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Research Advances

Termination Time of the Emeishan Basalts in the Buotuo Region, SW China

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Objective

The Emeishan Large Igneous Province (LIP) is considered to represent a major Later Permian basaltic magmatism in the western margin of the Yangtze Block in South China. Previous geochronological studies on mafic intrusion and felsic ignimbrite have assigned an eruption age of 259–263 Ma for the Emeishan LIP (Zhong et al., 2010), accompanied by regional domal uplift (Mabi Awei et al., 2017). The Xuanwei Formation was formed after the termination of the Emeishan flood basalt volcanism. The uppermost silicic members in the center of the LIP were eroded first and the "felsic" materials were transported and deposited in the eastern LIP, forming the lowermost part of the Xuanwei Formation. In this study, we report new data related to zircon LA-ICP-MS U-Pb and Hf isotope analysis at the bottom of Xuanwei Formation in the Butuo region of Sichuan Province, SW China. These data provide important insight into understanding the termination of the Emeishan LIP.

Methods

Zircon U-Pb dating and Lu-Hf isotopic analyses were conducted by LA-MC-ICP-MS at the State Key Laboratory of the Continental Dynamics, Northwest University. Detailed operation conditions for the laser ablation system and the MC-ICP-MS instrument and data reduction were described by Yuan et al. (2008). Off-line raw data selection and integration of background and analyze signals, time-drift correction and quantitative calibration for U-Pb dating were performed by Glitter4.0. Zircon 91500 and NIST610 was used as external standard for U-Pb dating and was analyzed twice every 5–10 analyses. Concordia diagrams and weighted mean calculations were made using Isoplot ver2.49. In-situ zircon Hf isotopic analyses were carried out on the dated spots using the Nu Plasma Ⅱ MC-ICP-MS, equipped with a 193 nm laser. During analyses, the standard zircon 91500 and Mud tank were 0.282307 and 0.282523. The detailed analytical technique and data correction procedure are described in Yuan et al. (2008).

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Results

Geochemical and its lithofacies paleogeography indicates that sedimentary tuff at the bottom of Xuanwei Formation originates from acid-volcanic material at the top of the Emeishan basalt. Zircons from sedimentary tuff are dominated by light pink to colorless euhedral crystal. They have perfect pyramids and prism. The zircon CL images exhibit good oscillatory zoning, indicative of magma zircons. Some zircons contain the core of inherited zircon. Fourteen zircon spots analyses (not including inherited zircons) have $^{206}Pb/^{238}U$ ages ranging from 250 to 257 Ma (Appendix 1) with a weigh mean age of 254±2.0 Ma (MSWD=0.17, n=14) show that 14 points are mostly concordant within error (Fig. 1), which is interpreted as the magma crystallization age in the Butuo region.

Fourteen Lu-Hf analyses were acquired on 14 zircon grains. The zircons have $^{176}Lu/^{177}Hf$ ratios of 0.001049–0.003018 and $^{176}Hf/^{177}Hf$ ratios of 0.282503–0.282625 (Appendix 2). The zircon $\varepsilon_{Hf}(t)$ values range from 0.98 to 2.37, yielding Hf model ages (T_{DM1}) between 559 and 1008 Ma (Appendix 2), suggesting a major episode of continental growth in the Proterozoic and a predominantly, or even exclusively, mantle source for the sedimentary tuff.

Conclusion

In this study, zircon U-Pb data of sedimentary tuff at the bottom of the Xuanwei Formation formed at 254 Ma, which constrain the termination time of the Emeishan Large Province in the Butuo region. Our study also implies that the middle belt of the Emeishan LIP also underwent contamination with crust under eruption.

