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Research Advances

Late Carboniferous Vertical Crustal Growth in Northern North China Craton: Evidence from Zircon U-Pb Age and Depleted Hf Isotope of the Dongwanzi Syenite

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Objective

Though the Central Asian Orogenic Belt (CAOB) is characterized by widespread Phanerozoic crustal growth, there is little juvenile crust documented in its southeastern segment, northern margin of the North China Craton (NCC) (Zhang et al, 2007, 2009). Late Carboniferous Dongwanzi ultramafic-mafic cumulate complex occurs in northern margin of the NCC and is intruded by a syenite with depleted Sr-Nd isotopes (Ma et al., 2014). However, the age and petrogenesis of this syenite is poorly constrained. In this study, we present new petrological, zircon U-Pb and Hf isotopic data of the Dongwanzi syenite, in order to put insights on its formation age and petrogenetic relationship with cumulates. We first suggest Late Carboniferous vertical crustal growth events in northern margin of the NCC.

Methods

Zircon grains were separated by conventional magnetic and density techniques, and then selected by hand picking under a binocular microscope. Cathodoluminescene (CL) images were taken at Peking University (Beijing) to identify the internal structures of individual zircon grains. According to CL images, the clear areas of zonings of zircon grains were chosen to operate U-Pb dating trial. Zircon U-Pb dating analyses for the Dongwanzi syenite were conducted by LA-MC-ICP-MS, and zircon Hf isotope analysis was carried out in situ using a Newwave UP213 laser-ablation microprobe, attached to a Neptune multi-collector ICP-MS, at the Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing. Zircon U-Pb analyses were carried out with a beam diameter of 25 μm, a repetition rate of 10 Hz, and energy of 2.5 J/cm^2. The zircons GJ-1 were used as internal standards during the analyses. In-situ zircon Hf isotopic analyses are on the same grains dated by U-Pb method and a stationary spot with a beam diameter of 44 μm was used. During the analysis, the ^{176}Hf/^{177}Hf and ^{176}Lu/^{177}Hf ratios of the standard zircon (GJ-1) were 0.282293 ± 15 (2σ$_n$, n = 20) and 0.00031, respectively.

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Results

Zircons from the syenite (DWZ-A) are euhedral, stubby and prismatic, and show pyramidal terminations and clear oscillatory zoning (Figure 1). Seventeen grains were analyzed; five grains with ages between 451 Ma and 354 Ma are inherited zircons. Remaining twelve grains yield a weighted mean ^{206}Pb/^{238}U age of 307 ± 1 Ma (MSWD = 1.3; Appendix 1; Figure 1). Zircon Hf isotopic data are shown in Appendix 2 and Figure 2. Initial isotopic ratios were calculated based on the zircon U-Pb age (307 Ma) of this study. Twelve spots yield ^{176}Hf/^{177}Hf ratios from 0.282730 to 0.282877, and show large ranges in εHf(t) values from +5.24 to +10.46.

Conclusion

Zircon U-Pb data of the Dongwanzi syenite show that it was formed at 307 Ma. The syenite is spatially and temporally associated with ultramafic-mafic cumulates. The Dongwanzi ultramafic-mafic cumulates were mixing

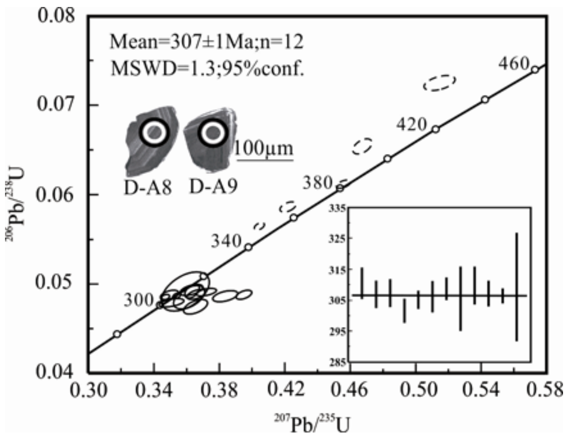

Fig. 1. Concordia diagrams showing zircon U-Pb age for Dongwanzi syenite.
Representative CL images of zircons from samples are also shown. Write circles are zircon U-Pb dating spots, and black circles are in-situ Lu-Hf analysis spots.

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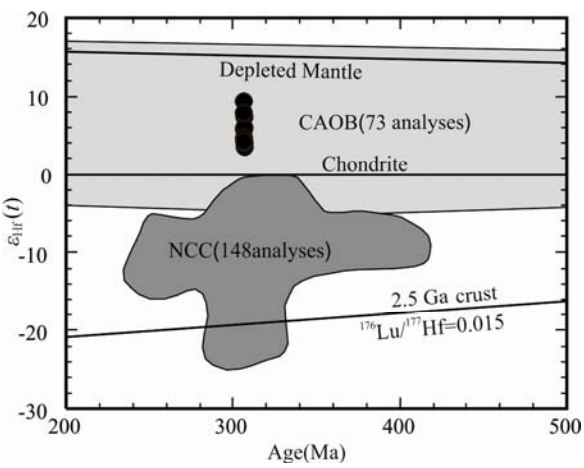

Fig. 2. Plot of zircon εHf(t) values of the Dongwanzi syenite.
Shadow data in the figure are based on Zhang et al (2007) and the references in it.

melts of depleted asthenospheric and enriched lithospheric sources. The syenite has positive zircon Hf isotopes similar to those of cumulates with depleted Nd-Hf isotopes, indicating that they are homologous magma mainly derived from asthenosphere melts endmember. With minor crustal contamination, fractional crystallization of ferromagnesian minerals from the parent magma gave rise to the cumulates and overlying syenite. The syenite may represent the juvenile crust originated from mantle-derived cumulate residual felsic melts in a back-arc extensional setting. Therefore, Late Carboniferous crustal growth occurred in northern margin of the NCC and a back-arc setting is an important site for vertical crustal growth.

