Geochronological evidence for existence of South Mongolian microcontinent——A zircon U-Pb age of grantoid gneisses from the Yagan-Onch Hayrhan metamorphic core complex

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Abstract **A zircon U-Pb age of (916±16) Ma is measured for grantoid gneisses from the Yagan-Onch Hayrhan metamorphic core complex and represents the crystallization age of the grantoid magma. This age provides evidence for the existence of the South Mongolian microcontinent, which is consistent with the analysis of the regional geology.**

Keywords: zircon U-Pb age, Proterozoic, gniesses, South Mongolian microcontinent.

A series of high-grade amphibolite facies metamorphic rocks and less metamorphosed dolomite and quartzite occurs in South Mongolia and in the Sino-Mongolian border area. Russian and Mongolian geologists regard them as Precambrian metamorphic basement and cover[1,2], respectively, and presumed that there existed a Proterozoic South Mongolian microcontinent[3] including South Gobi microcontinent[4]. Studies in the Yagan metamorphic core complex in the Sino-Mongolia border area indicate that the high-grade metamorphic rocks occur as the core crystalline rocks of the MCC[5,6]. Recently, an American geological group confirmed it as a larger-scale metamorphic core complex, the Yagan-Onch Hayrhan metamorphic core complex, which stretches across the Sino-Mongolian border. As they suggested, this carries important implications for the tectonic evolution of Asia. The recognition of Mesozoic metamorphism at Onch Hayrhan posed a question of the existence of the South Mongolian microcontinent[4]. The question concerns some important problems on the crustal strucure and tectonic evolution in the Middle-East Asian continent. The authors restudied the MCC and determined a set of ages. A zircon U-Pb age of (916±16) Ma was measured for the granitoid gneiss. This provides new clues to solving the problem.

1 Regional geology

In South Mongolia and its border area with China there are high-grade amphibolite facies metamorphic rocks, Proterozoic shallow marine carbonates locally containing stromatolites, Paleozoic weak metamorphic rocks and Mesozoic sedimentary rocks. The Proterozoic carbonates were thrust over the Paleozoic and Mesozoic strata[7]. The high-grade metamorphic rocks have not been extensively studied. In Chinese maps, they are designated as Changcheng system and named the "Gashuilai group"1). In Mongolia maps of various editions, they are shown as a Proterozoic complex and are assigned to a Proterozoic massif within Caledonian fold belts[1] or Precambrian basement of the South Gobi Microcontinent[2]. The recognition of the Yagan-Onch Hayrhan MCC in the Sino-Mongolia border area shows that these rocks occur as the metamorphic core beneath the detachment fault of the MCC, which is distributed in the border area as an elliptic anticlinal uplift with a total area of 90 km×20 km. The upper plate of the MCC is made of Permian, Jurassic and Cretaceous rocks. The Permian experienced folding and low greenschist facies metamorphism. The Triassic is characterized by terrestrial redbeds and conglomerates and did not experience regional metamorphism. The Jurassic (?) and Lower Cretaceous sediments filled in synextensional basins. Most biotite K-Ar and Ar-Ar ages of the high-grade metamorphic rocks and granites are 150—126 Ma[4—6], recording strong tectono-thermal events in the final formation stage of the MCC in the late Mesozoic (Late Jurassic-Early Cretaceous).

2 Composition of crystalline rocks of the Yagan-Onch Hayrhan MCC

The core crystalline rocks exhibit variable compositions. These rocks can be divided into 3 members by detailed mapping: gneiss, marble-mylonitic gneiss, and quartzite members, and the two former are the main members. The gneiss members, distributed in the center of the core, mainly consist of banded, augen biotite-plagioclase gneiss, hornblende-biotite plagioclase gneiss, banded migmatic gneiss, grantoid gneiss, and grantoid mylonites. The marble-mylonitic gneiss member consists of banded mylonitic marble and mylonitic gneiss, and granitoid mylonite. In the mass, the granitoid gneiss and migmatic gneiss, which are uniform in outcrop, are the main compositions of the crystalline rocks in the MCC. Most granitoid gneisses have some protolith features of deformed/ metamorphosed palaeo-plutons. Layered paragneiss makes up only about 10%—20% of the core complex.

