

ULTRA-DEEP (> 300km), ULTRAMAFIC XENOLITHS:  
DIRECT PETROLOGICAL EVIDENCE FOR THE TRANSITION ZONE.

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The seismologically delineated transition zone from 400 to 670 km depth is a fundamental discontinuity in the bulk Earth between the upper and the lower mantle. The mineralogy and chemistry of this inaccessible zone is of enormous interest but its petrology is highly controversial, mainly because of two competing models (pyrolite versus piclogite), but compounded by the uncertainty of whether the transition zone is the lower limit of ocean slab subduction (Anderson, 1989 ; Ringwood, 1975), or whether slabs continue to the core-mantle boundary. High pressure experiments predict that both pyroxene to garnet and olivine to  $\beta$ -spinel transformation occur at the 400 km seismic discontinuity. Natural analogs of pyroxene-garnet solid solution have recently been recognized in diamond inclusions from South Africa (Moore and Gurney 1985) and Brazil (Wilding et al. 1989) and represent the first mineralogical evidence from the transition zone. We present here the first petrological evidence from the 400 km discontinuity (Haggerty and Sautter, 1990 ; Sautter et al. 1991).

The xenoliths (24 samples) are from the Jagersfontein kimberlite pipe in South Africa. The biggest xenolith (9 x 5 cms) is a four phase garnet lherzolite (garnet, olivine, clinopyroxene, orthopyroxene). The rock is heterogeneous because garnet (15 to 10 % by volume) forms a 1 to 1.5 cm thick band throughout a matrix dominated by olivine (40 to 50 %) and orthopyroxene (30-40 %) and 5 to 10 % clinopyroxene. Other samples range from garnet-clinopyroxene-orthopyroxene associations to discrete garnet ; these specimens are less than 3 cm in diameter. A common feature of the entire set of samples is pyroxene exsolution rods within single garnet crystals that are parallel to apparent  $\langle 111 \rangle$  directions of the cubic host. Based on the crystal chemistry of pyroxene exsolution, the xenoliths are divided into two groups. The first group is

composed of purple garnet (1 to 2 % wt Cr<sub>2</sub>O<sub>3</sub>, Pyr<sub>69-73</sub>Alm<sub>15-20</sub>Gross<sub>11-12</sub>) with clinopyroxene exsolution (Jd<sub>13-20</sub>Wo<sub>36-43</sub>Hyp<sub>43</sub>) and attached single crystals of apple green clinopyroxene of similar composition ; the garnet lherzolite sample falls into this group. The second group is defined by discrete pink garnet crystals (up to 80 % mole of pyrope) with orthopyroxene exsolution (Mg/Mg + Fe = 0.95). In both groups, the garnet is of ultramafic affinity. Modal proportions, however, are higher for Cpx exsolution (between 85Gt:15Cpx and 70Gt:30Cpx) than for Opx exsolution (90Gt : 10Opx).

Primary garnet compositions are calculated by recombining the estimated quantity of pyroxene rods within the garnet host. This calculation rests on the interpretation of the present textures as conclusive evidence that the pyroxene exsolved from a homogeneous Ca-Na majorite. Exsolution induced by a disproportionation of a solid solution implies rigorous orientation of the crystalline precipitate within the host. Preliminary TEM observations indicate that the  $\langle 001 \rangle$  direction in the pyroxene rods is parallel to the  $\langle 111 \rangle$  direction in garnet. Such a relationship would minimize Si and Al diffusion paths as it matches the tetrahedral chains of Si in pyroxenes with the octahedral sites of garnet that contain both Si and Al under very high pressures (> 80 kbar). The relative orientation of the two phases is further described by (110) garnet parallel to (010) clinopyroxene.

Reconstitution of pyroxene in garnet in the MAS, CMAS, NCMAS systems and natural analogs require P of at least 100 kb (Fig.1). A conservative estimate is 130 kb, placing the xenoliths at or close to the 400 km seismic discontinuity. The seismic discontinuity thus appears to be due to the olivine to  $\beta$ -spinel transition as well as pyroxene dissolution in garnet. From these xenoliths and the high Si garnet inclusions in diamonds we infer that there is a mixture of eclogite and lherzolite at the discontinuity. Such data (on centimeter scale samples) do not permit, however, evaluation of the degree of chemical heterogeneity at those depths. Consequently a homogeneous pyrolitic mantle with centimeter wide eclogitic layers due to stretching of

oceanic slabs by convection, or a heterogeneous mantle with a chemical change from lherzolite to piclogite at the 400 km discontinuity due to piling up of oceanic slabs in the transition zone, are both valid petrological models. As presently constituted, the xenoliths have reequilibrated at 900-1000°C and 45 kb in the lithosphere prior to crustal emplacement. Upward transport at the head of a plume is proposed (Haggerty and Sautter, this volume).

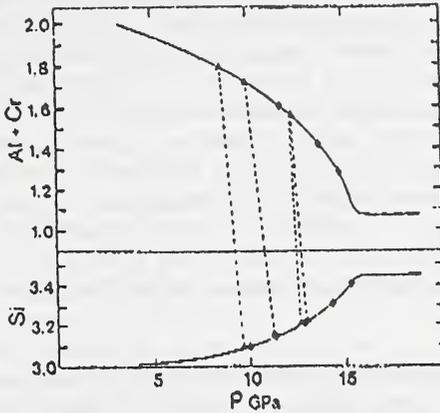


Figure 1 Geobarometer from Irifune (1987) and Akaogi and Akimoto (1979) : excess Si in garnet as a function of pressure. Solid triangles are the reconstructed garnet from Jagersfontein. The diamond symbols corresponds to garnet inclusions in diamonds.

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