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Research Advances

The Discovery of ~310 Ma Back-Arc Basin Basalt in the West Junggar, Xinjiang, NW China and its Geological Significance

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Objective

Mafic magmas can form in different tectonic settings with various geochemical characteristics depending on their mantle sources. Basalts generated in back-arc basins provide valuable perspectives on mantle structure and composition, on controls for melt generation, and on the sources responsible for arc magma genesis. This is because back-arc basin basalts (BABB) are generated by decompression melting and erupt along spreading ridges in a manner indistinguishable from that of true MORB and in most compositional aspects are similar to MORB. At the same time, a subduction component also is clearly involved, so BABB provides insights into modifications of the mantle at convergent margins (Gribble et al., 1996).

Situated in the southwestern segment of the Central Asian Orogenic Belt, the West Junggar is considered to be an important area for Phanerozoic crustal growth owing to the occurrence of voluminous Carboniferous magmatism. The southern part of the West Junggar developed a suite of Carboniferous volcano-sedimentary strata and voluminous late Carboniferous to early Permian granitoids (Fig. 1a). However, the tectonic setting of the Late Carboniferous magmatism still remain controversial in the region, with three major competing viewpoints being proposed, i.e., post-collisional setting, subduction-related island-arc setting, and newly proposed ridge subduction model. Previous studies mainly concentrated on the voluminous granitoids and ophiolitic mélanges in the area, with less attention paid to the volcanic rocks.

This work studied the newly discovered Late Carboniferous (~310 Ma) back-arc basin basalts (BABB) from the Chengjisihanshan Formation in the southern West Junggar to determine its formation age and tectonic environment, magma source and petrogenesis, providing new constraints for the tectonic evolution of the Junggar Ocean in the Late Carboniferous.

Methods

LA-ICP-MS zircon U-Pb isotopic dating and in situ zircon Hf isotope analyses were conducted at the Key Laboratory for the Study of Focused Magmatism and Giant Ore Deposits, MNR, Xi'an Center of Geological Survey, CGS. Laser sampling was performed using a GeoLas Pro. An Agilent 7700x ICP-MS instrument was used to acquire ion-signal intensities. In situ zircon Hf isotope analyses were performed using a Geolas Pro laser-ablation system coupled to a Neptune multiple-collector ICP-MS. Zircon GJ-1 was used as the reference standard and yielded a weighted mean $^{176}Hf/^{177}Hf$ ratio of 0.282030±40 (2SE). Major and trace element analyses were conducted at the Key Laboratory for the Study of Focused Magmatism and Giant Ore Deposits, MNR, Chang'an University. Bulk-rock major element oxides were analysed using SHIMADZU LAB CENTER XRF-1800 sequential scanning X-ray fluorescence spectrometer. Trace elements were analysed using Thermo-X7 inductively coupled plasma mass spectrometry (ICP-MS).

Results

One sample from the basalt was chosen for age determination. Zircons separated from the basalt have well-developed but incomplete crystal morphology, and are half-baked with indistinct growth zoning or no growth zoning, and also lack visible inherited cores in cathodoluminescence images (Fig. 1b). The U-Pb isotope analytical results of 29 zircons have Th/U ratios of 0.37–0.75 and with concordant $^{206}Pb/^{238}U$ ages ranging from 304 to 319 Ma, which obtained a concordant age of 310.3±3.9 Ma (n=29, MSWD=0.16), representing the crystallization age of the basalt.

Zircons from the Late Carboniferous basalts possess relatively homogeneous Hf isotopic compositions. Ten zircon spot Hf isotopic analyses were obtained for the basalt sample (ca. 310 Ma), yielding variable $\varepsilon_{Hf}(t)$ values of between −8.1 and 15.7, with two-stage model ages (T_{DM2}) mainly between 321 and 481 Ma, only three ancient ages of 909Ma, 1069Ma and 1840Ma, and giving initial $^{176}Hf/^{177}Hf$ ratios ranging from 0.282357 to 0.283027 (0.282884 on average), indicating their depleted mantle features.

Eight basalt samples were selected for geochemical analysis. Whole-rock compositions suggest that the basalts are of sub-alkaline tholeiitic showing geochemical characteristics similar to those of island arc basalt (IAB), with low TiO_2 (1.09wt%–1.36wt%) and K_2O (0.32wt%–0.74wt%), medium SiO_2 (47.76wt%–52.06wt%), high TFe_2O_3 (11.20wt%–13.58wt%), MgO (6.55wt%–7.68wt%, $Mg^{\#}$=53–59), Al_2O_3 (13.26wt%–14.39wt%) and Na_2O (2.34wt%–4.00wt%). The studied basalts are low in