Gneissic foliation occurs widely in the granitoid gneiss and quartzo-feldspathic gneiss. The foliation is characterized by parallel arrangement of light-colored quartzo-feldspathic (vein) bands and dark bands (base) consisting mainly of biotite, quartz, and feldspar. Some

1) Geological Survey Team of Ningxia, China, 1∶20000 Scale Geological Map of Hariaoribuhe (k-48-xx), 1982, 14.

gneisses exhibit quartzo-feldspathic bands that are 0.4—0.6 cm in width and 10—40 cm in length. Their boundaries are not clear and show features of metamorphic differentiation bands. Mineral assemblages of these gneisses include biotite + quartz + plagioclase + K-feldspar, hornblende + biotite + plagioclase, and hornblende + plagioclase. These features show amphibolite facies metamorphism. Sheath folds and a-type folds are present at outcrop scale. In thin section, plagioclase and k-feldspar both exhibit strong recrystallization and show high-temperature deformation. All these display some features of composition and metamorphism/deformation at lower to middle crustal levels.

3 Sample of granitoid gneiss, preparation and analysis results

The augen-granitoid gneisses of the gneiss unit were selected for dating. The rocks are characterized by banded gneissic foliation. In thin section, recrystalized mylonitic texture is common. Porphyroclasts (30%—40%) consist of plagioclase (25%—30%) and K-feldspar (10%—15%), while the matrix consists of biotite (5%), quartz (20%—30%) and feldspar (20%—40%) and muscovite (5%). On the whole, the rocks have a high content of feldspar (50%—70%). Based on our analysis of two samples and the data of 1:20000 scale regional geological mapping, these rocks have the following geochemical compositions: SiO_2 varies between 72%—73%, TiO_2 0.27%—0.36%, Al_2O_3 13%—14%, CaO 1.26%—1.99%, K_2O 4.33%—4.95%, and MgO 0.65%—0.69%. A/CNK = 1.04—1.14. Total REE is 230—270 μg/g. δEu = 0.33— 0.53. In outcrop, the rocks are uniform in composition and have clear boundaries with their neighbors, but they are consistent in deformation and metamorphism, suggesting that they are not exotic tectonic-blocks. No shear zones exist between them. All these characteristics show that the protoliths of gneisses may be a granitic pluton, which have some features of S-type granites.

The granitic gneiss was sampled in Jingdouaobao, near the center of the MCC (fig. 1). The samples were processed for heavy minerals and 1.3 g of colorless to very light tan zircon grains, which ranged up to 250 microns in length, were extracted. The grains are all very similar in shape, with length:width of 3∶1 and well-

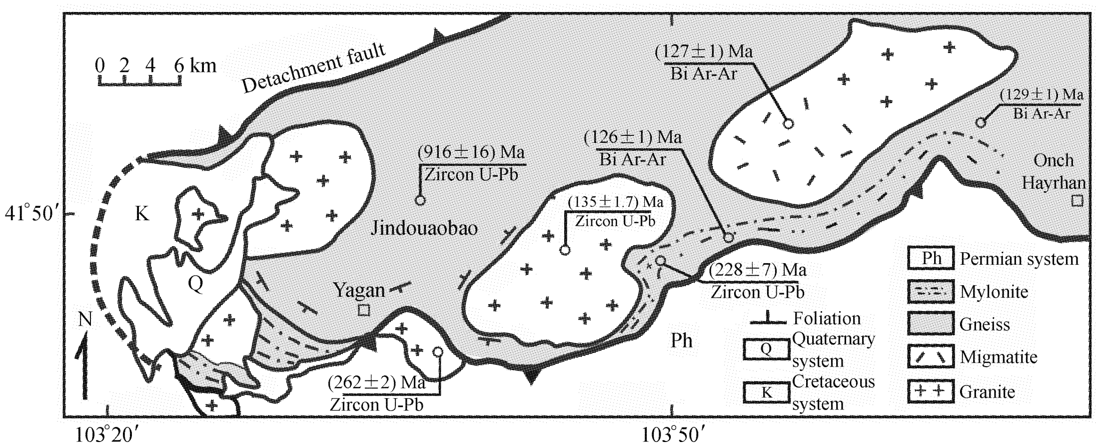

Fig. 1. Geological sketch of the Yagan-Onch Hayrhan MCC and location of the samples Ar-Ar ages after [4] and U-Pb ages are measured by authors.

