Research Advances

The Late Archean Tectonic Events in the Jining Area of North China Craton: New Evidence from Zircon SHRIMP U-Pb Geochronology of Charnockite

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Citation: Shi et al., 2019. The Late Archean Tectonic Events in the Jining Area of North China Craton: New Evidence from Zircon SHRIMP U-Pb Geochronology of Charnockite. Acta Geologica Sinica (English Edition), 93(4): 1146–1148. DOI: 10.1111/1755-6724.14315

Objective

Early Precambrian rocks are widely distributed in the khondalite series belt of the North China Craton (NCC), and previous studies have shown that the metamorphic ages of ~2.5 Ga and ~1.95 Ga are widespread. The Neoarchean charnockite of the Yinshan Block has been a topic of great interest for understanding the Precambrian geology of the NCC. Although there is a broad consensus that there were two stages of the Late Neoarchean and Late Paleoproterozoic tectonic events in the northern margin of the NCC, there are still few reports of Archean research in the Jining area and ongoing controversy about whether the Jining area was involved in Archean tectonic events. SHRIMP zircon U-Pb dating of newly discovered charnockite and retrogressive biotite-hornblende gneisses together represent direct evidence for the superimposed reformation of two stages of Late Neoarchean and Paleoproterozoic tectonic thermal events in this region.

Methods

Charnockite and biotite-hornblende gneiss samples were collected near the south of Jining along the northern margin of the NCC (JN54–1: 112°56′48″E, 41°01′06″N; JN44–1: 112°57′19″E, 41°00′53″N; JN40–1: 112°35′26″E, 41°04′02″N). Samples were crushed and zircons were separated at the Langfang Regional Geological Survey Institute in Hebei Province, China. The internal structure of zircons was revealed with the cathodoluminescence imaging. Zircon U-Pb dating was carried out using the SHRIMP II instrument at the Beijing SHRIMP Center, Institute of Geology, Chinese Academy of Geological Sciences (Data in Appendix 1). Samples were collected from the eastern segment of the khondalite series belt, which is sandwiched between the Yinshan and Ordos Blocks in the Western Block, east of the Central Orogenic Belt of the Jining area in the NCC. We aim to study the petrogenesis and tectonic geological significance of the charnockite and retrograde metamorphic biotite-hornblende gneiss by means of petrogeochemistry and isotopic chronology.

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Results

Based on the SiO_2 content, the charnockite was divided into intermediate charnockite (SiO_2 content: 55.55–63.70 wt%; composed of hypersthene (3%), diopside (2%), plagioclase (50%), microcline (25%), and quartz (15%)) and silicic charnockite (SiO_2 content: 69.99–71.79 wt%; composed of hypersthene (3%), diopside (2%), plagioclase (35%), microcline (40%), and quartz (20%)). The retrograde metamorphic biotite-hornblende gneiss was composed of plagioclase (35%), microcline (40%), quartz (15%), and biotite (5%). Zircon grains from these samples were 100–200 μm in length and usually had core–mantle–rim structures. A portion of the core zircons were completely dissolved and replaced by mantle zircon (4.1C and 11.1C in Fig. 1c). A portion of the core and mantle zircons had textural and compositional features similar to both metamorphic and magmatic zircons; they also had homogenous or blurred oscillatory zoning, with a high U content, but the Th/U ratios were 0.20–0.47; all of these characteristics may indicate an anatectic origin. Some gray mantle zircons and white-edged zircon had typical metamorphic zircon characteristics. The zircon U-Pb dating data can be classified into three groups. ① Core and mantle zircons of anatectic origin yielded $^{207}Pb/^{206}Pb$ weighted-mean ages of 2,469 ± 9 Ma (MSWD=1.6, n=6; Th/U=0.33–0.51; Fig. 1c, 4.1C, 5.1C, 7.1C, 11.1C, 13.1C, 15.2C) and 2,474 ± 15 Ma (MSWD = 0.63, n=2; Th/U=0.20–0.47; Fig. 1b, 4.1M, 5.1M), and metamorphic recrystallized zircon yielded $^{207}Pb/^{206}Pb$ weighted ages of 2492±29 Ma (MSWD=2.0, n=4; Th/U=0.31–0.37; Fig. 1a, 1.1C, 8.1C, 9.1C, 10.1C), which represent a stage of metamorphic anatectic events related to the Late Neoarchean tectonic thermal events. ② The gray mantle-rim zircons of metamorphic origin yielded $^{207}Pb/^{206}Pb$ weighted-mean ages of 1921±8 Ma (MSWD=0.96, n=3; Th/U=0.01–0.07), 1918±9 Ma (MSWD=2.0, n=7; Th/U=0.39–3.67), and 1944±30 Ma (MSWD=2.0, n=5, Th/U=0.58–3.66), which were related to a stage of Paleoproterozoic tectonic thermal events. ③ The metamorphic white-edged zircon was very narrow, and we only obtained $^{207}Pb/^{206}Pb$ weighted-mean ages of 1851±12 Ma (Th/U=0.15), which may be related to a ~1.85 Ga metamorphic event in the NCC. The Jining charnockite and biotite–hornblende gneiss are strongly depleted in