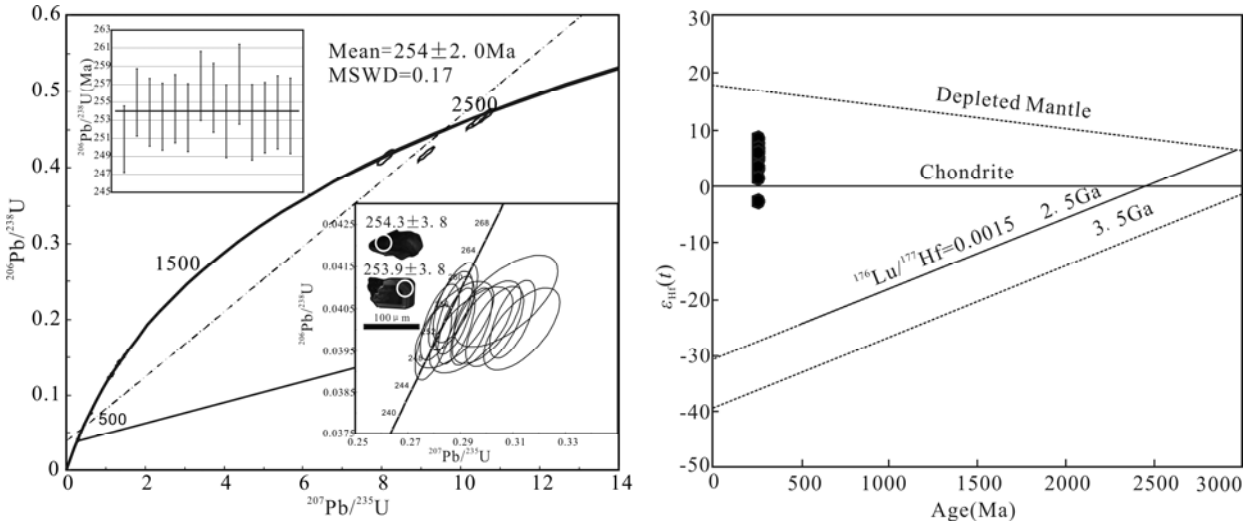

Fig. 1. LA-ICP-MS zircon U-Pb concordia diagrams for sedimentary tuff sample in the Buotuo region, Sichuan Province.

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Appendix 1 LA-ICP-MS U-Pb isotopic data for zircon from sedimentary tuff in the Butuo region, Sichuan Province, China

PM12	Th/U	Isotopic ratios						Age (Ma)						Concidence
Spot		$^{207}Pb/^{206}Pb$	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	(%)
6.1	0.85	0.06711	0.00210	1.28098	0.02163	0.13842	0.00209	841.1	63.7	837.3	9.6	835.7	11.9	100
9.1	0.31	0.14195	0.00447	8.09774	0.14222	0.41368	0.00652	2251.2	53.4	2242.0	15.9	2231.7	29.7	100
10.1	0.25	0.05789	0.00180	0.67079	0.01129	0.08402	0.00127	525.4	67.6	521.2	6.9	520.1	7.6	100
11.1	0.39	0.06933	0.00215	1.44466	0.02404	0.15110	0.00229	908.7	62.7	907.7	10.0	907.1	12.8	100
12.1	1.11	0.16423	0.00513	10.57335	0.18269	0.46687	0.00738	2499.7	51.7	2486.4	16.0	2469.8	32.4	99
16.1	0.37	0.15831	0.00484	9.12129	0.14472	0.41782	0.00639	2437.7	50.9	2350.2	14.5	2250.6	29.1	94
17.1	0.81	0.16374	0.00501	10.39865	0.16625	0.46053	0.00707	2494.7	50.6	2470.9	14.8	2441.9	31.2	98
19.1	1.16	0.06566	0.00238	1.14923	0.02857	0.12693	0.00206	795.6	74.1	776.9	13.5	770.3	11.8	96
22.1	0.65	0.06396	0.00212	1.07593	0.02184	0.12199	0.00191	740.4	68.5	741.6	10.7	742.0	11.0	99
24.1	0.61	0.06797	0.00233	1.34708	0.03011	0.14372	0.00222	867.7	69.6	866.3	13.0	865.7	12.5	99
1.1	1.39	0.05111	0.00158	0.27973	0.00456	0.03969	0.00059	245.6	69.8	250.4	3.6	250.9	3.7	101
2.1	1.24	0.05175	0.00161	0.28792	0.00481	0.04034	0.00061	274.5	69.9	256.9	3.8	255.0	3.8	100
3.1	0.86	0.05093	0.00161	0.28217	0.00493	0.04018	0.00060	237.8	71.3	252.4	3.9	253.9	3.8	100
4.1	2.25	0.05219	0.00162	0.28849	0.00471	0.04008	0.00060	293.8	69.0	257.4	3.7	253.4	3.7	99
5.1	2.16	0.05583	0.00180	0.30978	0.00573	0.04024	0.00061	445.2	70.0	274.0	4.4	254.3	3.8	96
7.1	1.29	0.05324	0.00169	0.29421	0.00526	0.04007	0.00061	339.1	70.5	261.9	4.1	253.3	3.8	96
8.1	0.44	0.05141	0.00168	0.28807	0.00560	0.04064	0.00062	259.2	73.5	257.0	4.4	256.8	3.8	100
13.1	0.89	0.05133	0.00167	0.28625	0.00554	0.04044	0.00062	255.9	73.3	255.6	4.4	255.5	3.8	99
14.1	1.06	0.05679	0.00229	0.31336	0.00950	0.04001	0.00065	482.7	87.5	276.8	7.3	252.9	4.1	96
15.1	0.63	0.05481	0.00276	0.30743	0.01299	0.04068	0.00072	404.5	108.5	272.2	10.1	257.0	4.4	93
18.1	0.73	0.05333	0.00238	0.29411	0.01044	0.03999	0.00068	343.0	97.5	261.8	8.2	252.8	4.2	94
20.1	1.00	0.05485	0.00196	0.30307	0.00727	0.04007	0.00063	406.1	77.2	268.8	5.7	253.3	3.9	93
21.1	0.98	0.05415	0.00213	0.29997	0.00869	0.04017	0.00065	377.2	85.5	266.4	6.8	253.9	4.1	94
23.1	0.74	0.05203	0.00226	0.28777	0.00987	0.04011	0.00068	286.5	96.4	256.8	7.8	253.5	4.2	98

