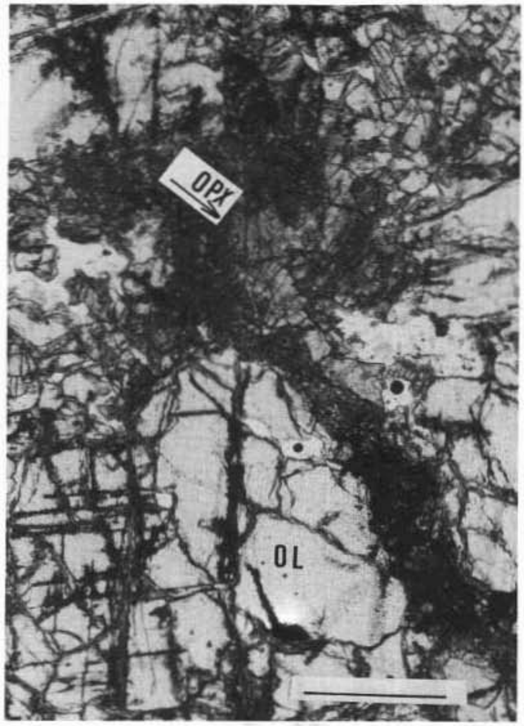
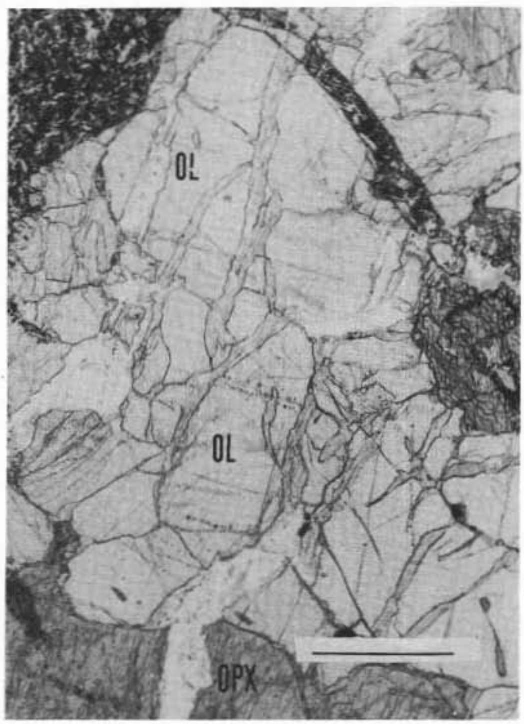


b)

c)



d)

below the microprobe's detection limit, but a little Mn content was sometimes revealed (tab. 2).

The *orthopyroxene* exhibits a rather constant Mg/(Mg+Fe) value (=0.908), but its aluminium content varies from 0.64 up to 2.70 (wt%) ($\bar{x} = 1.56$). CaO varies from 0.19 up to 0.73 ($\bar{x} = 0.38$), Cr_2O_3 from 0.1 up to 0.5 ($\bar{x} = 0.31$) (wt%). Some representative analyses are shown in tab. 3 (cf. also fig. 5). The other minor elements always result below the detection limits.

The *spinel* is a chromian variety exhibiting heterogeneous compositions even within a single grain, the Cr/(Cr+Al) atomic ratio varying from 0.20 up to 0.70 ($\bar{x} = 0.53$) and Mg/(Mg+Fe) from 0.35 to 0.60 ($\bar{x} = 0.48$). The Ni and V contents are too low to be detected by the used analytical equipment. It must be emphasized the lowest Cr/(Cr+Al) value (= 0.20) was found in few anhedral spinels interfingered with, or rimmed by, a diopsidic pyroxene (tab. 4; fig. 6).