Table 1 U-Pb isotopic data of the grantoid gneiss

Grain type	Grain Wt/μg	Pb /pg	U/ μg • g^{-1}	$^{206}Pb/^{204}Pb$	$^{206}Pb/^{208}Pb$	$^{206}Pb^*/^{238}Pb$	±error%	$^{207}Pb^*/^{235}U$	±error %	Apparent age/Ma		
										$^{206}Pb^*/^{238}U$	$^{207}Pb^*/^{235}U$	$^{207}Pb^*/^{206}Pb^*$
8A	41	17	968	15900	10.1	0.10891	±0.55	0.99830	±0.83	666±3	703±4	824±5
6B	68	15	563	20600	21.1	0.12406	±0.62	1.15974	±1.29	754±4	782±5	862±5
5C	76	40	992	16350	14.6	0.13750	±0.64	1.29986	±0.94	831±5	846±6	886±5
4D	82	34	856	16500	10.9	0.12721	±0.89	1.18628	±1.19	772±6	794±6	857±5
1Ea	31	12	924	22600	19.5	0.14817	±0.55	1.41620	±0.87	891±5	896±5	908±7
1Ea	28	8	407	13600	24.3	0.14737	±0.56	1.37054	±0.89	866±4	876±5	903±7
1Ea	22	5	265	9790	25.9	0.13197	±0.58	1.23810	±0.92	799±4	818±5	870±8

*Radiogenic Pb. Grain type: A = ~100 μ, B = ~120 μ, C = ~140 μ, D = ~170 μ, E = ~200 μ, a = abraded in air abrasion device. Number refers to number of grains analyzed. $^{206}Pb/^{204}Pb$ is measured ratio, uncorrected for blank, spike, or fractionation. $^{206}Pb/^{208}Pb$ is corrected for blank, spike, and fractionation. All uncertainties are at the 95% confidence level. Uncertainties in isotope ratios are in percent. Uncertainties in ages are in millions of years. Most concentrations have an uncertainty of 25% due to uncertainty in weight of grain. Constants used: $^{238}U/^{235}U$ = 137.88. Decay constant for $^{235}U = 9.8485\times10^{-10}$. Decay constant for $^{238}U = 1.55125\times10^{-10}$. Pb blank ranged from 2 to 10 pg. U blank was <1 pg. All analyses conducted using conventional isotope dilution and thermal ionization mass spectrometry, as described by Gehrels (see ref. [9]).

formed crystal faces and pyramidal terminations. Many grains contain tiny dark (rutile?) inclusions, but no cores were observed. The zircon grains were divided into four groups based on grain size and three polished grains were measured (table 1).

The U-Pb analyses were made in the U-Pb Isotope Laboratory of the Department of Geology, University of Arizona, Tucson, Arizona, USA. The analytical methods and processes have been described in detail[8]. The results (table 1 and fig. 2) show that 7 data points produce a good discordia line, and the upper and lower intersections with the concordant curve yield ages of (916±16) Ma and (326±89) Ma, respectively. The MSWD value is 3.6 and confidence level is 95%. The well-constrained line suggests that the zircon grains have the same igneous origin and are not relict sedimentary zircon grains. The age of the upper intersection point, therefore, can be explained as the crystallization age of the zircon. The age of the lower intersection point may be a reflection of interaction interference of late tectono-thermal events (such as late Paleozoic orogeny) or may have little exact meaning.

4 Implications of the age: Evidence for the existence of the South Mongolia microcontinent

The recognition of the Yagan-Onch Hayrhan MCC brings into question the age of the high-grade metamorphic rocks in the region. Webb et al.[4] obtained biotite

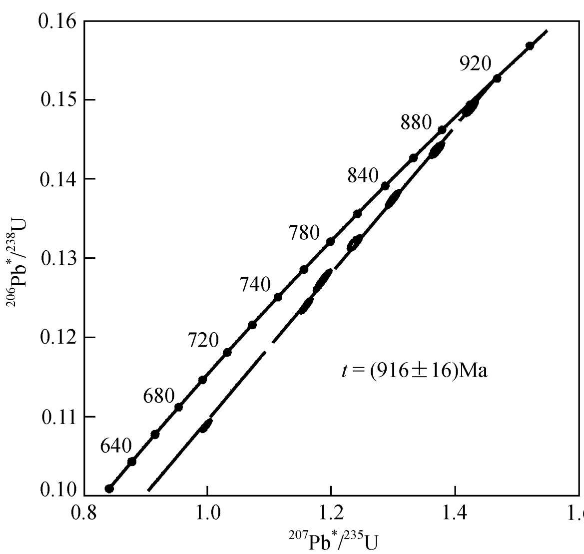

Fig. 2. The zircon U-Pb age of the grantoid gneiss near the core of the Yagan-Onch Hayrhan MCC.

