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Research Advances

SHRIMP Zircon U-Pb Age of the Piqiang Layered Intrusion in the Tarim Large Igneous Province and Subducted Slab-Plume Interaction in Its Petrogenesis

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Objective

During the Permian, at least four mafic continental large igneous provinces (LIPs) were formed in eastern Asia, i.e., the Siberian traps (~251 Ma), Emeishan LIP (~260 Ma), Tarim LIP (~290–270 Ma) and Panjal traps (~290 Ma) (Shellnutt et al., 2015). The Emeishan and Tarim LIPs in China are both known for the presence of several magmatic Fe-Ti-V oxide deposits hosted in layered mafic-ultramafic intrusions. The origin of such magmatic Fe-Ti-V oxide deposits is enigmatic. One of the long-lasting debates is the mechanism by which large amounts of Fe-Ti oxides accumulated in the layered intrusions. Regardless of mechanism, there is still considerable debate regarding the mantle source compositions of the Fe-Ti-V oxide ore-bearing intrusions. In the Tarim LIP, a giant Fe-Ti-V oxide deposit is hosted by the Piqiang layered intrusion at the northern margin of the Tarim block. This intrusion consists mainly of gabbro and minor plagioclase-bearing clinopyroxenite and anorthosite (Fig. 1a). For this study we present new SHRIMP zircon U-Pb age and whole-rock geochemical data for the Piqiang layered gabbroic intrusion to evaluate the nature of its possible source compositions, which in turn aids in understanding the formation of the giant Fe-Ti-V oxide deposit in the plume-related LIPs.

Methods

Zircon U-Pb age determination was performed using the

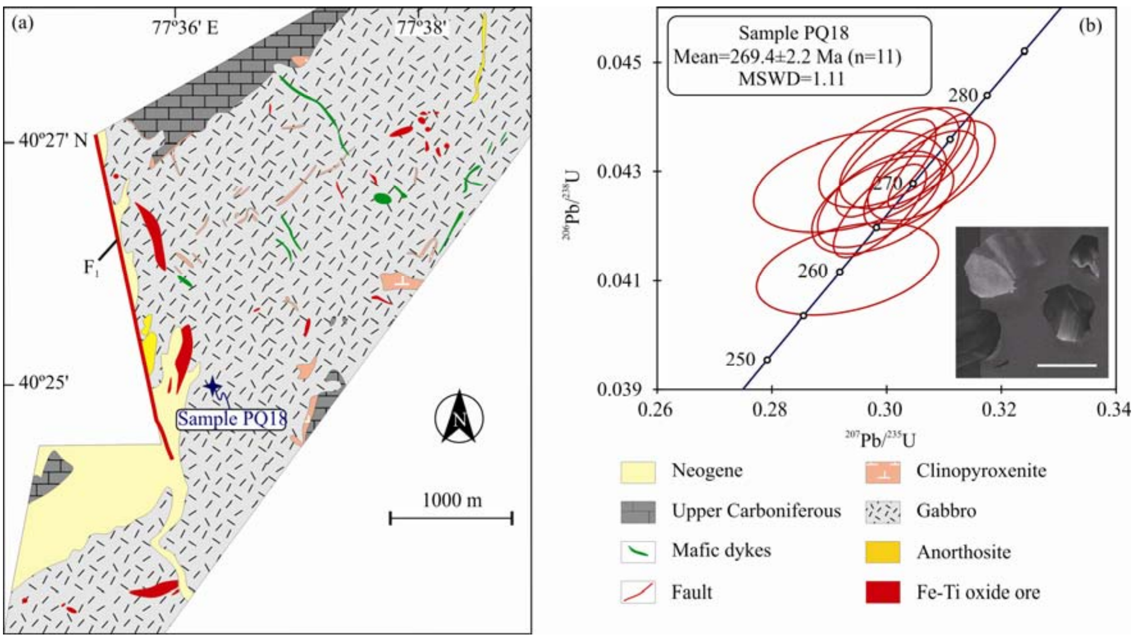

Fig. 1. (a), Geological map of the Piqiang layered intrusion, Atushi County, with sample locations for U-Pb dating; (b), U-Pb concordia diagram and CL image of zircons from the Piqiang layered intrusion. The length of white line in CL image denotes 100 μm.

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SHRIMP II instrument at the Beijing SHRIMP Center, Chinese Academy of Geological Sciences. Whole-rock major and trace element analyses were analyzed using Rigaku ZSX-100e X-ray fluorescence spectrometry and PerkinElmer Sciex ElAN 6000 inductively coupled plasma mass spectrometry (ICP-MS) at Guangzhou Institute of Geochemistry, Chinese Academy of Sciences (GIG-CAS), respectively. Whole-rock Sr-Nd-Hf isotopic analyses were carried out using a Neptune Plus multi-collector ICP-MS at GIG-CAS.

