Acta Geologica Sinica (English Edition), 2021, 95(2): 699–701

Research Advances

Discovery of ~409 Ma Amphibolite in the Zhikong-Songduo Subduction Complex, Southern Tibet

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Citation: Xie et al., 2021. Discovery of ~409 Ma Amphibolite in the Zhikong-Songduo Subduction Complex, Southern Tibet. Acta Geologica Sinica (English Edition), 95(2): 699–701. DOI: 10.1111/1755-6724.14667

Objective

Discovery of Songduo eclogites exposed in southern Tibet has attracted wide attention from geologists. The recently completed regional geological surveys show that a lithotectonic belt extends at least 100 km from Zhikong in the west to Songduo in the east and is mainly composed of oceanic fragments such as eclogites, blueschists, ophiolites and oceanic island assemblages, with their associated arc igneous and metasedimentary rocks. This is referred to hereafter as the Zhikong-Songduo (ZS) subduction complex. The complex is interpreted to have been produced during Permo-Triassic subduction of the Paleo-Tethys oceanic plate. Nevertheless, the detailed composition of the ZS subduction complex and the evolutionary history prior to its Permo-Triassic subduction-accretion still lack constraints. In this paper, we report the zircon U-Pb ages and Hf isotopes of the Gecaiyong amphibolite in the ZS subduction complex to determine the crystallization age and magmatic source characteristics of the protolith, thus providing a new perspective for understanding the tectonic history of the ZS Paleo-Tethys Ocean during the Late Paleozoic.

Methods

Zircon U-Pb dating analyses were performed using an ESI NWR 193 nm laser ablation system, coupled with an Analytik Jena PQMS Elite ICP-MS instrument at the Beijing Createch Testing Technology Co. Ltd., Beijing, China. During the analysis, the spot size (in diameter) was set to 25 μm. Zircon GJ-1 was used as an external standard for U-Pb dating and zircon 91500, Ple and QH were dated as unknown samples. The weighted mean $^{206}Pb/^{238}U$ ages for the zircon GJ-1, 91500, Ple and QH were 600.6 ± 6.2 Ma (2σ, n = 8), 1062 ± 15 Ma (2σ, n = 4), 337.3 ± 4.6 Ma (2σ, n = 4) and 160.1 ± 2.1 Ma (2σ, n = 4), respectively. Zircon Hf isotopes were measured on the dated zircons using LA-MC-ICP-MS at the aforementioned institution. For this analysis, a spot diameter of 38 μm was used. The weighted mean $^{176}Hf/^{177}Hf$ of 0.282000 ± 0.000018 (2σ, n = 4) for Zircon GJ-1 is consistent with the reference value within the margin of error. For recommended values of the standard zircons, detailed experimental conditions and data processing, the reader is referred to the relevant references.

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Results

Sample D3690-N1 is an amphibolite collected from ~2 km northwest of the Gecaiyong area in the Zhikong-Songduo subduction complex (Fig. 1a). The amphibolite shows massive structure (Fig. 1b) and porphyroblastic texture with amphibole and plagioclase porphyroblasts (~2%) in the groundmass (~96%) containing elongated amphibole, plagioclase and quartz with minor accessory minerals (Fig. 1c). Some amphibole and plagioclase porphyroblasts show poikiloblastic texture. Zircons from this sample are mainly euhedral to subhedral prisms in shape, with length to width ratios of 1:1 to 2:1. Most zircons show magmatic oscillatory zones in cathodoluminescence (CL) images (Fig. 2a), indicating a magmatic origin. Some of these zircons have broad CL bands on core or high luminescence on overgrowth rims. Of the thirty zircons analyzed by LA-ICP-MS, twenty-six zircons with oscillatory zones give a weighted mean $^{206}Pb/^{238}U$ age of 409.3 ± 2.9 Ma (MSWD = 1.7, n = 26) (Appendix 1, Fig. 2b), representing the crystallization age of the protolith of the amphibolite. Three zircons are excluded, due to large error or discordant ages. The remaining zircons with high luminescence yield a $^{206}Pb/^{238}U$ age of 48 ± 1 Ma (Appendix 1), which is interpreted as reflecting the tectonothermal event following the protolith crystallization of the amphibolite. Fourteen zircons from the amphibolite have relatively uniform $\varepsilon_{Hf}(t)$ values ranging from −0.9 to +1.0, with corresponding Hf-depleted mantle model ages (T_{DM}) of 990−1068 Ma (Appendix 2), suggesting the partial melting of an enriched lithospheric mantle.