Appendix 2 In situ LA-MC-ICP-MS zircon Lu-Hf isotope analyses from sedimentary tuff in the Butuo region, Sichuan Province, China

Sample	$^{176}Yb/^{177}Hf$	1σ	$^{176}Lu/^{177}Hf$	1σ	$^{176}Hf/^{177}Hf$	1σ	$(^{176}Hf/^{177}Hf)_i$	$(^{176}Hf/^{177}Hf)_{CHUR}$	$\varepsilon_{Hf}(t)$	T_{DM1}(Ma)	$f_{Lu/Hf}$
6.1	0.054237	0.000403	0.001732	0.000013	0.282454	0.000027	0.282426	0.282250	6.25	1151	-0.95
9.1	0.017008	0.000208	0.000611	0.000008	0.281314	0.000023	0.281288	0.281359	-2.53	2676	-0.98
10.1	0.059847	0.000951	0.001525	0.000024	0.282588	0.000027	0.282573	0.282448	4.42	953	-0.95
11.1	0.039353	0.000385	0.001216	0.000011	0.282476	0.000024	0.282455	0.282205	8.86	1104	-0.96
12.1	0.021770	0.000108	0.000747	0.000003	0.281279	0.000046	0.281244	0.281205	1.38	2733	-0.98
16.1	0.028683	0.000361	0.001156	0.000013	0.281246	0.000028	0.281196	0.281347	-5.37	2807	-0.97
17.1	0.030671	0.000314	0.001071	0.000011	0.281219	0.000050	0.281169	0.281223	-1.94	2838	-0.97
19.1	0.063244	0.000524	0.002200	0.000018	0.282329	0.000055	0.282297	0.282291	0.22	1345	-0.93
22.1	0.030065	0.001190	0.001114	0.000040	0.282497	0.000030	0.282481	0.282309	6.10	1071	-0.97
24.1	0.043839	0.000484	0.001477	0.000015	0.282864	0.000102	0.282840	0.282231	21.58	557	-0.96
1.1	0.156513	0.000935	0.003892	0.000019	0.282809	0.000038	0.282791	0.282616	6.18	680	-0.88
2.1	0.015196	0.000069	0.000381	0.000002	0.282746	0.000027	0.282744	0.282614	4.63	705	-0.99
3.1	0.129369	0.000357	0.002986	0.000004	0.282718	0.000023	0.282703	0.282614	3.15	799	-0.91
4.1	0.020860	0.000041	0.000376	0.000000	0.282802	0.000018	0.282800	0.282615	6.57	627	-0.99
5.1	0.109897	0.000392	0.001878	0.000005	0.282765	0.000027	0.282756	0.282614	5.03	706	-0.94
7.1	0.108433	0.001800	0.002683	0.000049	0.282846	0.000041	0.282833	0.282615	7.73	603	-0.92
8.1	0.032812	0.000147	0.001042	0.000003	0.282541	0.000022	0.282535	0.282612	-2.72	1008	-0.97
13.1	0.035743	0.000128	0.000997	0.000004	0.282808	0.000023	0.282803	0.282613	6.71	630	-0.97
14.1	0.028044	0.000559	0.000752	0.000013	0.282770	0.000032	0.282766	0.282615	5.35	679	-0.98
15.1	0.021874	0.000113	0.000653	0.000004	0.282713	0.000027	0.282709	0.282612	3.43	757	-0.98
18.1	0.055316	0.000623	0.001846	0.000022	0.282668	0.000114	0.282659	0.282615	1.58	846	-0.94
20.1	0.078914	0.001130	0.002527	0.000033	0.282873	0.000047	0.282861	0.282615	8.73	559	-0.92
21.1	0.042054	0.000257	0.001313	0.000008	0.282815	0.000049	0.282809	0.282614	6.88	625	-0.96
23.1	0.106133	0.000255	0.002703	0.000005	0.282802	0.000043	0.282789	0.282614	6.16	669	-0.92