Rocks in Western Yunnan

Subjects: Geology
Contributor: Huimin Liu, Yongqing Chen, Zhi Shang

The zircon U–Pb data indicated that the Santaishan serpentinized pyroxene peridotite (SSPP) was formed 186–190 Ma, and the Yingjiang hornblende pyroxenite (YHP) was formed 182–183 Ma.

Keywords: western Yunnan ; ultramafic rock ; Bangong–Nujiang suture zone ; zircon U–Pb age

1. Introduction

The Tethys tectonic domain, with a total length of about 15,000 km, starts from northeastern Australia in the east; crosses successively to southeast Asia, the Indo-Myanmar Mountains, the southern Qinghai–Tibet Plateau and the Iranian Plateau; and ultimately extends to western Europe through the Mediterranean Sea [1]. The Tethys tectonic domain has attracted substantial attention because of its abundant geological phenomena and mineral resources. A systematic study of it may not only reveal the evolutionary history of the crust but also guide exploration for mineral resources [2][3][4][5][6][7].

On the basis of plate tectonics, previous works have proposed a division of the Paleo-Tethys and Neo-Tethys Oceans and argued that the southern subduction of the Paleo-Tethys Ocean led to the splitting and expansion of the northern margin of the Gondwana continent, resulting in the formation of the Neo-Tethys Ocean. In China, the Neo-Tethys Ocean is composed of two main ocean basins, the Bangong–Nujiang Ocean and the Yarlung Tsangpo Ocean [1][2][3]. The Tengchong Bloc is located between the Yarlung Tsangpo suture zone and the Bangong-Nujiang suture zone, which is the southern extension of the Lhasa Block. It is separated from the Baoshan Block by the Nujiang fault in the east and connects with the Burma Block along the Myitkyina ophiolite belt in the west [8][9][10][11]. The Bangong–Nujiang ophiolite belt is cut by the Karakoram fault at its westernmost and passes eastward from Bangong Lake to Gaize, Dingqing and other places in Tibet. Thereafter, the Bangong–Nujiang ophiolite belt enters Yunnan, which is covered by the Gaoligong thrust belt, and finally arrives in northern Myanmar and extends into the Andaman Sea along the Saging fault [12][13]. The exact subduction time of the Bangong–Nujiang Ocean is still controversial. Qiu et al. believed that the Bangong–Nujiang Ocean began to subduct southward in the Middle Jurassic and closed in the Early Cretaceous [14]. Mo et al. supposed that the opening time of the Neo-Tethys Ocean should be at the Late Triassic or earlier, the subduction started before 170 Ma, and the closure time might be in the Late Jurassic (ca. 159 Ma) to the end of the Early Cretaceous (ca. 99 Ma) [3]. With the closure of the Neo-Tethys Ocean, the Lhasa Block collided with the Qiangtang Block. Shi et al. studied Bangong Lake’s ophiolite and found that the maximum age of the gabbro was 177 Ma, suggesting that the subduction of the Bangong–Nujiang Ocean was earlier than 177 Ma [15][16].

Small amounts of ultramafic rock are exposed in Santaishan Village, Tengchong Block, and the rocks are generally serpentinized. Previous studies have had different understandings of the genesis and tectonic settings of the ultramafic rocks in Santaishan. The attribution of the ultramafic rocks in the Santaishan has always been controversial, with the main viewpoints being that (1) they are remnants of the oceanic lithospheric mantle, (2) they belong to the ancient continental basement and (3) they are part of the Bangong–Nujiang ophiolite belt. The Yunnan Bureau of Geology and Mineral Resources Exploration found that the Middle Jurassic coarse clastic rocks exposed around the Santaishan ultramafic rocks contained chromite fragments, indicating that the Santaishan ultramafic rocks were formed before the Middle Jurassic. Zhang et al. believed that the ultramafic rocks in Santaishan were formed in the Late Triassic to Early Jurassic and experienced strong tectonic deformation [12]. Zhong et al. supposed that there was no ophiolite in Santaisan because no record of an oceanic crust was found in this area [8][17]. Liu et al. believed that the Santaishan ultramafic rocks may represent rootless ophiolite fragments, and the Longling–Ruili fault represents the suture zone between the Tengchong and Baoshan Blocks [18]. Through Os isotope studies, Chu et al. concluded that the Santaishan ultramafic rocks were derived from the enriched lithospheric mantle, rather than part of the Bangong–Nujiang ophiolite belt [13]. Wang et al. speculated that the peridotite underwent 25%–35% partial melting at the mid-ocean ridge in the early stage and was modified by the subducted oceanic crust, which has similar characteristics to the ophiolite in the Yarlung Tsangpo suture zone [19].

