Northernmost paleo-tethyan oceanic basin in Tibet: Geochronological evidence from $^{40}Ar/^{39}Ar$ age dating of Dur'ngoi ophiolite

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Abstract **Whole rock $^{40}Ar/^{39}Ar$ age dating has been conducted on a basalt sample from Dur'ngoi ophiolite, Qinghai Province, which was reported to be the northernmost paleo-tethyan oceanic basin in Tibet. A high temperature plateau age (345.3±7.9 Ma) with an isochorn age (336.6±7.1 Ma) has been obtained, representing the eruption time of oceanic crust. Considering related geological settings, the new age provides constraints on the northernmost paleo-tethyan suture zone in Tibet and the tectonic evolution of Paleo-tethys in Northeast Tibet and adjacent areas.**

Keywords: Dur'ngoi ophiolite, ^{40}Ar-^{39}Ar age, Paleo-tethys.

It has been generally accepted that the formation age of ophiolite represents the spreading time of oceanic basins of a couple of types, which include mature oceanic basins, intracontinent basins, back-arc basins, etc. Thus the geochronolgical study on ophiolite can provide a key message on the evolution process of disappeared basins.

Dur'ngoi ophiolite occurs in the east of A'nyemaqen orogens, near Dur'ngoi copper mine, Maqen county, Qinhai Province (fig. 1). With a section thickness of about 2 km, the ophiolite is composed of 3 elements bordered by brittle faults, which are massive basalts, massive coarse grained gabbros and metaperidotites with pyroxenite lens[1]. Geochemistry on major and trace elements of the basalts show typical characteristics of Normal Oceanic Ridge Basalt (MORB), which indicates that the ophiolite is formed in central ridge of a mature oceanic basin [1]. The absence of radiolarian chert in sections makes isotope measurement the only method to date the age of ophiolite. Here we report the whole rock step heating $^{40}Ar/^{39}Ar$ dat-