The primary *clinopyroxene* (to be distinguished from a neogenetic one occurring in the vitrophyric blebs: see below) plots in the lower limit of the diopside field in the Ca-Mg-Fe diagram shown in fig. 5; the atomic ratio Ca/(Ca+Mg) varies from 0.46 up to 0.48 the Mg/(Mg+Fe) from 0.86 to 0.88. The Al(VI) per formula unit (O = 6) is 0.15, computed on stoichiometric basis according to PAPIKE et al. (1974). Cr_2O_3 ranges between 0.8 and 1.5 (wt%) and Na_2O content is about 2 (wt%), that can account for about 8 mol% of jadeite end term calculated following CAWTHORN and COLLERSON (1974) (tab. 5; fig. 5).

TABLE 3

Representative microprobe analyses of orthopyroxene in the studied harzburgite xenoliths. Formulae were calculated assuming all Fe as divalent

ORTHOPYROXENE

Wt%	F	G	H	J	K
SiO_2	58.01	56.93	57.47	57.82	58.06
Al_2O_3	1.25	2.25	1.34	1.53	1.23
FeO(*)	6.06	6.09	5.97	5.89	6.04
MgO	33.73	33.37	33.87	33.93	33.88
MnO	.00	.00	.22	.00	.00
TiO_2	.00	.00	.00	.00	.00
Cr_2O_3	.25	.40	.13	.37	.05
CaO	.55	.48	.31	.38	.19
Na_2O	.00	.00	.48	.00	.00
Total	99.85	99.52	99.79	99.92	99.45
cations in formula (O=6)					
Si	1.988	1.960	1.976	1.979	1.994
Al(iv)	.012	.040	.024	.021	.006
Al(vi)	.039	.052	.031	.041	.044
Fe(*)	.175	.177	.173	.170	.175
Mg	1.741	1.730	1.753	1.749	1.752
Mn	.000	.000	.000	.000	.000
Ti	.000	.000	.000	.000	.000
Cr	.007	.011	.004	.010	.001
Ca	.020	.018	.012	.014	.007
Na	.000	.000	.032	.000	.000
Ca	1	.78	.6	.7	.4
Mg	90	90	90	90	90
Fe	9	9.2	9.4	9.3	9.6

Evidence for partial melting within the harzburgite xenoliths

Patches consisting of a selvage of fine grained mafic minerals, seldom occur in the above described mineral assemblages. These are here called « blebs » (MAALOE and PRINTZLAU, 1979) and exhibit varying shape and size; in fact they appear stretched between the edges of two coarse grains but exhibit roughly equant shapes at the junction of three or more crystals (fig. 3, *a-b*). Some blebs appear quite isolated from the host lava; some others, on the contrary, are joined

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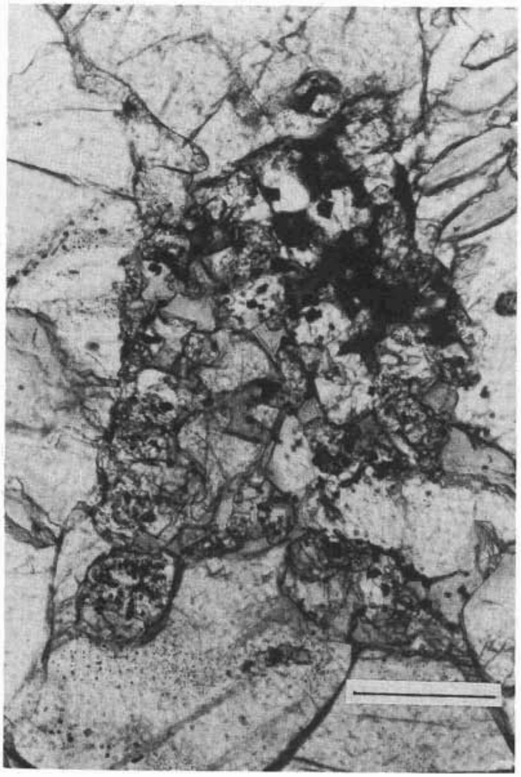
(1) The analyses were performed using a JEOL electron microanalyser fitted with a LINK E.D.S.; 1.5 was the operative voltage, 100 seconds the counting time.