Previous studies on ultramafic rocks in western Yunnan have mainly focused on Santaishan and have defined the evolution of the Neo-Tethys Ocean through isotopic chronology studies. However, systematic studies on the magma sources, petrogenesis, and the formation of the tectonic setting of these ultramafic rocks are still scarce, although these are vital to understanding the evolution of western Yunnan [12][13][14][15][16][17][18][19].

2. Geologic Background and Petrography

The western Yunnan experienced frequent tectono-magmatic activities and has a complex geological background. The strata, structures and magmatic rocks in this region are arc-shaped. The main tectonic zones from west to east are Binlangjiang fault (BJF), Dayingjiang–Guyong fault (DGF), Qipanshi–Tengchong fault (QTF) and Bangong–Nujiang fault (BNF), and the sedimentary strata outcrops are mainly a series of Late Paleozoic and Early Mesozoic carbonates and clastic rocks. The crystalline basement of the Tengchong Block is composed of the Paleoproterozoic Gaoligong Mountain Group, which consists of amphibolite, feldspathic gneisses, quartzite, migmatite and marble [20]. The Early Paleozoic strata are dominated by the lower Ordovician carbonate rocks and miss the middle to upper Ordovician and Silurian strata. The Late Paleozoic strata are a set of clastic and carbonate rocks formed in a continental margin environment, and the Devonian–Permian is mainly clastic rocks containing minor basic volcanic and carbonate rocks, which were covered by Mesozoic and Cenozoic volcanic activity. The Mesozoic strata are less distributed and were mainly deposited in the Triassic and Middle Jurassic; their lithology is composed of clastic rocks and limestone. The lithology in the Cenozoic is complex, including coal-bearing clastic rocks and conglomerates, pyroclastic rocks and a small amount of basic to intermediate volcanic rocks [20].

There have been four periods of magmatic activity: the Cambrian–Ordovician, Triassic–Early Jurassic, Early Cretaceous and Late Cretaceous–Early Palaeogene [20][21][22]. Ultramafic rocks are mainly distributed in Luxi and Yingjiang. The SSPP is located at the western margin of the Nujiang–Bangong–Ruili fault, occurring as a lens-like shape in the NEE direction along the shear zone. The SSPP is in fault contact with the Jurassic–Cretaceous red thick layer of clastic rocks. The YHP is distributed near the BJF and has an intrusion relationship with the Cenozoic volcanic rocks. The ultramafic rock samples in this research were collected from Santaishan Village in Luxi County and Luluo Village in Yingjiang County.

The SSPP rocks have a vein-like appearance and a grayish-to-black color (**Figure 1**a). The main mineral composition is olivine and pyroxene, with spinel as a secondary mineral. The rocks exhibit lamellar and massive structures (**Figure 1**b). Olivine content accounts for about 65% of the total mineral, and its highest interference color is grade Ⅲ green. The serpentinization of the olivine along the cleavage. A small amount of magnetite is the product of olivine dissociation during serpentinization. Pyroxene accounts for about 25% of the total mineral content, with the main grain size being 0.5–2 mm. Bastite takes the place of pyroxene and assumes its appearance with a metasomatic structure. Spinel makes up about 2% of the total minerals; the main particle size is 0.2–0.5 mm (**Figure 2**a,b). Strong serpentinization and sericitization are obvious in the rocks. Therefore, researchers supposed that the original rock was pyroxene peridotite, and, under the subsequent metamorphism, the peridotite and pyroxene strongly metamorphosed into serpentine, presenting a metasomatic structure.