Ar-Ar ages of (127±1) Ma, (126±1) Ma, and (129±1) Ma from migmatic gneiss in the center of the MCC and augen quartzo-feldspathic gneiss and mylonite near the detachment zone. These ages were interpreted to record the formation of the MCC, as supported by the formation of extensional basins at the same time. Consequently, they inferred that the gneissic rocks were metamorphosed at the same time as the formation of the MCC, i.e. during Cretaceous metamorphism, and proposed that "Dating of the high-grade metamorphism at Onch Hayrhan clearly contradicts the Precambrian ages previously assumed for the rocks"[4], "The presence of Mesozoic metamorphism at Onch Hayrhan, previously presumed to be Precambrian, bring into question the existence of the South Gobi microcontinent"[4]. Lamb and Badarch[9] also suggested that it is likely that Ripean and Vendian-Cambrian carbonate and quartzites in south Mongolia are allochthonous klippen, and therefore the basement of south Mongolia may consist only of volcanic arcs accreted during the Paleozoic.

These Ar-Ar ages, however, may represent late thermal events or disturbances during the final stage of formation of the MCC. We also measured three whole-rock and biotite Rb-Sr isochron ages of 110—130 Ma for the same rock dated by U-Pb and for a nearby banded biotite-plagioclase gneiss1). These ages indicate that this thermal event had a strong influence on the Rb-Sr and Ar-Ar isotopic systems of the rocks. In fact, U-Pb dating of a mylonitic granitoid pluton (containing xenoliths of the gneisses) yielded an age of (228±7) Ma, which indicates that deformation and metamorphism occurred before (228±7) Ma1). In addition, structural analysis of early foliations and folds1) in the MCC also confirms that deformation predated this foliation. Moreover, a late, undeformed granitic pluton, that makes up 50% of the area of the core complex, was dated by the U-Pb method at (135±7.6) Ma[8]. The emplacement of these plutons may provide sources for the thermal disturbances of 110—130 Ma. Therefore, the Ar-Ar and Rb-Rr ages of 110—130 Ma may represent cooling ages rather than the age of the main metamorphism/deformation of the core complex.

The protolith of the granitoid gneiss dated in this note is probably an old pluton, as described above. The features of the zircon and the well-constrained discordia line indicate that the age represents the crystallization age of the magmatic zircon. This indicates that the protoliths of the core complex were formed before Neoproterozoic time and were reworked by Neoproterozoic tectono-magmatic events such as the origin and emplacement of the crustal-derived granitic magmatism. Thus, the age suggests the existence of old (Precambrian) continental blocks. If the zircon grains were metamorphic in origin, the age would have represented the metamorphic age and would have further proved the existence of old metamorphic rocks, i.e. the Precambrian basement. Obviously, in any case, the age provides evidence for the existence of Proterozoic continental blocks, which may be part of the previously presumed South Mongolia microcontinent.

On the regional scale, the metamorphic rocks have complicated compositions and underwent poly-phase metamorphisms and deformations, showing a feature of an old complex. This is also supported by a zircon U-Pb age of 770 Ma measured for similar rocks in Mongolia (personal communication with Prof. Bardach). Additionally, the high-grade metamorphic complex is structurally lower than the Paleozoic low-grade metamorphic rocks, and a large-scale detachment zone occurs in between[5]. This suggests that the metamorphic complex lay in much deeper levels than the cover and experienced different thermal histories from those of the cover, showing some features of a metamorphic basement. The wide distribution of Proterozoic shallow-marine carbonate, regarded as the cover in the region, may provide additional evidence for the existence of the microcontinent.

All above analyses suggest that the South Mongolia microcontinent existed, and may have been combined with other Precambrian metamorphic rocks as part of the Proterozoic Rodinia continent in the region.

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