(2) The atomic Fe in formulae, if not specified, would be taken as Fe^{2+} total.

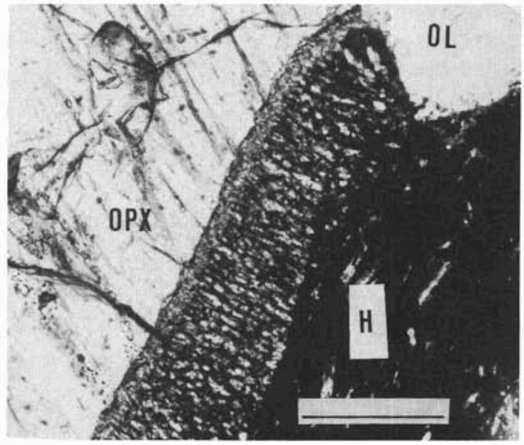
Fig. 2. — *a*) Photomicrograph of a coarse harzburgite xenolith occurring in the studied lava. Equant fosterite (*OL*) and enstatite (*OP*) grains are evident; the arrows indicate some vitrophyric blebs. *Plane polarized light; scale bar = mm 0.5.* *b*) Harzburgite, where heavily fractured forsterite grains (*OL*) and minor disrupted enstatite (*OP*) are permeated by a dark coloured micro-cryptocristalline selvage and glass. *Plane pol. light; scale bar = 1 mm.* *c*) Magnification of a coarse enstatite grain exhibiting a remarkable pattern of fractures and fluid inclusions trails. Note the corona rim where at contact with the host lava (uppermost edge of the photo. *Harzburgite, plane pol. light; scale bar = 0.19 mm.* *d*) Harzburgite, where the olivine grains are crossed by serpentine veinlets (clear in the photo), whereas a microfracture is filled by the host lava (dark). *Plane pol. light, scale bar = 0.5 mm.*



a)

b)

Fig. 3. — Rather high magnification of two «blebs» in one of the studied harzburgite xenoliths. The different shape the two blebs exhibit can account for the different degree of partial melting. The blebs are both surrounded by coarse olivine and they consist of diopsidic pyroxene and spinel micro-grains plus olivine relics, plunged into cryptocrystalline material and glass. *Plane pol. light, scale bars: a*) = *0.15 mm; b*) = *0.07 mm.*



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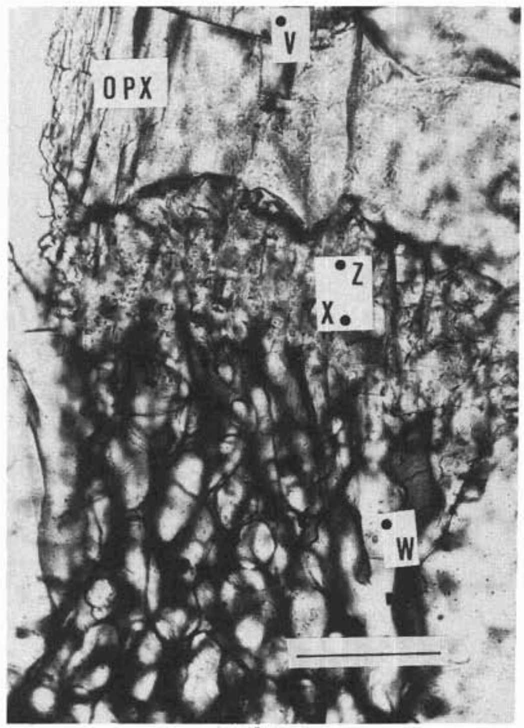

b)

Fig. 4. — *a*) Photomicrograph showing the reaction-corona in enstatite (OP) at contact with the host lava (H). This rim consists of a selvage of olivine microlites (facing to the host lava) and a thinner shell of cryptocrystalline material gradually passing to the untransformed pyroxene. (See the text for further explanation). Note the olivine grain in the upper right corner of the photo is not affected by any reaction rim. *Plane pol. light, scale bar* = *0.3 mm. b*) Another reaction rim as the precedent, looked at higher magnification; the points indicate as « V, Z, X, W » correspond to the analyses in tab. 7. *Plane pol. light, scale bar* = *0.085 mm.*