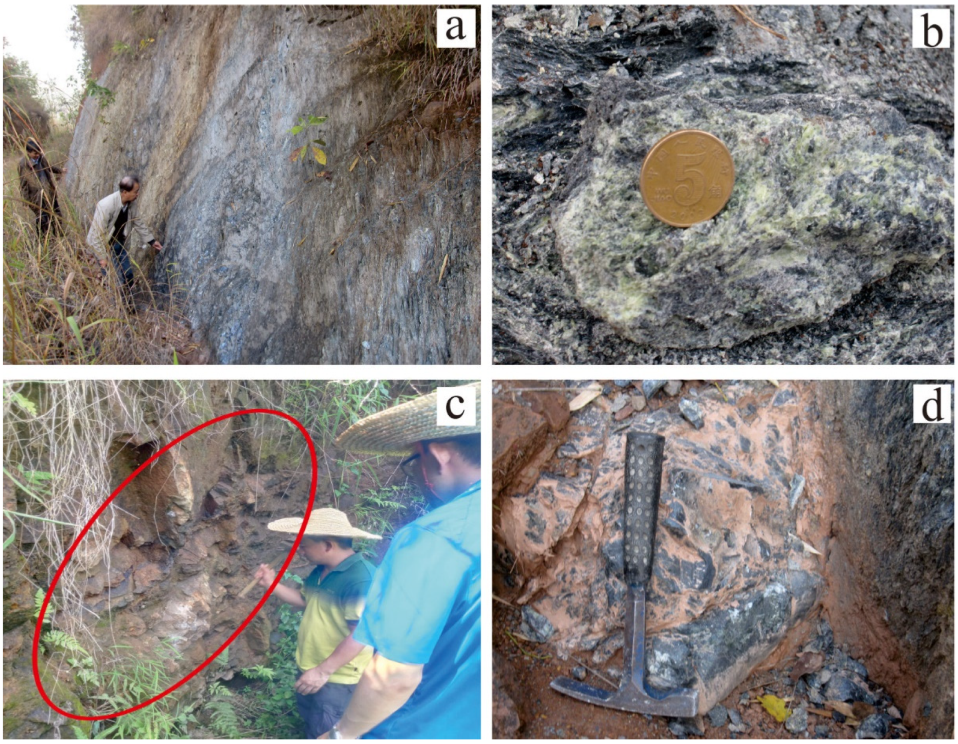

Figure 1. Santaishan ultramafic outcrops and hand specimens (**a**,**b**), Yingjiang ultramafic outcrops and hand specimens (**c**,**d**).

