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Short Communications (Research Advances)

SHRIMP zircon U-Pb age and O isotopic analysis of the dunite from Kudi ophiolite in the West Kunlun, China

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1. Objective

The West Kunlun in Xinjiang is located on the northwestern margin of the Qinghai-Tibet Plateau (Fig. 1a) and at the junction of the Paleo-Asian tectonic domain and the Tethys tectonic domain. It serves as an important area for the study on the geologic evolution of the Karakorum-West Kunlun due to its special tectonic position. The Kudi ophiolite in the West Kunlun Orogenic Belt is mainly composed of metamorphic peridotite, super crystalline peridotite, basic volcanic rock, and quartzite. The ultramafic cumulates in the lower part of the Kudi ophiolite can be divided into dunite and harzburgite (Fig. 1b). Previous studies suggest that the Kudi ophiolite keeps a record of the breakup and subduction history of the Proto-Tethys Ocean. The K-Ar, Rb-Sr, and zircon U-Pb geochronology of the upper rock units (such as pyroxenite, gabbro, or basalt) has been studied, thus indirectly determining that the Kudi ophiolite was formed from 1023 Ma to 359 Ma. However, the formation age is puzzling. In recent years, it has been discovered that primary zircons can also be found in the peridotite of the orogenic belt and they can be used for direct geochronologic studies. In this study, zircons were selected from the dunite of the Kudi ophiolite for U-Pb isotopic dating, aiming to directly define the formation age of the ophiolite and to provide new data for the tectonic evolution of the West Kunlun-Karakoram and the formation of the Proto-Tethys Ocean.

2. Method

Three large samples (about 30 kg each) were selected for mineral sorting of the dunite. As a result, one of them bore more zircons and had better microscopic characteristics according to cathodoluminescence and thus was suitable for dating. Zircon dating was carried out using the SHRIMP II ion microprobe at the Beijing SHRIMP Centre, CAGS. The intensity of the primary O^{-2} ion beam was 5 nA and the spot sizes were about 30 μm. Each analytical site was rastered for 120 s prior to analysis to remove contamination from gold coating. Zircon standard M257 with an age of 561.3 Ma and U content of 840×10^{-6} was used as calibration standard, and standard TEM with an age of 417 Ma was used to monitor the performance. Decay constants used for the age calculation were those recommended by the Subcommission on Geochronology of IUGS. The common lead correction was conducted using the measured ^{204}Pb abundances and assuming lead composition. Meanwhile, data processing was carried out using the SQUID and ISOPLOT programs. The uncertainties in Supplementary Table 1 and the concordia diagrams for individual analyses are quoted at the 1σ level. The weighted mean ^{207}Pb/^{206}Pb age or ^{206}Pb/^{238}U and concordia ages in this paper are quoted at the 95% confidence level (2σ). Five scans through the mass stations were made for each age determination, and the ratio of standard TEM analyses to sample analyses was 1∶3–1∶4.

3. Results

The dunite ($Pz_1\varphi$, Fig. 1b) is distributed in the shape of "Π" in the harzburgite, with joints and fissures developing on the rock surface. It has yellowish-green fresh surface, massive structure, and euhedral to subhedral medium-fine grained texture. Meanwhile, it is mainly composed of olivine (90%–98%) and chrome spinel (2%–8%). Among them, the olivine crystals are colorless and euhedral, with a particle size generally ranging from 0.5 mm to 4.0 mm. Cracks are developed on the crystal surface, and amphibolization and talc

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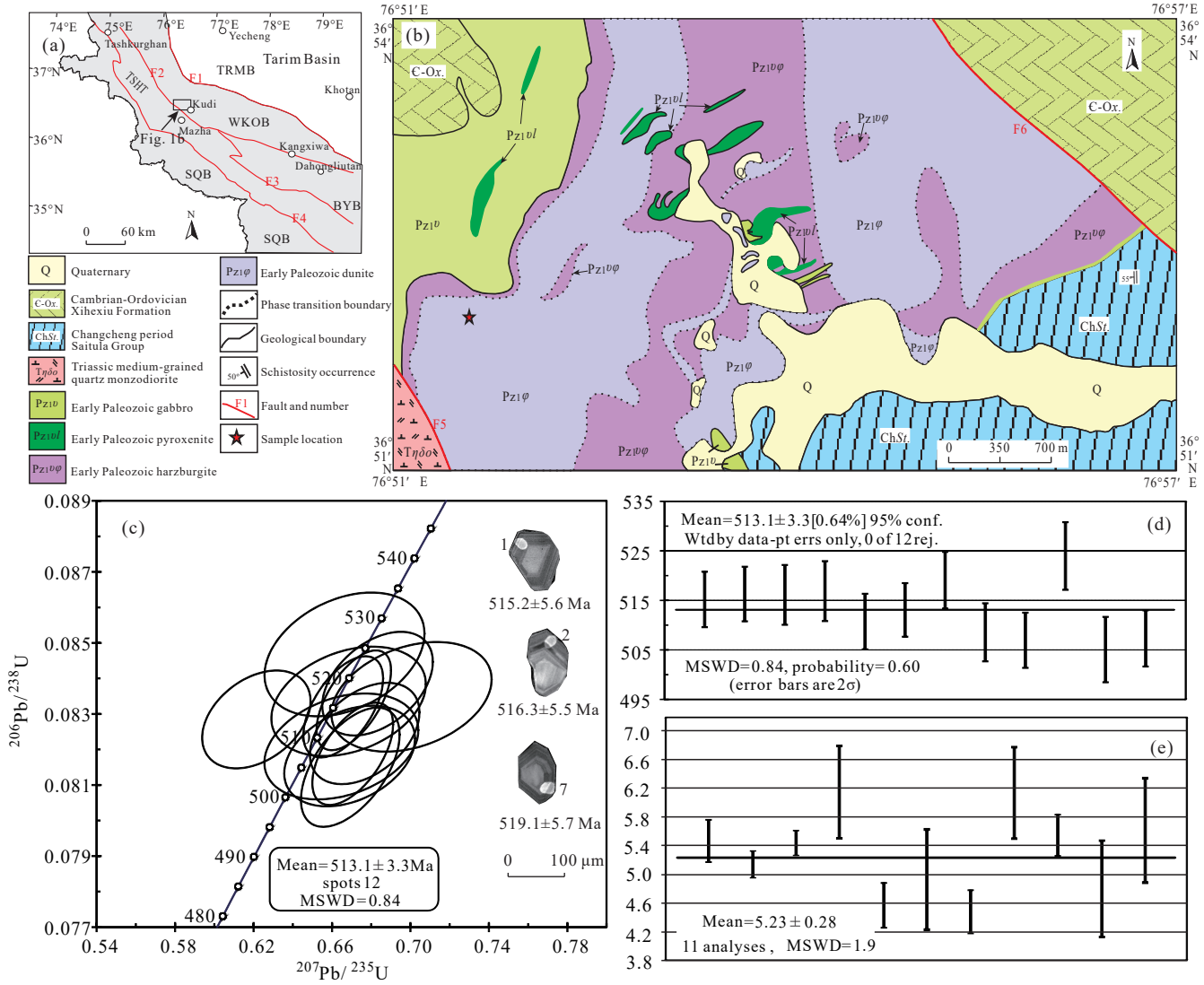