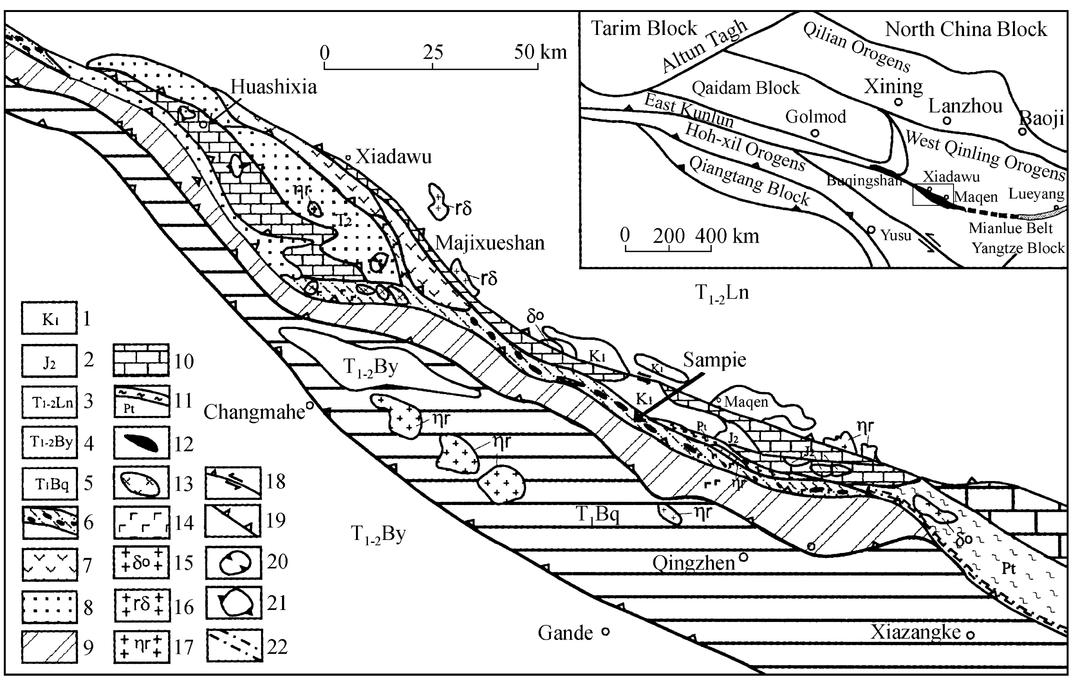

Fig .1 Sketch geological map of east part of A'nyemaqen orogens. 1, Upper Cretaceous coarse-grained terrestrial clastic sediment; 2, Mid-Jurassic terrestrial clastic sediment with coal; 3, Lower-Mid Triassic Longwuhe formation and Gulangti Group clastic flysch; 4, Triassic Bayan Har clastic flysch; 5, Lower Triassic Buqingshan clastic flysch; 6, ophiolitic melange; 7, island arc volcanics; 8, fore arc flysch; 9, sedimentary melange; 10, Upper Cretaceous to Lower Permian block limestone nappe; 11, Proterozoic basement blocks; 12, ultramafic blocks; 13.gabbros; 14, lava; 15, Indosinian tonalite; 16, Indosinian granodiorite; 17, Indosinian adamellite; 18, slipping-thrusting boundaries; 19. thrusting boundaries; 20, klippe; 21, tectonic windows; 22, ducite shear zones/mylonites.

Table 1 Step heating data for DN-13

Step	T/℃	$(^{40}Ar/^{39}Ar)_m$	$(^{36}Ar/^{39}Ar)_m$	$(^{37}Ar/^{39}Ar)_m$	$(^{40}Ar_r/^{39}Ar)_m$	$^{39}Ar_K$ (10^{-14}mol)	Apparent age/Ma
1	400	32.07780	0.09690	4.16760	3.73900	10.15	95.60±19.4
2	500	23.32230	0.06120	3.81200	5.52790	12.36	139.60±8.6
3	600	28.88880	0.06530	3.08850	9.83160	16.43	241.30±12.8
4	700	33.82560	0.07200	4.28240	12.89860	16.93	310.40±19.4
5	780	33.81780	0.07730	4.28240	11.31840	15.39	275.10±13.0
6	850	17.34800	0.02210	3.35130	11.09010	24.38	270.00±4.90
7	930	24.11960	0.03660	4.15580	13.65360	28.87	327.00±6.20
8	1010	24.11960	0.04310	36.27470	14.37490	60.62	342.80±18.30
9	1100	17.34800	0.02500	53.10950	14.33900	97.52	342.00±5.40
10	1200	17.34800	0.02460	53.10940	14.45040	32.50	344.40±5.30
11	1300	21.81240	0.03240	33.26390	14.99290	48.18	356.10±8.40
12	1400	21.56270	0.04540	3.00000	8.38150	0.10	207.70±20.40

Plateau age t_p = (345.3±7.9) Ma (steps 8—11), t_i = (336.6±7.1) Ma (isochorn age for steps 8—11). m, Measured; r, radiogenic.

ing of a basalt sample and its geological significance.

1 Sample and measurement

The basalt sample (DN-13) for geochronolgical study is collected from the Jialige section, which is about 10 km east of Dur'ngoi copper mine, Maqen County. The basalt segment experiences slight deformation and metamorphism of low greenschist facies. The sample has a homogenous and aphanitic appearance without vesicles and almond.

212.25 mg sample was irradiated in Nuclear Reactor 49-2 for 355 h in the Chinese Academy of Nuclear Energy, irradiation coefficient J = 0.14557, integral neutron flux was 1.4×10^{18}n/cm^2. ZBH-25 Biotite was used as flux monitor. Isotopic measurement of argon is made on a gas-source masspectormeter MM1200 in the Institute of Geology, the Chinese Academy of Geological Sciences.

2 Result and discussion

The $^{40}Ar/^{39}Ar$ age spectrum we obtain after 12 heating steps (shown in fig. 2) is a typical single plateau spectrum. It is composed of 2 parts: low to mid-temperature part (steps 1—6, 400—850℃) and the high-temperature part (steps 7—12, 930—1400℃). The former has discordant apparent age range from 95.6 to 310.4 Ma, which indicates radiogenic argon loss process during low to mid-temperature thermal events, and probably corresponding to the greenschist metamorphism. Steps 8–11 yield a well correlated high-temperature plateau age (345.3±7.9 Ma) with an isochorn age (336.6±7.1 Ma, MSWD = 0.7427), and the total argon release rate for the 4 heating steps exceeds 70%. The initial $^{36}Ar/^{40}Ar$ ratio of the sample is 320.44±20.21, consistent with the ratio of the atmosphere ratio (295.5±5) within errors, which exclude the interference of excess argon on the dating result.

