W. L. GRIFFIN, N. M. MCGOWAN, J. M. GONZALEZ-JIMENEZ, E. A. BELOUSOVA, D. HOWELL, J. C. AFONSO, YANG J.S., SHI R., Suzanne Y. O'REILLY and N. J. PEARSON, 2015. Transition-Zone Mineral Assemblages in Peridotite Massifs, Tibet: Implications for Collision-zone Dynamics and Orogenic Peridotites. Acta Geologica Sinica (English Edition), 89(supp. 2): 90-91.

Transition-Zone Mineral Assemblages in Peridotite Massifs, Tibet: Implications for Collision-zone Dynamics and Orogenic Peridotites

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Diamonds have been reported from Tibetan "ophiolites" for ≥30 years, but have been widely dismissed as contaminants, because their unusual morphology and light C ($\delta^{13}C$=-18 to –27) are unlike those of kimberlitic diamonds. However, the diamonds have now been found in situ in both the chromitites and the peridotites of "ophiolites" along the Yarlung-Zangbo suture (Tibet) and the Polar Urals (Yang et al., 2014). These massifs are dominated by depleted spinel harzburgite; some yield whole-rock Re-Os T_{RD} ages back to 3.4 Ga (Shi et al., 2012), suggesting ancient SCLM.

LA-ICPMS analyses of the diamonds show LREE-enriched trace-element patterns parallel to those of kimberlitic fibrous diamonds; the "ophiolitic" diamonds thus appear to be natural. However, the Tibetan diamonds also have: negative anomalies in Sr, Sm, Eu, Yb; very low Fe; high Ta and inclusions of $Ni_{70}Mn_{20}Co_5$ alloy. The diamonds are accompanied by a range of alloys, native metals, carbides and silicides, implying fO_2 down to IW=-8. Exsolution of coesite, diopside and enstatite from chromite implies the former existence of the CF ($CaFe_2O_4$) structure, stable at P≥12.5 GPa (380 km) (Yamamoto et al., 2009).The recent discovery (first reported here) of "phase BWJ" (anhydrous "antigorite" with an inverse-ringwoodite structure) implies P≥18 GPa, and that the highly-reduced assemblage and the diamonds may reflect interaction of chromitites and low-fO_2 fluids in the Transition Zone (TZ).

The presence of these super-reducing ultra-high pressure (SuR-UHP) assemblages in "orogenic peridotites" raises many questions. Some have suggested that the chromitites crystallized in the TZ, and rose to be emplaced in suboceanic mantle. However, the trace-element signatures of the chromites are identical to those of typical ophiolitic chromitites, and imply primary crystallization at shallow depths; this is consistent with the inferred UHP metamorphism of antigorite. In situ analyses of PGE sulfides give T_{RD}=290–630 Ma, peaking at 325 Ma. Euhedral zircons separated from the chromitites give U-Pb ages of 376±7 Ma, and εHf= 9.7±4.6 (T_{DM} ca 2 Ga), suggesting some crustal input. However, T_{RD} model ages of Os-Ir nuggets in the chromitites are much younger: 234±3 Ma (Shi et al., 2007). We interpret the sulfide+zircon ages as dating the shallow formation of the chromitites, while the Os-Ir model ages record the timing of intense reduction and chromite recrystallisation in the TZ following deep subduction. Dynamic modeling suggests that the rise of the peridotites from the TZ to the crust during the Early Tertiary/Late Cretaceous was rapid (ca 6 Ma), and probably driven by the rollback of the Indian slab after it had stalled in the TZ.

Mantle samples from the TZ thus may be present in other collision zones; how should we recognize them? One striking feature is the absence of eclogites or similar UHP crustal rocks in or around the peridotite massifs, or along the 3000 km of the Yarlung-Zangbo suture. If these massifs represent oceanic mantle, or ancient SCLM that became seafloor as in Liguria (Rampone et al., 2005), their deep subduction was driven at least partly by the negative buoyancy of an eclogitic crust. If that detached from the slab in the TZ, it would sink deeper into the mantle, while the buoyant harzburgites would try to rise. These SuR-UHP massifs carry unique information on the tectonics of collision zones, and the physical and chemical makeup of the TZ.

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