

more distorted than TB) are linked in two distinct chains (A and B respectively). The TB tetrahedron is the only one in which Si- $Al^{IV}$  substitution takes place ( $Al^{IV}$ : 0.11—0.01 afu). Both TB-O bond lengths and TB volume increase strongly as Si- $Al^{IV}$  substitution takes place. The kinking angle of chains A and B (03-03-03) show opposite behaviour as mg increases; their variations (about  $1^\circ$ ) are related to the octahedral layer and inversely to TB sizes respectively.

The M2 site (the biggest and most distorted among opx sites) is described as a 4 + 2 coordinated polyhedron (DOMENIGHETTI, MOLIN and TAZZOLI, 1985, Amer. Miner. 70 987-995), largely filled by Mg (0.81—0.86 afu) and minor amounts of  $Fe^{2+}$  (0.16—0.12 afu) and Ca. Ample geometrical variations involve M2 site as mg increases, by shortening the four shortest (M2—01, M2—02) and lengthening the two longest M2—03 bond lengths.

*High-temperature disordering:* X-ray refinements carried out on two crystals, respectively the richest and poorest in  $R^{3+}$  ions, heated to 1050 and 1150  $^\circ C$ , allowed evaluation of the amount of Mg- $Fe^{2+}$  disorder and related structural modifications near 1 atm. melting point. For both crystals similar  $Fe^{2+}$  displacement from M2 to M1 was observed (0.015 afu, about 1/10 of the  $Fe^{2+}$  [M2]). This suggests that the structure of Mg-rich opx prefers an ordered partition even at high temperatures, not related to  $R^{3+}$  content. Moreover, the heated  $R^{3+}$  — richest crystal ( $R^{3+}$  = 0.100 afu) gives no geometrical evidence of disorder of trivalent ions between M1 and M2 in spite of: (a) the relevant amount of  $R^{3+}$ ; (b) the high temperature reached; (c) the low M2 volume. Similarly, disorder of  $Al^{IV}$  between TB and TA sites must be excluded.

*Petrological implications:* the behaviour of the Mts. Leura and Porndon opx suites highlights the principal implications of M1 and TB sites with temperature (i.e. mg increase). A comparison with the clinopyroxenes (cpx) of the same series (DAL NEGRO, CARBONIN, DOMENIGHETTI, MOLIN, CUNDARI and PICCIRILLO, 1984, Contr. Miner. Petrol. 86, 221-229) shows close relationships among M1 and T (TB) sites of both cpx and opx, the relationship  $Al^{VI}$ ,  $Al^{IV} \leftrightarrow Mg$  (M1), Si being confirmed. Instead, M2 site only partially depletes its  $Fe^{2+}$  in the opx ( $Fe^{2+}$  opx being about 10  $Fe^{2+}$  of the related cpx), never falling below 0.12 afu.

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investigated by X-ray structure refinements and microprobe analysis. The main aim of this study was to evaluate crystal-chemical evidence which may be related to that of clinopyroxenes (cpx) of distinctive alkaline suites characterized by leucite or nepheline rock-types (DAL NEGRO et al., 1985, Journ. of Petrol., 26 1027-1040) (DAL NEGRO et al., 1986, Contr. Miner. Petrol. 92, 35-43). The investigated cpx are of salitic composition, characterized by relatively low Ca content (0.80—0.86 atoms per formula unit = afu), and generally Na-free.

The M2 eight-coordinated polyhedron, mainly filled by Ca and Na ions, shows volume variation (VM2) from about 25.5 to 25.7  $\text{\AA}^3$ , being distinctly smaller than that of cpx of leucite-bearing rocks (VM2 ranging from 25.7 to 26.0  $\text{\AA}^3$ ), essentially reflecting lower Ca content. On the other hand, cpx from nepheline-bearing basanites show a similar range in VM2 variation for Ca content similar to that of Sonda cpx. Notably, the single M2-O bond lengths indicate a different geometrical configuration for M2 site of Sonda cpx, referred to that of the other suites.

