A possible Permian suture in the Lhasa Block, Tibet: Evidence from eclogites and probable ophiolite

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The Sumdo eclogite belt was found recently in the Lhasa block, Tibet, over 100 km northeast of the city of Lhasa. Most of the Sumdo eclogites are massive, coarse-grained and fresh, occurring as tectonics slices in garnet-bearing mica-quartz schist. And three distinct types are recognised: phengite eclogite, quartz eclogite and rutile eclogite.

The mineral assemblage of the Sumdo ecologite is garnet +°mphacite+epidote±phengite±quartz±rutile. The rock has been intensely retrograded and the retrograde minerals include amphibole, epidote, quartz, albite and chlorite. Growth zonation can be seen in garnet porphyroblasts. The garnet porphyroblasts and matrix garnet mainly plot in the group C eclogite field, but some rims of garnet porphyroblasts and some matrix garnet plot in the group B eclogite field. Clinopyroxenes are mainly omphacite with minor augite of generations and . According to the garnet-omphacite-phengite geothermobarometer, the P-T estimations are 2.58-2.70 °C Gpa and 630-777 °C Gpa, suggesting that the condition of peak matamorphism are close to the phase boundary between quartz and coesite. Petrographic observation and P-T estimation indicate that the protolith of the eclogites experienced a matamorphic process from high greenchist facies through amphibolite facies, eclogite facies and amphibolite facies to high greenchist facies metamorphism, which suggests that there occurred progressive metamorphism concerning subduction related to the closing of the ocean and subsequent retrogressive metamorphism concerning exhumation.

Petrochemistry and Sr-Nd isotope analysis suggest that its protolith was typical MORB, derived from the depleted mantle. All of the rocks have whole-rock chemical compositions similar to tholeiitic MORB with 45.3-50.6 wt % SiO_2, 12.93-14.27 wt% Al_2O_3 and 1.3-2.8 wt% total alkalis (K_2O + Na_2O). Generally, it has the compositional features of basaltic or gabbroic rocks, belonging to the calc-alkaline suite, and shows the features of MORB, indicating that its protolith came from the oceanic basalt. The chondrite- normalized REE patterns of most samples show depletion in LREE and no pronounced Eu anomaly, with flat HREE patterns. The MORB-mormalized trace element spidergrams show depletion in LREE, with flat patterns from Zr to Yb, and no fractionation of the fraction. The La_N/Yb_N, La_N/Ce_N and La_N/Sm_N, ratio are 0.19-0.56, 0.75-0.81 and 0.37-0.81respectively, the three ratios being all <1. The Hf/Th ratios of most samples are 11.10-33.97, being >8. The Ce/Nb ratios are 2.72-19.02, all being >2. The Th/Yb ratios are 0.01-0.10, all being <1, and $^{143}Nd/^{144}Nd$=0.513000-0.5131777. This also shows that its protolith has the features of typical MORB. And the ($^{87}Sr/^{86}Sr$)i=0.703574-0.705478 suggests the protolith derived from the depleted mantle.

The SHRIMP U-Pb zircon dating of the eclogite yielded ages from 242.4±15.2 Ma to 291.9±12.8 Ma, with a mean age of 261.7±5.3 Ma. According to the regional geological data, it is inferred that the eclogite protolith is Carboniferous-Permian in age. All of the zircons contain abundant inclusions, typically concentrated in the cores of grains. Garnet is by far the most common and widespread inclusion, followed by quartz, apatite, rutile and omphacite. Other common inclusions include amphibole, sphene, phengite and albite. Three main inclusion assemblages are recognized: Grt+Omp+Rt+Phe (eclogite facies), Amp+Spn+Ab (amphibolite facies) and Qtz+Ap (uncertain facies). The compositions of the inclusions are identical to the compositions of the same minerals in the bulk rock. The concentration of the inclusions in the cores of the zircon grains and the abundance of eclogite facies minerals indicate that the zircons grew during, or shortly after, peak metamorphism. All of the zircons have very low Th/U ratios consistent with their metamorphic origin in the Permian.

During the field period, we have found blocks of serpentinite, cumulates of gabbro and pyroxenite, and basic volcanic rocks, which occur together with the eclogites. We presume these blocks belong to ophiolitc units, but they need to be proved by petrochemical data soon after.

On the other hand, we also checked the island arc basalt reported in Chinese journal, and collected the samples. Although we have not completed the chemical analysis on these rocks yet, based on the field occurrences, we agree the conclusion from previous publication.

In general, there are different lithologic units, including MORB-type eclogite, ophiolite, and island arc volcanic rocks in the same zone, which most likely indicate a suture in the region. Based on the available age data, it is probable a Permian suture.