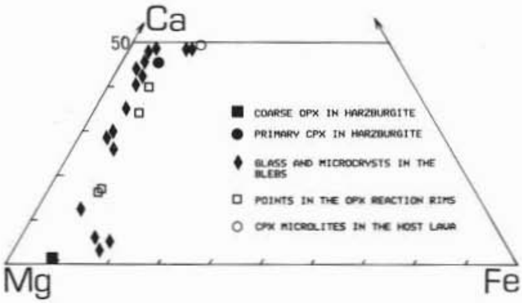

Fig. 5. — Ca-Mg-Fe diagram where pyroxene in harzburgite are plotted together with analyses representing glass and microcrysts in the blebs, points in the enstatite reaction rims and the clinopyroxene occurring in the host lava's groundmass.

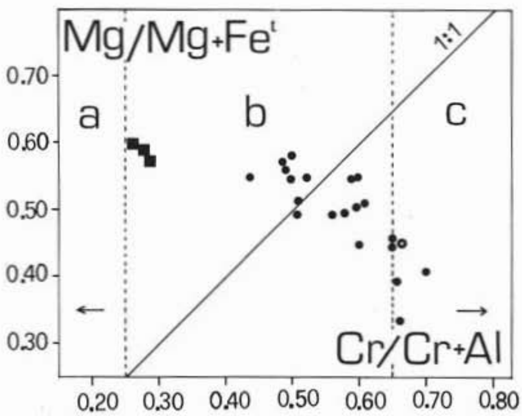

Fig. 6. — Cr/(Cr+Al) over Mg/Mg+ΣFe) atomic ratios in the spinels occurring in the harzburgites. « *a* » represents the upper limit of the Al-spinel-peridotite field drawn on the Cr/Al ratio in spinels basis conforms CARSWELL (1980); « *b* » is the Cr-spinel-peridotites and « *c* » the chromite-peridotite field. The square symbols indicate anhedral spinel rarely occurring in the studied harzburgites interfingered with diopside; the full dots represent the more commonly occurring spinel compositions. Note that the entire compositional interval could be found in any single, semicoarse spinel grain.

with the host lava by channel-like fractures either crossing the coarse crystals or following their rims. Such blebs must be related partial melting episodes inside the previous holocrystalline assemblages (e.g. MAALOE and PRINTZLAU, 1979).

In a few of the studied xenoliths, the fine grained selvage and the glass exceed 30 % of the modal occurrence; the coarse minerals here exhibit numerous fractures marked by

TABLE 4

Representative microprobe analyses of spinels in the harzburgite xenoliths. Fe^{3+} in formulae was estimated imposing stoichiometry

SPINEL					
Wt%	Q	R	S	T	U
TiO_2	.00	.00	.00	.00	.36
Al_2O_3	21.71	16.57	23.92	15.71	38.36
FeO(*)	22.57	25.22	23.21	24.80	20.45
MnO	.00	.00	.00	.26	.00
MgO	13.28	11.92	14.71	11.61	15.61
Cr_2O_3	41.99	46.05	37.10	45.92	22.10
Total	99.55	99.76	98.94	98.30	96.98
cations in formula (O=32)					
Ti	.000	.000	.000	.000	.064
Al	6.456	5.096	7.072	4.920	10.728
Fe(2+)	3.007	3.360	3.622	3.368	2.544
Fe(3+)	1.755	2.136	1.242	2.136	1.512
Mn	.000	.000	.000	.056	.000
Mg	4.993	4.632	5.496	4.592	5.512
Cr	8.374	9.488	7.352	9.640	4.144
Cr/(Cr+Al)	.564	.650	.509	.670	.280

(*)FeO total

brownish isotropic material and, when large enough, filled with the selvage itself. Somewhere else the coarse minerals appear largely disrupted (fig. 2 *b*). The positive volume change due to the liquid produced by partial melting which forced the sorrounding solids, and the shock for the pressure release during the xenoliths ascent, might account for such « sheared » textures.