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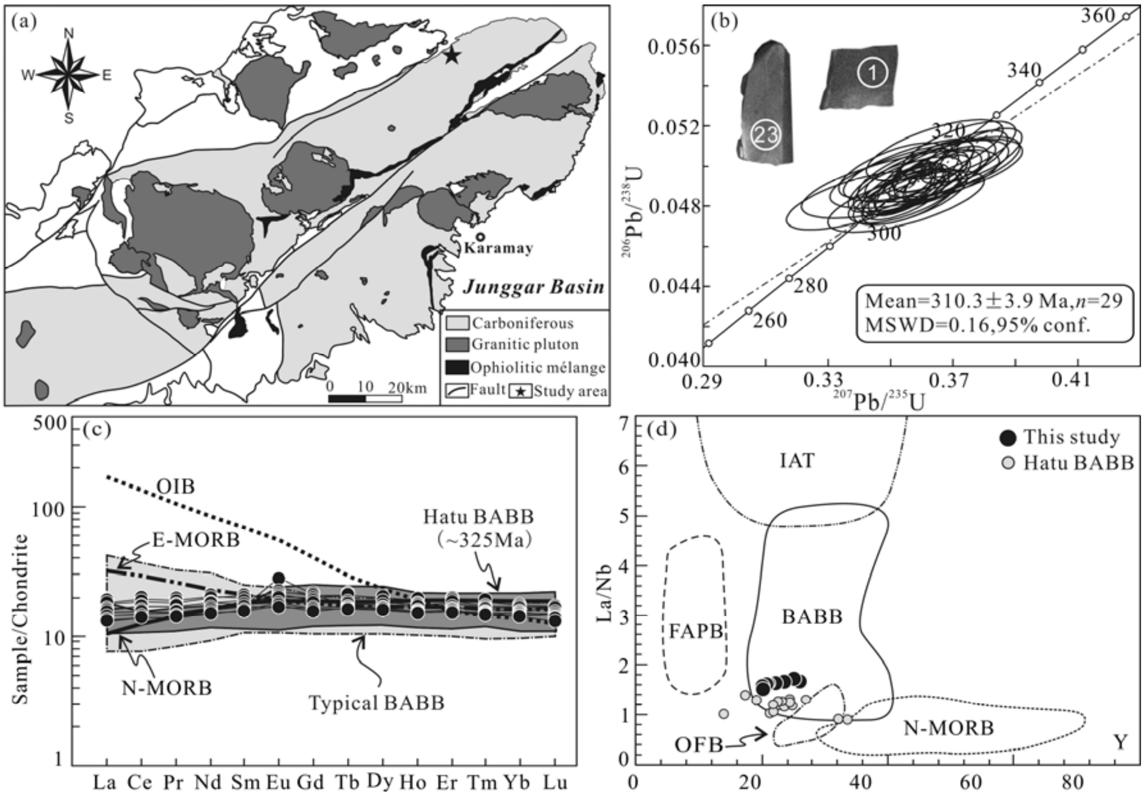

Fig. 1. Regional geological map of the southern West Junggar, NW China(a), U-Pb concordia diagram of zircon grains (b), chondrite-normalized rare earth element patterns (c) and La/Nb-Y diagram (d) for the basalts of the Chengjisihanshan Formation in West Junggar.

REE (ΣREE=37.83–49.83 ppm), exhibit slightly flat REE patterns with $(La/Yb)_N$=0.87–1.07, weak or no Eu anomaly (Eu/Eu^*=0.99–1.16, only one sample 1.48), and have ratios of Lu/Yb (~0.15), Zr/Y (~2.53) and Y/Tb (~34), which are similar to those of normal mid-oceanic ridge basalts (N-MORB), but relatively enriched in large ion lithophile elements (LILE) such as Rb, Ba, K, U and Sr with weak negative Nb, Ta, Ti and P anomalies, display the affinities of IAB (Perfit et al., 1980) or typical BABB (Gribble et al., 1996) and Early Carboniferous BABB in the Hatu (ca. 325 Ma; Shen et al., 2013), southern West Junggar (Figs. 1c and 1d), suggesting that the basalts were derived from 5% to 10% partial melting of a spinel lherzolite-depleted mantle source metasomatized by subducted fluids.

Conclusion

Based on new geochronological and geochemical data, this study determines the Late Carboniferous (310.3±3.9 Ma) tholeiites from the Chengjisihanshan Formation in southern West Junggar, which are similar to back-arc basin basalts exhibiting both MORB-like and arc-like geochemical characteristics, and are produced by partial melting of depleted spinel iherzolite mantle source with the participation of small amount of subducted fluids under back-arc basin tectonic setting.

The discovery and confirmation of the Late Carboniferous back-arc basin basalts indicate that the Junggar Ocean had not been closed before 310 Ma, and thus, an intra-oceanic arc and back-arc basin system was proposed for the Late Carboniferous evolution of the west Junggar.

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References

Gribble, R.F., Stern, R.J., Bloomer, S.H., Stüben, D., O'Hearn, T., and Newman, S., 1996. MORB mantle and subduction components interact to generate basalts in the southern Mariana Trough back-arc basin. *Geochimica et Cosmochimica Acta*, 60(12): 2153–2166.

Perfit, M.R., Gust, D.A., Bence, A.E., Arculus, R.J., and Taylor, S.R., 1980. Chemical characteristics of island-arc basalts: Implications for mantle sources. *Chemical Geology*, 30(3): 227–256.