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Appendix 1 LA-ICP-MS zircon U-Pb isotopic data for the Dongwanzi syenite.

Sample No.	Pb	Th (ppm)	U	Th/U	$^{207}Pb/^{206}Pb$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$	
					Ratio	1σ	Ratio	1σ	Ratio	1σ	Age (Ma)	1σ	Age (Ma)	1σ
D-A1	64	46	205	0.22	0.0514	0.0004	0.5146	0.0062	0.0725	0.0005	422	4.2	451	3.3
D-A2	504	353	788	0.45	0.0519	0.0003	0.4675	0.0038	0.0654	0.0005	389	2.6	408	3.3
D-A3	96	65	316	0.21	0.0540	0.0002	0.4559	0.0029	0.0612	0.0003	381	2.0	383	1.9
D-A4	104	76	324	0.24	0.0522	0.0003	0.4219	0.0032	0.0586	0.0004	357	2.3	367	2.3
D-A5	673	524	896	0.58	0.0520	0.0001	0.4045	0.0020	0.0565	0.0003	345	1.5	354	1.6
D-A6	97	103	236	0.44	0.0534	0.0007	0.3631	0.0046	0.0494	0.0004	314	3.4	311	2.4
D-A7	166	133	383	0.35	0.0520	0.0003	0.3497	0.0036	0.0488	0.0003	304	2.7	307	2.1
D-A8	358	283	870	0.32	0.0542	0.0002	0.3658	0.0037	0.0488	0.0003	317	2.7	307	2.1
D-A9	6	27	239	0.11	0.0531	0.0010	0.3508	0.0051	0.0479	0.0003	305	3.8	302	1.8
D-A10	3786	2745	1287	2.13	0.0519	0.0001	0.3469	0.0018	0.0485	0.0002	302	1.4	305	1.4
D-A11	160	117	352	0.33	0.0572	0.0006	0.3837	0.0051	0.0487	0.0004	330	3.7	306	2.4
D-A12	1381	889	1605	0.55	0.0550	0.0006	0.3721	0.0041	0.0491	0.0003	321	3.1	309	1.7
D-A13	77	49	395	0.12	0.0541	0.0007	0.3616	0.0064	0.0485	0.0008	313	4.8	306	5.1
D-A14	2919	2466	1120	2.20	0.0536	0.0005	0.3634	0.0031	0.0492	0.0005	315	2.3	310	2.9
D-A15	2698	2199	2380	0.92	0.0587	0.0003	0.3951	0.0032	0.0488	0.0003	338	2.3	307	1.9
D-A16	1579	1431	773	1.85	0.0527	0.0002	0.3540	0.0017	0.0487	0.0002	308	1.2	306	1.1
D-A17	1236	891	1266	0.70	0.0530	0.0005	0.3592	0.0098	0.0492	0.0014	312	7.3	309	8.6

Appendix 2 In situ LA-MC-ICP-MS zircon Lu-Hf isotope analyses for the Dongwanzi syenite (T = 307 Ma)

Sample No.	$^{176}Yb/^{177}Hf$	$^{176}Lu/^{177}Hf$	$^{176}Hf/^{177}Hf$(corr)	2sm	$^{176}Hf/^{177}Hf_i$	εHf(0)	εHf(t)	T_{DM1}(Hf)	T_{DM2}(Hf)	$f_{Lu/Hf}$
D-A6	0.008350	0.000304	0.282753	0.000037	0.282751	–0.67	6.01	695	938	–0.99
D-A7	0.014414	0.000516	0.282733	0.000024	0.282730	–1.38	5.26	727	986	–0.98
D-A8	0.021477	0.000779	0.282882	0.000060	0.282877	3.87	10.46	523	653	–0.98
D-A9	0.106119	0.003542	0.282860	0.000126	0.282840	3.12	9.15	596	737	–0.89
D-A10	0.093208	0.003300	0.282771	0.000022	0.282752	–0.03	6.04	727	936	–0.90
D-A11	0.091039	0.001462	0.282797	0.000021	0.282788	0.87	7.32	654	854	–0.96
D-A12	0.076602	0.001847	0.282761	0.000025	0.282750	–0.39	5.98	713	940	–0.94
D-A13	0.088298	0.001909	0.282839	0.000018	0.282828	2.38	8.74	600	764	–0.94
D-A14	0.020151	0.000403	0.282759	0.000024	0.282756	–0.47	6.19	689	926	–0.99
D-A15	0.064222	0.001827	0.282804	0.000020	0.282793	1.12	7.50	650	843	–0.94
D-A16	0.078470	0.001437	0.282755	0.000017	0.282746	–0.62	5.84	714	949	–0.96
D-A17	0.169370	0.004464	0.282845	0.000025	0.282819	2.58	8.42	636	784	–0.87