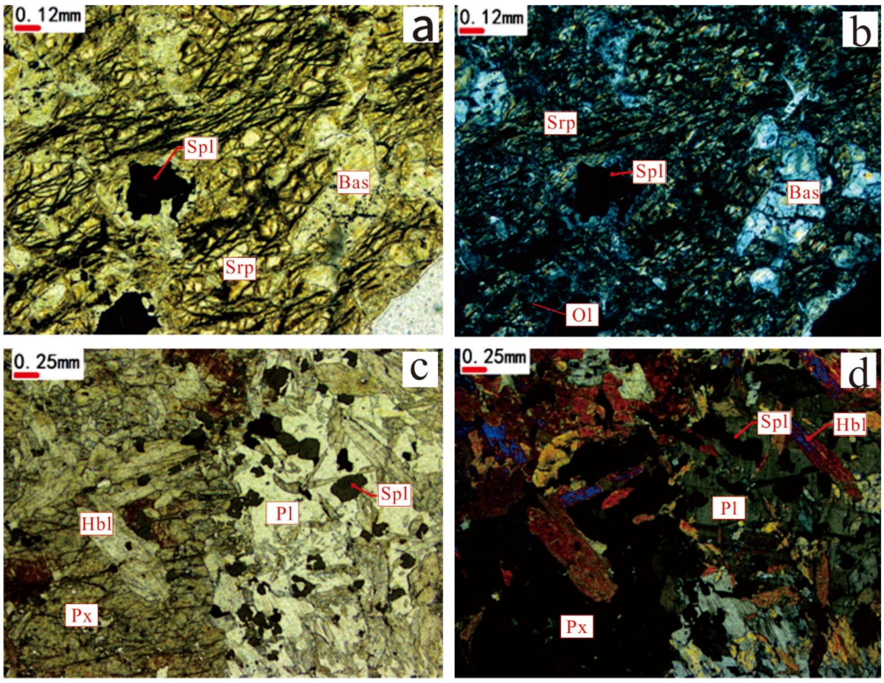

Figure 2. Single-polarized (**a**,**c**), cross-polarized (**b**,**d**). Light photomicrographs of ultramafic rocks in Santaishan (**a**,**b**) and Yingjiang (**c**,**d**). Px—pyroxene, Pl—plagioclase, Hbl—hornblende, Ol—olivine, Spl—spinel, Bas—Bastite, Srp—serpentine.

The YHP rocks have a vein-like occurrence with a weak alteration. The fresh rocks are gray-green, with high hardness (**Figure 1**c). Most pyroxene and hornblende can be observed in hand specimens. The rocks have a hypidiomorphic granular texture and a massive structure (**Figure 1**d). The main mineral components are pyroxene and hornblende. The secondary minerals are spinel and plagioclase. The pyroxene content is about 60%, for which the main particle size is 0.5–2 mm. This is mainly clinopyroxene pyroxene, followed by orthopyroxene. Orthopyroxene precipitates iron oxides to various degrees. Hornblende makes up 25% of the total minerals and has a principal grain size of 0.5–2 mm. The content of plagioclase is about 7%, and it often contains hornblende, spinel and magnetite inclusions. The content of spinel accounts for about 6% of the total minerals and is filled between pyroxene and hornblende grains; the main particle size is 0.1–0.5 mm (**Figure 2**c,d). The Yingjiang ultramafic rocks contain clinopyroxene, indicating that the degree of melting was lower than that of the Santaishan ultramafic rocks without clinopyroxene.