Plateau ages records the time intervals after sample cooling below the ^{40}Ar-closure temperature[2], thus it represents crystallizing age or metamorphism age[3]. The well-correlated high-temperature $^{40}Ar/^{39}Ar$ age spectrum pattern we obtain indicates that the low to mid-temperature thermal events did not reset argon isotope system. Therefor, the high-temperature plateau age (345.3±7.9 Ma) should represent crystallizing time of the basalt, which can be interpreted as the eruption age of Dur'ngoi ophiolite.

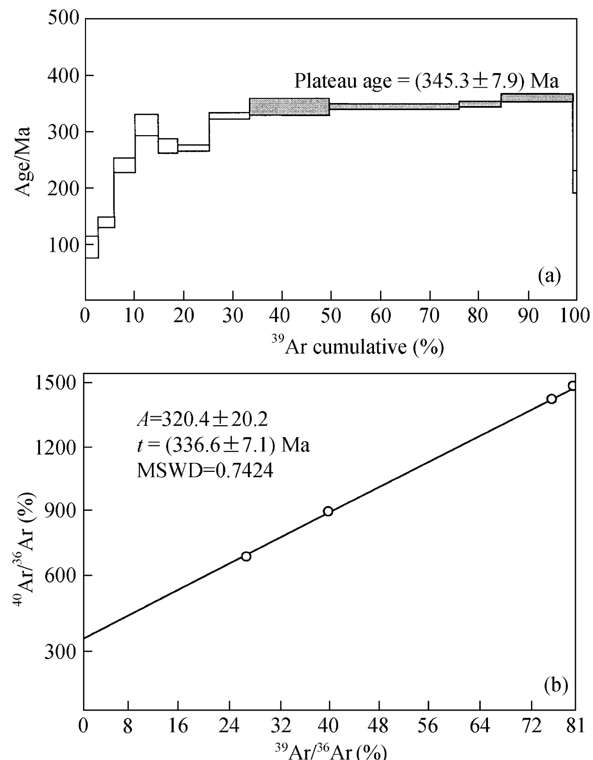

Fig. 2. $^{40}Ar/^{39}Ar$ step-heating age spectrum and isochron diagram of DN-13.

The 500-km-long A'nyemaqen orogen is a southeastwards branch of Kunlun orogens, extending to the northeastern edge of the Tibetan Plateau. The ages of sediment strata in A'nyemaqen range from the Carboniferous to the Triassic, which leads researchers to interpret it as an Indosinian or Hercyian orogenic belt[4, 5]. However, a variety of isotopic ages of different rock types outcropped in ophiolitic mélange in west A'nyemaqen have been reported recently by different authors. They are (260 ±10) Ma Rb-Sr isochorn age of island arc lava from Xiadawu[4, 6], (340.3±11.6) Ma Rb-Sr isochorn age of pillow basalt[7], (402±24) Ma zircon U-Pb age of granodiorite-tonalite from Buqingshan[8] and (517.89±101.6) Ma Rb-Sr isochorn age of diabase from Muyangshan[7], which complicate the oceanic lithosphere evolution process of western part of A'nyemaqen belt.

Dur'ngoi ophiolite is a typical N-MORB ophiolite reported that represents the northernmost paleo-tethyan suture zone in Tibet[1]. Our $^{40}Ar/^{39}Ar$ dating result shows that a mature oceanic basin exists in East A'nyemaqen during the early Carboniferous period, providing new chronological evidence for the above opinion. In consideration of age data in the West, we suppose that a throughout paleo-tethyan oceanic basin should exist in whole A'nyemaqen, coinciding with strata age of Carboniferous to Triassic. And the ophiolitic mélange ages (>400 Ma) probably imply some Paleozoic remnant oceanic crust involved in the orogenic process in West A'nyemaqen, probably inherited from West Kunlun, which has a prolonged evolution from the Precambrian to the Ordovician[9].