Chemistry of the blebs

Numerous microprobe analyses were carried out both in the microcrysts and in the glass patches which constitute the blebs. The former consist of chromian diopsidic pyroxene whose averaged composition is reported in tab. 6 (the analyses « N », « O » in tab. 5 instead represent single points). It must be firstly emphasized these clinopyroxene micrograins differ from the primary ones (cf. the mineral chemistry section) by their lower Al, Fe and Na, but higher Si and Mg contents. It is also note worthy that Al(VI) in these quench-minerals ranges from 0.02 to 0.06 atoms per formula unit that is much less than in the originary diopside

TABLE 5

Representative microprobe analyses of primary clinopyroxene occurring in the harzburgite xenoliths (an. I, L), analyses of the quench crystals in the blebs (N, O) and the host lava clinopyroxene (P). Formulae were computed following PAPIKE et al. (1974)

CLINOPYROXENES

wt%	I	L	N	O	P
SiO_2	52.64	52.54	53.67	54.42	46.08
Al_2O_3	5.59	5.33	2.39	2.57	6.70
Fe_2O_3	1.28	.68	.70	.00	6.31
FeO	2.52	3.21	1.95	2.54	2.88
MgO	15.62	15.32	18.04	16.40	12.83
MnO	.00	.00	.00	.00	.27
TiO_2	.30	.42	.26	.00	3.23
Cr_2O_3	1.09	.85	1.46	.83	.00
CaO	18.30	19.25	21.23	22.59	22.07
Na_2O	2.03	1.73	.67	.94	.80
Total	99.37	99.34	100.37	100.30	101.16

cations in formula (O=6)

	I	L	N	O	P
Si	1.910	1.914	1.935	1.966	1.705
Al(iv)	.089	.086	.065	.034	.295
Al(vi)	.150	.143	.037	.075	.003
Fe(2+)	.076	.098	.059	.077	.089
Fe(3+)	.035	.019	.019	.000	.176
Mg	.845	.832	.969	.883	.708
Mn	.000	.000	.000	.000	.008
Ti	.008	.012	.007	.000	.090
Cr	.031	.024	.042	.024	.000
Ca	.712	.751	.820	.875	.875
Na	.143	.122	.047	.066	.057
Ca/(Ca+Mg)	.46	.47	.47	.49	.55
Mg/(Mg+Fe*)	.88	.87	.92	.92	.73

(Al(VI) = 0.16-0.14 a.u.f.). It is also stressed that these microcrystalline pyroxene compositions span over wide interval (fig. 5); these variations seem to be related the glass/crystals proportion in the blebs.

The analyses performed in the glass and cryptocrystalline zones give composition much more variable than the microcrysts; some of them fit in a wide range of subcalcic pyroxene compositions (fig. 5); the averaged composition calculated on the bleb's modal occurrence basis, is shown in tab. 6. In spite of the SiO_2 (= 46.5 wt%) and total alkalies (= 2.8 %) so obtained plot close to the boundary line between the alkalic and subalkaline fields in the MACDONALD and KATSURA (1964) diagram, the whole analysis does not fit in any natural occurring primary magma composition.

Corona rims in enstatite

The boundary surfaces of the studied xenoliths are rather sharp where olivine is in contact with the host lava, they are on the contrary marked by rather thick reaction rims where an orthopyroxene is (fig. 4 *a*). These coronas consist of a thin shell (5-30 μm) of pale coloured cryptocrystalline material (zones « *x, z* » in fig. 4 *b*) mantled by a selvage of olivine microlites which somewhere appear stretched and alligned normally to the contact surface (zone « *w* » in fig. 4 *b*); an interstitial film of glass is also present between these microcrysts.