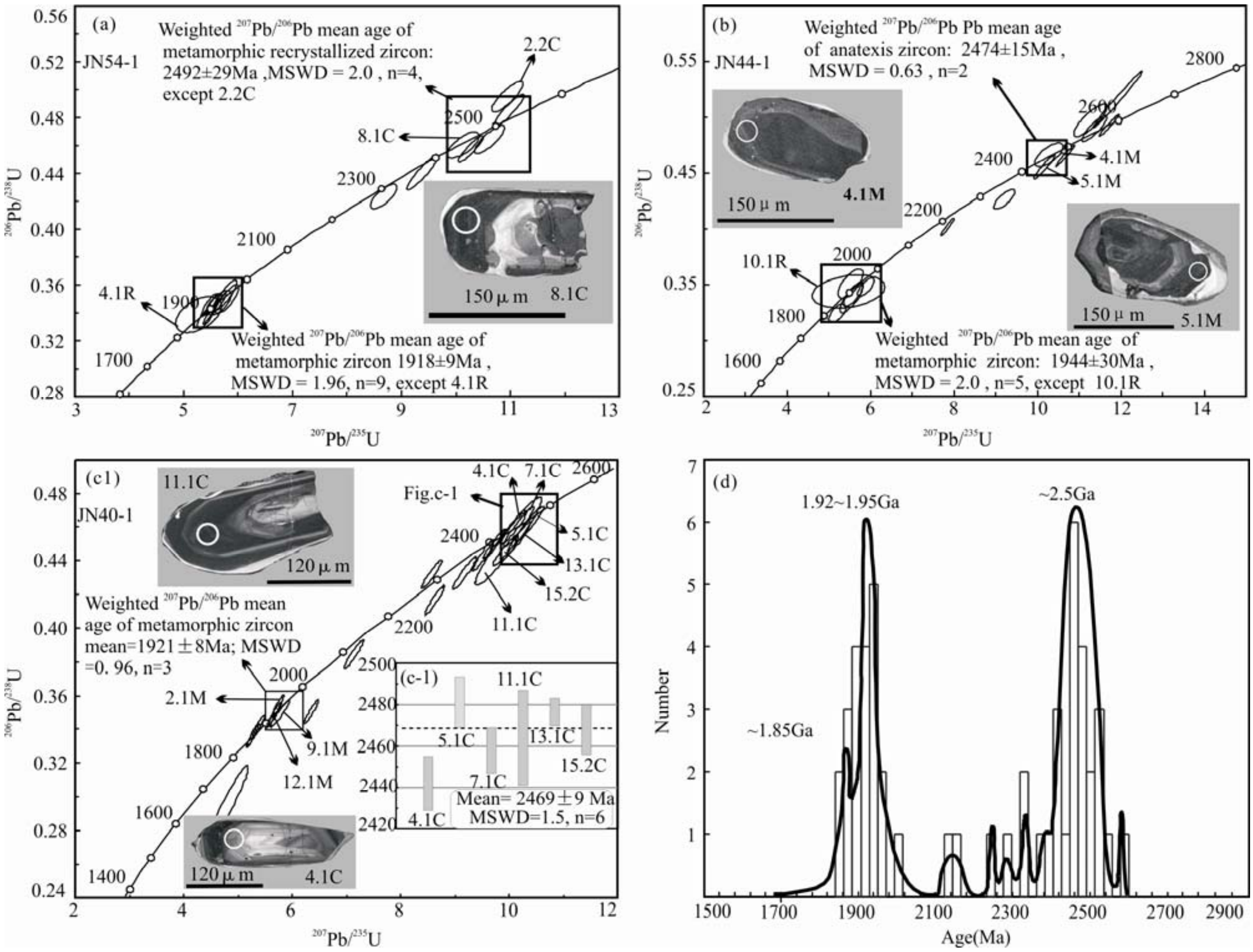

Fig. 1. SHRIMP zircon U-Pb concordia diagram of silicic charnockite (a), intermediate charnockite (b), biotite–hornblende gneiss (c) and age histogram diagram (d).

LILEs (e.g., Cs), heat-producing elements (e.g., U and Th), and HFSEs (e.g., Nb, Ta, P, and Ti), and enriched in Sr, and also exhibit both positive and negative Eu anomalies.