Mianlue orogens in the South Qinling range has been long believed to be an east counterpart of A'nyemaqen due to their abuttal in space distribution[4, 10] (see fig. 1), although the possible jointing position of two belts is covered by Quaternary sediment in Songpan swamp. Geological and geochemical research indicates Mianlue belt experiences continental breakup in the Ordovician and collision orogeny in late Permian to early Triassic [10, 11]. The occurrence of typical N-MORB[12] and Carboniferous Radiolarian silicolites in ophiolitic melange of the Mianlue belt[13] provides constraints on the nature of the oceanic basin. In consideration of the spreading age we obtained and the geochemistry of Dur'ngoi ophiolite there exists apparent similarity in the evolution of two Mesozoic basins, which strongly suggests that A'nyemaqen paleo-tethyan oceanic basin probably extends eastwards to connect with the Mianlue Basin, forming a paleo-tethyan channel into central and eastern China.

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References

1. Chen, L., Sun, Y., Liu, X. M. et al., Geochemistry of Derni Ophiolite, Qinghai Province and its tectonic significance, Acta Petrologica Sinica (in Chinese with English abstract), 2000, 16(1): 106.
2. Zhang, Z. Q., Application and limitation of isotopic chronology, Recent Methodology of Lithosphere Research (ed. Zhang, B. X.) (in Chinese), Beijing: Nuclear Energy Publishing House, 1998, 111—135.
3. Zhang, Z. K., Wang, S. S., Technique of $^{40}Ar/^{39}Ar$ dating and applying of isotope chronology, Foreign Geology (in Chinese), 1981(4): 10.
4. Jiang, C. F., Yang, J. S., Feng, B. G. et al., Opening-closing Tectonics of Kunlun Mountains (in Chinese with English abstract), Beijing: Geological Publishing House, 1992, 45—60.
5. Chengdu Institute of Geology, Chinese Academy of Geological Sciences, Introduction to Geological Map of Tibet and Adjacent Areas (1:500000) (in Chinese)7, Beijing: Geological Publishing House, 1990, 1—15.
6. Yang, J. S., Robinson, P. T., Jiang, C. F. et al., Ophiolites of Kunlun Mountains, China and their tectonic implications, Tectonophysics, 1996, 258: 215.
7. Bian, Q. T., Lou, X. Q., Li, H. S. et al., Discovery of Early Paleozoic and Early Carboniferous-Early Permian Ophiolites in the A'nyemaqen, Qinghai Province, China, Scientia Geologica Sinica (in Chinese with English abstract), 1999, 34(4): 523.
8. Bian, Q. T., Luo, X. Q., Chen, H. H. et al., Zircon U-Pb age of Granodiorite-tonalite in the A'nyemaqen ophiolitic Belt and its tectonic significance, Scientia Geologica Sinica (in Chinese with English abstract), 1999, 34(4): 420.
9. Pan, Y. S., The discovery and demonstration of the Fifth Suture Zone in the Tibet Plateau, Acta Geophysica Sinica (in Chinese with English abstract), 1994, 37(2): 184.
10. Zhang, G. W., Meng, Q. R., Yu, Z. P. et al., Orogenesis and dynamics of Qinling Orogen, Science in China, Series, D, 1996, 39(3): 225.
11. Li, S. G., Sun, W. D., Zhang, G. W. et al., Paleozoic oceanic basin in Mianlue Belt, South Qinling Mountains: Evidence from chronology and geochemistry of Heigouxia Meta-volcanics, Science in China (in Chinese), Series D, 1996, 26(3): 223.
12. Xu, J. F., Yu, X. Y., Li, X. H. et al., Discovery of highly depleted NMORB: New evidence for Mianlue Oceanic Basin, Chinese Science Bulletin (in Chinese), 1997, 42(22): 2414.
13. Yin, H. F., Du, Y. S., Xu, J. F. et al., The discovery of radiolarian fauna in Mianlue Belt and its paleoceanography significance, Earth Science-Journal of China University of Geoscience (in Chinese with English abstract), 1996, 21(2): 184.

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