Numerous microprobe analyses through the orthopyroxene outer rim show the Ca, Cr and Na contents increase, Mg and Si decrease while Al and Fe remain roughly constant; in few points this trend is dramaticaly emphasized yelding a clinopyroxene stoichiometry (analysis « X » in tab. 7). The olivine of the selvage exhibits a rather constant Mg/(Mg+Fe) value (=0.77) and some Ti, Mn and Ca contents (analysis «W» in tab. 7).

Discussion and concluding remarks

The harzburgite orthopyroxene low CaO and Al_2O_3 contents as well as the rather high Cr/(Cr+Al) values in the spinels, suggest these peridotites suffered a rather high depletion by partial melting processes, probably more than 20 % (DICK and FISHER, 1984; HERVIG et al., 1980) (fig. 7). It is also note worthy that the Cr content in spinel never exceeds the limits CARSWELL (1980) puts for Cr-spinel in garnet free as-

TABLE 6

Averaged blebs composition (calculated on the basis of microprobe analyses, both in the microcrysts, the cryptocrystalline material and the glass) and averaged quench clynopyroxene composition

wt%	AVERAGED BLEBS COMPOSITION	AV. MICROCRYSTS COMPOSITION
SiO_2	46.48	52.91
Al_2O_3	11.03	2.63
FeO(*)	6.18	2.80
MnO	.05	.00
MgO	18.56	17.00
TiO_2	.22	.13
Cr_2O_3	2.99	1.50
CaO	11.37	21.61
Na_2O	2.06	.72
K_2O	.87	.00
TOTAL	99.61	99.30

TABLE 7

Microprobe analyses taken across a reaction rim in enstatite; the analyses V, Z, X, W correspond to the points shown in fig. 4 b).

REACTION RIMS IN ENSTATITE

wt%		V	Z	X	W
SiO_2		57.06	56.06	53.08	39.10
Al_2O_3		1.99	1.61	1.65	.00
FeO(*)		6.30	6.76	4.58	20.49
MgO		33.67	26.37	17.95	38.84
MnO		.00	.16	.00	.33
TiO_2		.00	.00	.52	.21
Cr_2O_3		.36	.66	1.79	.00
CaO		.34	8.49	18.93	.45
Na_2O		.00	.36	.68	.52
TOTAL		99.72	100.47	99.18	99.94
	Wo	.6	17	40	Fo_{77}
	En	88.9	73	52	
	Fs	9.5	10	8	

semblages; but few spinels found in the studied rocks interfingered with clinopyroxene (tab. 4, analysis « U ») exhibit the same Cr content as the spinels occurring in Al-spinel lherzolites and in some garnet lherzolites (CARSWELL, 1980) (fig. 6).

Concerning the estimate of equilibrium temperatures and pressures it must be stressed that only few published geothermometers and no geobarometers are reliable for mantle derived mineral assemblages (e.g. FUJII and SCARFE, 1982). Nevertheless an attempt to estimate *P, T intervals* was done. Using the Al content in enstatite at equilibrium with forsterite and spinel as geothermometer, an upper limit of $T = 730°$ C was found for equilibration temperature following MAC GREGOR (1974); this upper limit should be dropped down to $\sim 650°$ C using the GASPARIK'S (1984) experimental data on the CMAS system. On the other hand, the olivine-spinel geothermometer that should give reliable results for such low-aluminous spinel compositions (FABRIES, 1979) is however rather obstructed by the chemical zoning shown by the studied spinel. Nevertheless, taking to account for this calculations the averaged Cr, Al, Mg, Fe contents in these minerals, a temperature value of about 800° C was found according to the above quoted Author (the T interval being between 600 and 850° C). The more aluminous spinel here rarely occurring interfingered with diopside was not considered for these computations.

Considering the equilibration pressure values, the lack of garnet in these mineral assemblages provides an upper pressure limit at about 1.5 GPa (for $T = 700°$ C) (MAC GREGOR, 1974; GASPARIK, 1984). On the other hand, the lack of plagioclase suggests a minimum pressure value at 0.7 GPa (HERZBERG, 1978).