Conclusions

We report our new discovery of ~2.5 Ga charnockite and biotite–hornblende gneiss from the Jining area of the North China Craton, and obtained metamorphism ages of 1.92–1.95 Ga and ~1.85 Ga. Based on comparison with previous studies, we confirmed that the Jining area shows superimposed reformation of two stages of late Neoarchean and Paleoproterozoic tectonic thermal events (Fig. 1d). In a summary, similar to the Archaean subduction of oceanic crust tectonic event of Wuchuan–Guyang–Xiwulanbulang–Siziwangqi areas of Inner Mongolia (North China Craton), we confirmed the Jining area might be involved in the subduction of oceanic crust event, which had commenced at the time before ~2.47Ga. They are strongly modified by the metamorphism of the Paleoproterozoic collision orogeny event of the North China Craton.

Acknowledgments

This research was supported by the National Natural Science Foundation of China (grants No. 41872194, 41872203).

Appendix 1 SHRIMP U-Pb data of zircons from charnokite and biotite-hornblende gneiss in the Jining area

Spot No.	U	Th	Th/U	Isotope ratio						Isotopic age				Discordance (%)
	ppm	ppm		$^{207}Pb/^{206}Pb$	±%	$^{207}Pb/^{235}U$	±%	$^{206}Pb/^{238}U$	±%	$^{206}Pb/^{238}U$	1σ	$^{207}Pb/^{206}Pb$	1σ	
JN40-1														
1.1R	241.80	36.07	0.15	0.1132	0.6683	5.2296	1.5444	0.3351	1.3923	1862.9	±23	1851.4	±12	-1
1.2M	877.41	56.53	0.06	0.1142	0.3159	5.3650	1.3657	0.3407	1.3287	1890.2	±22	1867.3	±6	-1
2.1M	1929.9	23.04	0.01	0.1175	0.2506	5.7138	1.3326	0.3526	1.3088	1947.1	±22	1918.9	±4	-1
3.1C	554.51	114.72	0.21	0.1489	0.3842	8.5321	1.4061	0.4155	1.3526	2240.2	±26	2333.5	±7	4
4.1C	198.32	93.93	0.47	0.1587	0.7558	10.0607	1.6038	0.4597	1.4146	2438.3	±29	2442.1	±13	0
5.1C	225.08	113.93	0.51	0.1626	0.7781	10.3511	1.7329	0.4618	1.5484	2447.7	±32	2482.4	±13	1
6.1C	631.15	238.61	0.38	0.1530	0.6595	9.1172	1.6357	0.4321	1.4968	2315.3	±29	2380.0	±11	3
7.1C	790.52	259.09	0.33	0.1602	0.6412	10.1683	1.8477	0.4603	1.7328	2440.7	±35	2458.1	±11	1
8.1M	584.40	32.13	0.05	0.1345	0.8337	7.1118	1.6998	0.3834	1.4813	2092.2	±26	2157.9	±15	3
9.1M	2278.12	18.96	0.01	0.1198	1.4012	5.7517	2.0379	0.3481	1.4797	1925.5	±25	1953.8	±25	1
9.1C	1174.25	539.87	0.46	0.1446	0.7250	8.6172	1.5028	0.4321	1.3163	2315.4	±26	2283.3	±12	9
10.1M	805.36	62.36	0.08	0.1319	0.3368	6.3568	1.3962	0.3495	1.3549	1932.2	±23	2123.6	±6	-1
11.1C	159.34	72.09	0.45	0.1608	1.3531	9.6519	4.2176	0.4355	3.9946	2330.3	±78	2463.6	±23	5
12.1M	2321.1	18.82	0.01	0.1178	0.3618	5.6397	1.4608	0.3473	1.4153	1921.9	±24	1922.5	±6	0
13.1C	323.59	155.64	0.48	0.1620	0.3970	10.1220	1.4312	0.4532	1.3751	2409.3	±28	2476.6	±7	3
14.1M	611.48	97.04	0.16	0.1568	0.5087	9.7194	1.4250	0.4497	1.3311	2393.9	±27	2421.0	±9	1
15.1M	750.77	88.04	0.12	0.1559	0.2514	9.5248	1.4403	0.4432	1.4182	2365.0	±28	2411.3	±4	2
15.2C	373.47	141.91	0.38	0.1612	0.7115	9.9224	1.6016	0.4464	1.4349	2379.4	±29	2468.3	±12	4
16.1M	713.73	47.20	0.07	0.1180	0.5471	4.7997	4.9307	0.2949	4.9003	1666.2	±72	1926.5	±10	14