References

1. Zhu, R.X.; Zhao, P.; Zhao, L. Tectonic evolution and geodynamics of the Neo-Tethys Ocean. Sci. China Earth Sci. 2022, 65, 1–24. (In Chinese)
2. Hou, Z.Q.; Zhang, H.R. Geodynamics and metallogeny of the eastern Tethyan metallogenic domain. Ore Geol. Rev. 2015, 70, 346–384.
3. Mo, X.X.; Pan, G.T. From Tethys to Tibetan Plateau formation: Tectonic-magmatic event constraints. Earth Sci. Front. 2006, 13, 43–51. (In Chinese)
4. Deng, J.; Hou, Z.Q.; Mo, X.X.; Yang, L.Q.; Wang, C.M. Sanjiang Tethys composite orogeny and mineralization. Miner. Depos. 2010, 29, 37–42. (In Chinese)
5. Xu, Z.Q.; Yang, J.S.; Li, H.B.; Ji, S.C.; Zhang, Z.M.; Liu, Y. India-Asia collision geotectonics. Acta Geol. Sin. 2011, 85, 1–33. (In Chinese)
6. Ding, L.; Satybaev, M.; Cai, F.L.; Wang, H.Q.; Song, P.P.; Ji, W.Q.; Xu, Q.; Zhang, L.Y.; Qasim, M.; Baral, U. Processes of initial collision and suturing between India and Asia. Sci. Sin. (Terrae) 2017, 47, 293–309. (In Chinese)
7. Wu, F.Y.; Wan, B.; Zhao, L.; Xiao, W.J.; Zhu, R.X. Tethyan geodynamics. Acta Petrol. Sin. 2020, 36, 1627–1674. (In Chinese)
8. Zhong, D.L.; Ding, L.; Liu, F.T.; Lu, J.H.; Zhang, J.J.; Ji, J.Q.; Chen, H. Multi-oriented and layered structures of lith osphere in orogenic belt and their effects on Cenozoic magmatism. Sci. China Earth Sci. 2000, 43, 122–133.
9. Zhong, D.L.; Ding, L.; Zhang, J.J.; Ji, J.Q. Multi-Periodic Collisional Process between Indian and Asian Continents: A Case of Eastern Himalayan Syntaxis and Hengduan Mountains. Earth Sci. Front. 2000, S1, 47–48.
10. Yin, A.; Harrison, T.M. Geologic Evolution of the Himalayan-Tibetan Orogen. Earth Planet. Sci. 2000, 28, 211–280.
11. Zhou, K.K.; Mu, C.L.; Ge, X.Y.; Liang, W.; Chen, X.W.; Wang, Q.Y.; Wang, X.P. Lithofacies Paleogeography of the South China in Early Paleozoic and Its Reflection on Key Geological Problems. Acta Sedimentol. Sin. 2017, 35, 449–549. (In Chinese)
12. Zhang, Q.; Zhou, D.J.; Zhao, D.S. Wilson cycle of the PaleoTethyan Orogenic belt in western Yunnan: Record of magmatism and discussion on mantle process. Acta Petrol. Sin. 1996, 12, 17–28. (In Chinese)
13. Chu, Z.Y.; Wang, W.; Chen, F.K.; Wang, X.L.; Li, X.H.; Ji, J.Q. Os-Nd-Pb-Sr isotopic compositions of the Santaishan ultramafic rock in western Yunnan and its geological significances. Acta Petrol. Sin. 2009, 25, 3221–3228, (In Chinese with English Abstract).
14. Qiu, R.Z.; Cai, Z.Y.; Li, J.F. Boni nite of ophiolite belts in western QingHai-Tibet plateau and it's Geological implication. Geoscience 2004, 3, 305–308. (In Chinese)
15. Shi, R.D. Age of SSZ ophiolite in Bangong: Constraintion on formation age of Bangong-Nujiang suture. Chin. Sci Bull. 2007, 52, 223–227. (In Chinese)
16. Chen, Y.Q.; Li, G.J.; Qin, L.X.; Lu, Y.X.; Jiang, C.X. Geochronology and geochemistry of Cretaceous–Eocene granites, Tengchong Block (SW China): Petrogenesis and implications for Mesozoic-Cenozoic tectonic evolution of Eastern Tethys. Geosci. Front. 2022, 13, 220–242.
17. Zhong, D.L.; Ding, L.; Zhang, J.J.; Ji, J.Q. Study of Orogenic Belts in China: Retrospects and Prospects. Geol. Rev. 2002, 48, 147–152, (In Chinese with English Abstract).
18. Liu, B.P.; Feng, Q.L.; Chonglakmani, C.; Helmcke, D. Framework of PaleoTethyan archipelago ocean of western Yunnan and it's elongation towards north and south. Earth Sci. Front. 2002, 9, 161–170, (In Chinese with English Abstract).
19. Wang, Y.X.; Wang, G.H.; Yuan, G.L.; Wang, X.J.; Lu, Y.; Lin, Y. Tectonic genesis of the Santaishan peridotites in western Yunnan and its geological significance: Evidence from geology, mineralogy and petrogeochemistry. Earth Sci. Front. 2018, 25, 138–156, (In Chinese with English Abstract).
20. Zhou, S.M.; Wang, Q.F.; Li, G.J. Geochemistry, zircon U-Pb geochronology from the Late Triassic syenogranite in Lianghe area, Tengchong Block, and their geological implications. Acta Petrol. Sin. 2018, 34, 1359–1375. (In Chinese)
21. Chen, X.C.; Hu, R.Z.; Bi, X.W.; Zhong, H.; Lan, J.B.; Zhao, C.H.; Zhu, J.J. Petrogenesis of metaluminous A-type granitoids in the Tengchong-Lianghe tin belt of southwestern China: Evidences from zircon U-Pb ages and Hf-O isotopes, and whole-rock Sr-Nd isotopes. Lithos 2015, 212, 93–110.
22. Cong, F.; Lin, S.L.; Zou, G.F.; Xie, T.; Li, Z.H.; Tang, F.W.; Peng, Z.M. Geochronology and petrogenesis for the protolith of biotite plagioclase gneiss at Lianghe, western Yunnan. Acta Geol. Sin. 2011, 85, 870–880.