MAALOE and PRINTZLAU (1979) hypotized that the *blebs* were produced in peridotites during contact « anatexis » with a deep-seated magmatic chamber in the mantle. For

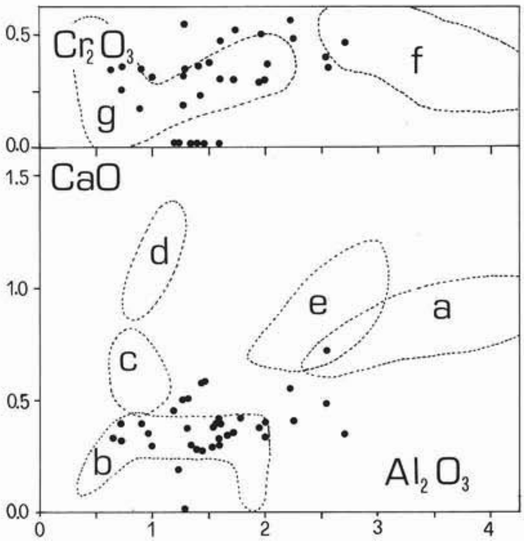

Fig. 7. — Al_2O_3 over CaO and Cr_2O_3 (wt%) variations in the studied orthopyroxenes. The field « *a* » in the bottom diagram is for orthopyroxene occurring in spinel-lherzolites, « *b* » in barren-harzburgites, « *c* » in coarse garnet lherzolites, « *d* » in porphyroclastic garnet lherzolites, « *e* » in fertile harzburgites. In the upper diagram « *g* » is the field for orthopyroxene in barren harzburgite and in the porphyroclastic garnet-lherzolites, « *f* » in spinel lherzolites. The field where the orthopyroxenes occurring in the fertile harzburgites plot is not represented in the figure (see HERVIG et al., 1980). Note for both the diagrams the compositions of the studied pyroxene plot in the barren-harzburgites fields.

the studied xenoliths it is however difficult to speculate whether the partial melting in the blebs occurred in the mantle or after the incorporation into the host magma. The latter hypotesis seems suitable, since the adiabatic pressure drop these minerals suffered during their (rapid) ascent to the earth's surface could have favoured such minor partial melting episodes, particularly in that zones where different minerals are each other touching. It seems also possible that some metasomatizing effects were exerted on them by the magmatic fluids, which penetrated into the xenoliths' microcracks and locally altered the « barren » character of these harzburgites. This is consistent with a relatively long residence time of the xenoliths in the host liquid as deduced by their rather small size (which could imply the fragmentation of previous larger blocks), the zonal variation of chromium in their spinels (e.g. FUJII and SCARFE, 1982) and by the thick reaction rims the enstatite exhibits where at the contact with the host lava (see before).

On the other hand, the lack of olivine microcrysts among the quench crystals in these blebs, better fit in the before quoted Author's hypotesis; in fact, considering the averaged bleb composition here reported (tab. 6) and the PRESNALL et al. (1978) and GASPARIK'S (1984) experimental results on the CMAS system, the appearance of diopside as only quench mineral phase should indicate high pressure conditions. In this case the postulated « fluids » could have acted in the mantle, too, producing their metasomatizing effect on the harzburgite body.

To conclude, in spite of the discrepancies between the equilibration temperature values here estimated by different geothermometers, it seems that the studied harzburgites re-equilibrated at rather low temperature. For the estimated pressure interval is too wide for any interpretative purpose, thus two different petrogenetic hypotheses are formulated.

The former hypotesis suggests that a deep-seated harzburgite body (produced by important partial melting episodes of primitive fertile peridotites) ascended along an ocean-type geotherm to the uppermost top of the mantle (or to the lowest crustal level) where it re-equilibrated prior to partial disruption and incorporation into the host magma. It must be hypothized that the Fe-depleted character of the harzburgites provided for their diapiric upwelling through the denser, less depleted other peridotites. On the other hand, neither pressure (depth) changes nor mass transfer, but a dropping-down of the thermal gradient in the Hyblean area could have produced the same effect on the harzburgite « body », wathever level it occupied in the upper mantle.