Results

Zircon crystals of sample PQ18, collected from the gabbro zone at 40°24′51.3″N, 77°36′11.4″E, show parallel zoning and have fragmented, euhedral-subhedral textures (Fig. 1b). The zircons from PQ18 have variable U (633–9002 ppm) and Th (63–5531 ppm) contents, yielding Th/U ratios of 0.17–0.61, with the exception of one analyse (PQ18@6) which tend to have Th/U ratios <0.1 due to the significantly low Th and relatively high U contents (Appendix 1). Analyses of eleven individual zircon crystals form a single age group and yield a mean $^{206}Pb/^{238}U$ age of 269.4 ± 2.2 Ma with a mean square of weighted deviates (MSWD) of 1.11 (Fig. 1b) (Appendix 1). The new zircon U-Pb age therefore confirms that the Piqiang intrusion was formed more than 6 Ma later than the emplacement of the Wajilitag intrusion (282±4 Ma; Cao Jun et al., 2017).

Gabbros from the Piqiang intrusion show a very wide range of chemical compositions. In the chondrite normalized REE diagram, the Piqiang gabbros are characterized by a slight to moderate enrichment of the light REE over the heavy REE ($(La/Yb)_N$ = 2.0–7.57) with positive Eu anomalies (Eu/Eu^*=0.88–2.12). The primitive mantle-normalized incompatible trace element diagrams show a slight enrichment of the large-ion lithophile elements (LILE) (e.g., Cs, Rb, Ba), pronounced positive Sr, Ti anomalies and depletions in Th, Nb, Ta, Zr and Hf. These patterns are clearly different from those of the Wajilitag intrusion, which are characterized by strong light REE and LILE enrichment and apparently positive Nb, Ta, Zr and Hf anomalies.

Initial $^{87}Sr/^{86}Sr$ and ε_{Nd} (t=269.4 Ma) values of the Piqiang gabbros range from 0.7051 to 0.7063 and from −2.27 to 0.93, respectively. These rocks have negative ε_{Hf} (t) values of −6.14 to −0.53. The whole-rock Nd-Hf isotope compositions for the Piqiang gabbros plot within the OIB field but slightly below the mantle array line, showing weak decoupling ($\Delta\varepsilon_{Hf}$ = −4.14 to −1.59).

Conclusions

The Piqiang intrusion was dated by the SHRIMP zircon U-Pb method at 269.4±2.2 Ma. The gabbros of the Piqiang intrusion have whole-rock Nd-Hf isotope compositions that display weak decoupling. The decoupling is possibly linked with recycled subduction-related materials in the mantle source that were derived from the early-middle Paleozoic subducted oceanic slab. Partial melting of an upwelling mantle plume involving contamination of newly subducted oceanic slab may play an important role in the generation of the Piqiang Fe-Ti-V oxide ore-bearing layered intrusion.

Acknowledgements

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Appendix 1 SHRIMP zircon U-Pb data for the Piqiang layered intrusion

Samples	Spot	$^{206}Pb^a$ (ppm)	$^{206}Pb^b$ (%)	U (ppm)	Th (ppm)	$^{232}Th/^{238}U$	$^{207}Pb/^{206}Pb$	±1σ (%)	$^{207}Pb/^{235}U$	±1σ (%)	$^{206}Pb/^{238}U$	±1σ (%)	$t_{206/238}$ (Ma)	±1σ (%)	$t_{207/206}$ (Ma)	±1σ	$t_{208/232}$ (Ma)	±1σ (%)
PQ18	1	91.9	0.12	2526	581	0.24	0.05126	1.2	0.2988	1.8	0.04228	1.3	266.9	3.5	253	27	263.9	5.1
	2	27.0	0.00	730	191	0.27	0.05190	1.9	0.3078	2.4	0.04301	1.4	271.5	3.7	281	44	263.0	7
	3	334	0.01	9002	5531	0.63	0.05163	0.77	0.3074	1.5	0.04319	1.3	272.6	3.6	269	18	269.3	4.9
	4	23.4	0.39	633	109	0.18	0.0497	3.5	0.294	3.8	0.04281	1.4	270.2	3.8	183	81	222	19
	6	38.1	0.22	1024	63	0.06	0.0504	2.3	0.3004	2.7	0.04325	1.4	272.9	3.7	213	53	199	30
	7	32.5	--	894	185	0.21	0.0512	2.3	0.2993	2.7	0.04239	1.4	267.6	3.7	250	54	279	11
	8	56.3	0.00	1521	457	0.31	0.05051	1.4	0.2998	1.9	0.04306	1.4	271.8	3.7	218	31	259.7	5.1
	9	26.4	0.21	708	153	0.22	0.0509	2.1	0.3036	2.6	0.04324	1.4	272.9	3.8	237	49	244.9	8.9
	10	73.3	0.46	2060	590	0.30	0.0516	3.3	0.293	3.6	0.04121	1.4	260.3	3.5	268	76	261	13
	11	44.3	0.01	1213	240	0.20	0.05100	2.0	0.2988	2.4	0.04249	1.4	268.3	3.6	241	45	270.7	9.3
	12	40.8	0.04	1107	231	0.22	0.05181	1.6	0.3060	2.1	0.04283	1.4	270.4	3.7	277	37	264.4	6.8

Pb^a and Pb^b indicate the radiogenic and common portions, respectively.