The M1 octahedron, mainly filled by Mg, shows a similar structural configuration in spite of its significant chemical variation: Mg ranging from 0.67 to 0.81 afu,  $Fe^{2+}$ (M1) from 0.03 to 0.20 afu, and trivalent ions from 0.11 to 0.21 afu. This is due to several possibilities of combining ions with different ionic radii so as to obtain M1 site configuration approaching that of diopside.

The tetrahedral T site configuration reflects the charge balance requirements of cpx composition. The substitution between divalent and trivalent ions in the M1 site requires Si- $Al^{IV}$  substitution in T site, M2 site generally being Na-free. The  $Al^{IV}$  content ranges from 0.13 to 0.20 afu, causing a lengthening of the T-O bond from 1.640 to 1.646  $\text{\AA}$  and a volume increase from 2.247 to 2.270  $\text{\AA}^3$ .

*Petrological implications:* on the basis of crystal-chemical considerations, a moderate «alkaline» character of the host magmas may be recognized in the Sonda cpx, mainly supported by the M2 site configuration (DAL NEGRO et al., 1982 in «Advances in Physical Geochemistry 2» Saxena ed. Springer-Verlag, Berlin, Heidelberg, New York, 117-150). Moreover, a comparison between the M1 site crystal-chemistry of distinctive leucite — and nepheline — bearing lavas allows potassic affinity to be ascribed to the Sonda cpx, considering both the geometry and relatively high  $Fe^{3+}$  content (0.00—0.15 afu) of M1 site.

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MOLIN G.M.\*, SALVIULO G.\* - *Crystal-chemistry and site configuration of clinopyroxenes from volcanic rocks of Tambora and Sangeang Api Island, Sonda Arc.: a genetic comparison with distinctive alkaline rock clinopyroxenes*

Clinopyroxenes from Sonda volcanic rocks (nepheline trachybasalts, phonolitic tephrite) and ejecta, were in-

OBERTI R.\*, ROSSI G.\* and BRITT M., MØRK E.\*\* - *Low degrees of order in omphacites from the Flemø Island, Western Horwø*

Omphacites crystallize in the P2/n space group and are characterized by an ordered distribution of the large

divalent cations (Mg, Fe<sup>2+</sup>) and of the small trivalent cations (Al, Fe<sup>3+</sup>) between the two octahedral sites M1 and M11. This distribution is never completely ordered; therefore a degree of order can be defined, which depends on both the chemical composition and the thermal history of the clinopyroxene. Completely disordered omphacites have been found only in ultramafic nodules from kimberlites, and belong to the C2/c space group.

Omphacites from two different kinds of eclogites from the Flemsøy island, Western Gneiss region of Norway, have been examined. The former is the final product of a progressive transition from gabbro to eclogite, of which all the intermediate stages have been preserved. The latter is represented by the country-rock eclogites, which are believed to be parts of the previous assemblage which suffered strong deformation, effects and were separated from the massive gabbro-eclogite body.

Omphacites belonging to the two different eclogites have been analyzed by electron microprobe and studied by means of X-ray structure refinement. Their chemical composition is very similar ( $X_{Mg} = 0.44$  and  $0.48$  respectively) and a remarkable constancy in composition has been noticed in crystals from the same rock samples. Their most important and unusual peculiarity is the observed degree of order. It can be expressed by means of the ratio of the volumes of the two M1 and M11 octahedra and can range from 1.0 (two identical octahedra, i.e. completely disordered omphacites) and to about 1.21. For Flemsøy omphacites, these ratios are 1.10 and 1.08 respectively. These values, which are very low in themselves, are definitely lower than those (1.18 and 1.15) found in omphacites of the same chemical composition coming from other eclogites of the same region which equilibrated at 700°C before being quickly cooled to the closure temperature (350°C).