In all the cases the considered xenoliths are believed to be accidental inclusions in the host basanitoid lava.

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REFERENCES

BARBERI F., CIVETTA L., GASPARINI P., INNOCENTI F., SCANDONE R. (1974) - *Evolution of a section of the Africa-Europe plate boundary: paleomagnetic and volcanological evidence from Sicily*. Earth. Planet. Sci. Lett., 22, 123-132.

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

CAWTHORN R.C., COLLERSON K.D. (1974) - *The recalculation of pyroxene end member parameters and the estimation of ferrous and ferric iron content from electron microprobe analyses*. Am. Miner., 59, 1203-1208.

COX K.G., BELL J.D., PANKURST R.J. (1984) - *The interpretation of igneous rocks*. London, 450 pp.

CRISTOFOLINI R., BATTAGLIA M. (1974) - *Le manifestazioni basaltiche della zona di Francofonte nel quadro del vulcanismo dell'altipiano Ibleo*. Boll. Soc. Geol. It., 94, 185-207.

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), Kimberlites II: The Mantle and Crust-Mantle Relationships, Elsevier, Amsterdam, 1984.

FABRIES J. (1979) - *Spinel-Olivine Geothermometry in Peridotite From Ultramafic Complexes*. Contr. Miner. Petr., 69, 329-336.

FUJII T., SCARFE C.M. (1982) - *Petrology of Ultra-*

mafic Nodules from West Kettle River, near Kelowna, Southern British Columbia. Contr. Miner. Petr., 80, 297-306.

GASPARIK T. (1984) - *Two-pyroxene thermobarometry with new experimental data in the system CaO-MgO-Al_2O_3-SiO_2.* Contr. Miner. Petr., 87, 73-87.

HARTE B. (1977) - *Rock nomenclature with particular relation to deformation and recrystallisation textures in olivine-bearing xenoliths.* J. of Geol., 85, 279-288.

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.

HERZBERG C.T. (1978) - *Pyroxene geothermometry and geobarometry: experimental and thermodynamic evaluation of some subsolidus phase relations involving pyroxenes in the systemCaO-MgO-Al_2O_3-SiO_2.* Geoch. Cosm. Acta, 42, 945-958.

IUGS SUBCOMMISSION ON THE SYSTEMATICS OF IGNEOUS ROCKS (1973) - *Recommendations.* N. Jb. Miner. Mh., 3, 149-164.

MAALOE S., PRINTZLAU I. (1979) - *Natural Partial Melting of Spinel Lherzolite.* J. of Petrol., 20, 727-742.

MACDONALD G.A., KATSURA T. (1964) - *Chemical composition of Hawaiian lavas.* J. Petrol., 5, 82-133.

MACGREGOR I.D. (1974) - *The system MgO-Al_2O_3-SiO_2: solubility of Al_2O_3 in enstatite for spinel and garnet peridotite compositions.* Am. Miner., 59, 110-119.

MITCHELL R.H. (1984) - *Garnet lherzolites from the Hanaus-I and Louwrensia Kimberlites of Namibia.* Contr. Miner. Petr., 86, 178-188.

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.

PRESNALL D.C., DIXON S.A., DIXON J.R., O'DONNEL T.H., BRENNER N.L., SCHROCK R.L., DYCUS D.W. (1978) - *Liquidus Phase Relations on the Join Diopside-Forsterite-Anorthite From 1 atm. to 20 Kbar: Their Bearing on the Generation and Crystallization of Basaltic Magma.* Contr. Miner. Petr., 66, 190-203.

ROEDDER E. (1965) - *Liquid CO_2 inclusion in olivine-bearing nodules and phenocrysts from basalts.* Am. Miner., 50, 1746-1782.

VARIOUS AUTHORS (1984) - *Carta Geologica della Sicilia sud-orientale a scala 1:100.000.* Regione Siciliana, Palermo.