JN44-1														
1.1C	253.19	156.55	0.62	0.1677	0.4324	11.9203	3.3311	0.5155	3.3029	2680.2	±72	2534.8	±7	-6
2.1C	573.24	308.94	0.54	0.1725	0.2808	11.7131	1.3718	0.4924	1.3427	2581.1	±29	2582.3	±5	0
3.1R	16.45	22.78	1.38	0.1190	1.9909	5.5496	3.2310	0.3382	2.5447	1877.8	±41	1941.6	±36	3
4.1M	333.23	157.13	0.47	0.1598	1.5959	10.2765	2.1978	0.4664	1.5111	2467.5	±31	2453.8	±27	-1
5.1M	221.87	45.34	0.20	0.1620	0.4749	10.1629	1.6459	0.4551	1.5759	2418.0	±32	2476.2	±8	2
6.1R	14.41	8.35	0.58	0.1142	2.5700	5.5181	3.5642	0.3504	2.4695	1936.6	±41	1867.5	±46	-4
7.1C	322.37	220.17	0.68	0.1645	1.3159	11.2738	2.3498	0.4971	1.9468	2601.4	±42	2502.2	±22	-4
8.1C	485.18	229.78	0.47	0.1416	0.3595	7.8408	1.3835	0.4016	1.3360	2176.2	±25	2247.1	±6	3
9.1R	82.77	302.91	3.66	0.1229	1.5593	5.8872	2.2232	0.3474	1.5847	1922.2	±26	1998.9	±28	-1
10.1R	12.85	9.47	0.74	0.1153	10.2061	5.4257	10.611	0.3412	2.9056	1892.5	±48	1885.0	±184	4
11.1C	484.09	258.02	0.53	0.1662	0.2934	10.6711	1.3863	0.4657	1.3549	2464.9	±28	2519.5	±5	2
12.1R	69.62	95.76	1.38	0.1164	2.0141	5.2010	2.6029	0.3241	1.6488	1809.7	±26	1901.5	±36	5
13.1C	421.47	237.64	0.56	0.1683	0.8655	11.3657	1.7541	0.4898	1.5257	2569.9	±32	2540.7	±15	-1
14.1C	483.21	142.84	0.30	0.1566	1.1708	9.2060	1.7895	0.4264	1.3533	2289.5	±26	2419.1	±20	5
15.1R	22.99	44.74	1.95	0.1189	1.7298	5.5972	2.7323	0.3413	2.1150	1893.1	±35	1940.2	±31	2
JN54-1														
1.1C	208.81	64.95	0.31	0.1659	0.9406	10.6199	1.7075	0.4642	1.4251	2458.2	±29	2516.8	±16	-6
1.2R	81.92	58.39	0.71	0.1166	1.2016	5.4164	2.0037	0.3370	1.6034	1872.0	±26	1904.5	±22	0
2.1R	67.44	77.87	1.15	0.1183	1.9024	5.6587	2.5270	0.3468	1.6634	1919.3	±28	1931.4	±34	3
2.2C	789.20	323.89	0.41	0.1604	0.9422	10.9468	1.7503	0.4948	1.4751	2591.6	±31	2460.4	±16	-1
3.1R	142.91	129.39	0.91	0.1162	0.9002	5.5481	1.7262	0.3463	1.4729	1917.0	±24	1898.4	±16	2
3.2C	700.15	268.40	0.38	0.1598	1.3465	10.1380	1.8871	0.4603	1.3223	2440.7	±27	2453.1	±23	-4
4.1R	17.10	62.70	3.67	0.1130	4.6272	5.2717	5.2788	0.3384	2.5406	1879.0	±41	1847.9	±84	-4
5.1C	371.88	222.15	0.60	0.1486	1.2338	8.6729	1.8469	0.4232	1.3743	2275.2	±26	2330.1	±21	3
6.1R	32.29	42.87	1.33	0.1204	1.4558	5.8103	2.4254	0.3499	1.9400	1934.2	±32	1962.6	±26	-1
6.2C	211.65	206.17	0.97	0.1188	1.1656	5.7706	2.3297	0.3524	2.0171	1946.2	±34	1937.6	±21	4
7.1R	116.13	190.77	1.64	0.1150	0.9079	5.4775	1.7964	0.3454	1.5501	1912.8	±26	1879.9	±16	2
7.2R	311.36	195.47	0.63	0.1183	0.4870	5.6596	1.5041	0.3469	1.4231	1919.6	±24	1931.4	±9	5
8.1C	275.21	118.35	0.43	0.1629	0.5825	10.2737	1.4918	0.4574	1.3734	2428.2	±28	2485.9	±10	-1
9.1C	208.79	86.39	0.41	0.1545	0.7446	9.3866	2.0509	0.4405	1.9109	2352.9	±38	2396.9	±13	5
10.1C	158.85	59.34	0.37	0.1641	0.6619	10.9767	1.6611	0.4852	1.5235	2549.7	±32	2498.3	±11	
11.1R	533.60	205.56	0.39	0.1173	0.4209	5.4665	1.4124	0.3381	1.3482	1877.5	±22	1915.0	±8	2

Remark: C represent the core zircon, M represent the mantle zircon of zircon, R represent the rim zircon.