The low degree of order observed in Flemsøy omphacites can be ascribed either to equilibration temperatures higher than 700°C or to equilibration times extremely reduced which did not allow the equilibration of the clinopyroxenes. Anyway, the omphacites from both eclogites have suffered the same metamorphic history. Another possible explanation for the low degree of order could be the presence of very small antiphase domains, which could sensibly lower the intensities of the  $h+k$  = odd reflections. In this case, however, these reflections should appear clearly diffuse; the sharp profiles observed for Flemsøy omphacites allow to reject this hypothesis. Anyway, a further study of these samples with transmission electron microscopy is supposed to give the final answer to this question.

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### *nodules from Victoria (Australia) and Rio Grande do Norte (NE Brazil)*

A crystal-chemical investigation by X-ray refinement and microprobe analysis of clinopyroxenes (cpx) from ultramafic mantle nodules shows strict dependence of the cpx structural framework on the evolution of the host nodule (progressive depletion in Fe<sup>2+</sup> and Al, and consequent enrichment in Fe<sup>2+</sup>, Cr and Si).

The investigated cpx refer to: (a) lherzolites and olivine-websterites from Mt. Leura (Australia); (b) lherzolites and harzburgites from Mt. Porndon (Australia); (c) lherzolites from Mt. Noorat (Australia) and (d) lherzolites from NE Brazil. These nodules are included in ne-normative lavas.

All the studied cpx are characterized by high-Ca content (> .73 atoms per formula unit afu); M1 site is largely occupied by Mg (> .17 afu) with variable amounts of trivalent ions R<sup>3+</sup> (R<sup>3+</sup> = Al<sup>VI</sup> + Fe<sup>3+</sup> + Cr<sup>3+</sup> + Ti<sup>4+</sup>): (0.01—0.26 afu). Electron neutrality is achieved by Si/Al<sup>IV</sup> substitution (Al<sup>IV</sup> = 0.00—0.15 afu) and by the Na occupancy M2 site (0.12—0.16 afu).

M1 site, smaller than that of low-pressure cpx, mainly involves the structural framework. The increase in site volume (VM1: 11.39—11.73 Å<sup>3</sup>) is strictly related not only to R<sup>3+</sup> decrease but also to (Al<sup>VI</sup> + Ti)/R<sup>3+</sup> ratio decrease. A general decrease of polyhedral distortion is related to R<sup>3+</sup> decrease ( $\sigma_{oct}^2$ : 25.64—18.50).

T site geometry, as observed in several low-pressure cpx suites, strictly depends on M1 configuration. T site volume (VT: 2.22—2.25 Å<sup>3</sup>), lower than that of low-pressure cpx, is related to Al<sup>IV</sup> content and M1 size.

M2 site geometry depends on Na/Mg substitution. Na depletion (Ca almost constant) is associated with shortening of M2-01,02 bond lengths and the lengthening of M2-03 bond lengths. This emphasizes the role of M1 (and T) sites on M2 site geometry. The opposite behaviour of the M2-0 bond lengths causes significant variations in polyhedral distortion. The volume of M2 site (VM2: 25.31—25.64 Å<sup>3</sup>) is generally comparable with that of low-pressure cpx.

*Applications:* a close negative correlation exists between VM1 and (Al<sup>VI</sup> + Ti)/R<sup>3+</sup>, (F.R.) ratio within the single cpx suites. For each suite there is a VM1 increase with decreasing F.R. ratio (i.e. from «undepleted» to «depleted» nodules).

Moreover, for the same F.R. ratio, there are important VM1 and cell volume increases from Leura to NE Brazil (and Noorat) cpx, which may be attributed to total pressure decrease within the stability field of spinel-peridotite.

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PRINCIVALLE F.\*, SECCO L.\*\*, DE MARCHI G.\*, MOLIN G.M.\*\* - *Crystal-chemistry of high-pressure clinopyroxenes of mantle*

ROSSETTI P.\*, ZUCCHETTI S.\* - *Paragenesi metalliche eoalpine nelle serpentiniti del giacimento amiantifero di Balangero e del Massiccio di Lanzo (Alpi Occidentali interne)*