Fig. 1. a–Geotectonic position of the West Kunlun, Xinjiang; b–geologic map of Kudi ophiolite in the West Kunlun; c–Cathodoluminescence (CL) images and U-Pb concordia diagram; d–U-Pb weighted average ages; e–O isotopic weighted average values of zircon grains from Kudi dunite. TRMB–Tarim Block, WKOB–West Kunlun Orogenic Belt, TSHT–Tianshuihai Terrane, BYB–Bayankala Block, SQB–Southern Qiangtang Block. F1–Kongur-Kegang fault zone, F2–Kangxiwa-Jingyuhu fault zone, F3–Dahongliutan fault zone, F4–Karakorum fault zone.

tend to occur along the fracture plane. Meanwhile, the Kenke band structures are widely developed in the crystals, indicating that the magma originated from the upper mantle. As an accessory mineral, chrome spinel is black and light-brown under transmitted light. It is anisotomic-subhedral granular, with a particle size of 0.10−0.85 mm. Thus most of the chrome spinel particles are smaller than the olivine crystals. Individual spinel particles are generally distributed between the olivine particles, with a few of them being found inside the olivine.

The zircons selected from the dunite have a relatively high degree of spontaneity. They are short columnar and are light-yellow to colorless and transparent, with a length-to-width ratio of about 2∶1 and a particle size of mostly 100–200 μm (Fig. 1c). As shown in zircon CL images, the zircons generally have apparent luminescence, obvious oscillatory zoning, and the characteristics of magmatic structure (Fig. 1c). According to the results of testing for 12 times, the Th content of the zircons ranges from 36×10^{-6} to 142×10^{-6}, the U content varies from 86×10^{-6} to 247×10^{-6}, and thus the Th/U ratio is mainly concentrated in a range of 0.32–0.74 (Supplementary Table 1). All these age data fall on the concordia curve (Fig. 1c), with a data range of 505.1–524.0 Ma. Meanwhile, 12 ablation spots yielded a weighted mean age of 513.1±3.3 Ma (MSWD=0.84, confidence level: 95%; Fig. 1d). *In situ* O isotopic tests were also carried out on the zircons. As a result, the $\delta^{18}O$ value of the zircons ranges from 4.57‰ to 6.15‰ (Supplementary Table 2), and 11 ablation spots yielded a weighted mean data of (5.23±0.28) ‰ (MSWD=1.9; Fig. 1e).

4. Conclusion

In this study, the *in-situ* $\delta^{18}O$ values of the dunite (i.e., the ultramafic unit of Kudi ophiolite) were measured, obtaining a weighted mean value of (5.23±0.28)‰. This is consistent with the $\delta^{18}O$ values of the olivine in the continental lithospheric mantle. Meanwhile, the zircon U-Pb isotopic analysis in this

study shows that the zircon crystallization age of the dunite is 513.1±3.3 Ma (n=12, MSWD=0.84). This age should represent the diagenetic age of the dunite, indicating that the Kudi ophiolite was formed in the early Cambrian of the Early Paleozoic. Comparing the diagenetic age of the dunite obtained in this paper with the zircon U-Pb ages of the pyroxenite and gabbro of Kudi ophiolite, it is found that these age values are concentrated and very similar, with a range of 494–525 Ma, indicating that SHRIMP U-Pb isotopic analyses of zircons from the Kudi dunite are reliable, and at least it shows that the diagenetic ages of ultramafic rocks are nearly the same. The Kudi ophiolite is the residual of the closed Proto-Tethys Ocean and was formed in an island arc environment above the subduction zone.

CRediT authorship contribution statement

Geng-biao Qiao and Wen-ming Li conceived of the presented idea. Geng-biao Qiao and Tian-hu Li performed the computations and verified the analytical methods. All authors discussed the results and contributed to the final manuscript.

Declaration of competing interest

The authors declare no conflicts of interest.

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Supplementary data

Supplementary Tables. 1–2 to this article can be found online at doi: 10.31035/cg2021047.