Shen, P., Pan, H.D., Xiao, W.J., Li, X.H., Dai, H.W., and Zhu, H.P., 2013. Early Carboniferous intra-oceanic arc and back-arc basin system in the West Junggar, NW China. *International Geology Review*, 55(16): 1991–2007.

Appendix 1 LA-ICP-MS zircon U-Pb isotopic analysis of the basalts from the Chengjisihanshan Formation in West Junggar, NW China

Spot	Isotope content (ppm)			Isopotic ratios						Age (Ma)					
	Th	U	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ
CJSH-1	391.7	726.0	0.54	0.05281	0.00157	0.36365	0.01056	0.05000	0.00105	321	32	315	8	315	6
CJSH-2	252.1	338.0	0.75	0.05372	0.00269	0.36957	0.01784	0.04995	0.00123	359	65	319	13	314	8
CJSH-3	80.42	167.6	0.48	0.05215	0.00199	0.35567	0.01320	0.04952	0.00110	292	46	309	10	312	7
CJSH-4	146.2	329.6	0.44	0.05338	0.00231	0.35632	0.01493	0.04846	0.00113	345	54	309	11	305	7
CJSH-5	65.18	150.3	0.43	0.05354	0.00186	0.36635	0.01237	0.04967	0.00108	352	39	317	9	312	7
CJSH-6	209.9	340.1	0.62	0.05325	0.00284	0.36485	0.01879	0.04974	0.00126	339	71	316	14	313	8
CJSH-7	79.81	185.5	0.43	0.05313	0.00221	0.37169	0.01499	0.05079	0.00117	334	51	321	11	319	7
CJSH-8	385.0	717.1	0.54	0.05286	0.00154	0.35522	0.01009	0.04878	0.00102	323	31	309	8	307	6
CJSH-9	179.4	398.4	0.45	0.05315	0.00156	0.36221	0.01039	0.04947	0.00104	335	31	314	8	311	6
CJSH-10	237.7	554.2	0.43	0.05380	0.00150	0.36690	0.00999	0.04950	0.00103	363	29	317	7	311	6
CJSH-11	153.0	280.5	0.55	0.05111	0.00211	0.35057	0.01403	0.04979	0.00112	246	52	305	11	313	7
CJSH-12	79.81	155.7	0.51	0.05306	0.00228	0.35464	0.01480	0.04851	0.00111	331	54	308	11	305	7
CJSH-13	53.08	144.3	0.37	0.05287	0.00381	0.36144	0.02518	0.04962	0.00141	323	107	313	19	312	9
CJSH-14	92.88	185.4	0.50	0.05341	0.00318	0.35498	0.02044	0.04824	0.00125	346	84	308	15	304	8
CJSH-15	206.8	339.7	0.61	0.0528	0.00161	0.36357	0.01077	0.04998	0.00106	320	33	315	8	314	7
CJSH-16	163.5	401.1	0.41	0.05373	0.00170	0.37348	0.01147	0.05045	0.00108	360	34	322	8	317	7
CJSH-17	173.5	412.5	0.42	0.05299	0.00175	0.35494	0.01134	0.04861	0.00105	328	36	308	8	306	6
CJSH-18	291.4	588.9	0.49	0.05365	0.00132	0.36478	0.00880	0.04934	0.00100	356	25	316	7	310	6
CJSH-19	23.31	48.31	0.48	0.05217	0.00395	0.35316	0.02587	0.04912	0.0014	293	115	307	19	309	9
CJSH-20	37.95	89.99	0.42	0.05202	0.00265	0.36414	0.01788	0.05079	0.00124	286	68	315	13	319	8
CJSH-21	235.0	581.3	0.40	0.05273	0.00138	0.35583	0.00909	0.04896	0.00100	317	27	309	7	308	6
CJSH-22	96.16	236.7	0.41	0.05269	0.00174	0.35479	0.01140	0.04886	0.00105	315	37	308	9	308	6
CJSH-23	313.9	699.3	0.45	0.05419	0.00175	0.37759	0.01182	0.05055	0.00108	379	35	325	9	318	7
CJSH-24	241.6	486.2	0.50	0.05253	0.00218	0.35548	0.01422	0.04909	0.00113	309	51	309	11	309	7
CJSH-25	79.59	195.7	0.41	0.05338	0.00196	0.35630	0.01265	0.04841	0.00107	345	42	309	9	305	7
CJSH-26	70.08	98.68	0.71	0.05104	0.00294	0.33989	0.0190	0.04830	0.00120	243	83	297	14	304	7
CJSH-27	197.6	274.0	0.72	0.05230	0.00300	0.35926	0.01991	0.04982	0.00128	299	80	312	15	313	8
CJSH-28	93.30	224.7	0.42	0.05190	0.00177	0.35061	0.01156	0.04899	0.00106	281	39	305	9	308	7
CJSH-29	465.0	887.1	0.52	0.05273	0.00120	0.35488	0.00791	0.04881	0.00098	317	23	308	6	307	6