Conclusions

As mentioned earlier, the zircons of the Gecaiyong amphibolite in the ZS subduction complex in southern Tibet developed magmatic oscillatory zones with high Th/U ratios, indicating that the zircons crystallized in the

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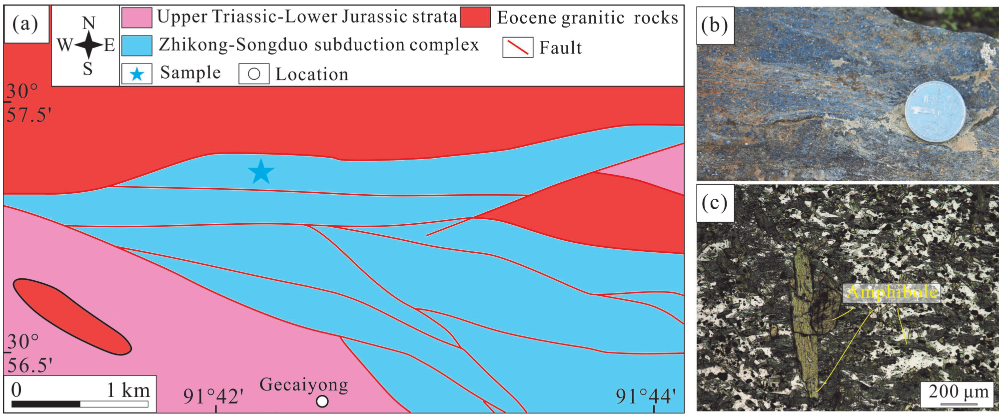

Fig. 1. Geological sketch map of (a) the study area, (b) outcrop photograph, and (c) photomicrograph of the Gecaiyong amphibolite from the Zhikong-Songduo subduction complex.

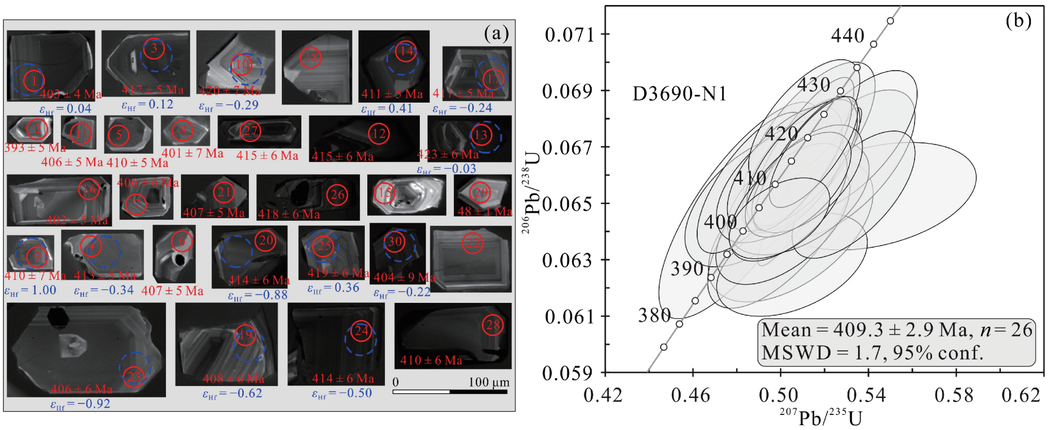

Fig. 2. Zircon cathodoluminescence images and U-Pb concordia plot of the Gecaiyong amphibolite from the Zhikong-Songduo subduction complex.

magma. The protolith of the Gecaiyong amphibolite was formed during the Early Devonian with a zircon U-Pb age of 409.3 ± 2.9 Ma (MSWD = 1.7, n = 26) and it was derived from the partial melting of an enriched lithospheric mantle. This new discovery indicates the existence of the Early Devonian mafic rock within the ZS subduction complex, providing a new clue for understanding the tectonic evolutionary history of the ZS Paleo-Tethys Ocean during the Late Paleozoic.

Acknowledgements

This study was financially supported by the Chinese Geological Survey (grants No. DD20160015-12) and National Natural Science Foundation of China (grants No. 41972118).

Appendix 1 LA-ICP-MS Zircon U-Pb dating results for the Gecaiyong amphibolite in the Zhikong-Songduo Subduction complex

Spot	(ppm)		Th/U	Isotope ratios						*rho*	Age (Ma)					
	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
D3690-N1-01	225	467	0.48	0.05610	0.00095	0.49898	0.00940	0.06447	0.00059	0.48	457	39	411	6	403	4
D3690-N1-02	343	411	0.84	0.05815	0.00136	0.50479	0.01405	0.06282	0.00075	0.43	600	52	415	9	393	5
D3690-N1-03	339	669	0.51	0.05588	0.00080	0.51459	0.00822	0.06682	0.00080	0.75	456	31	422	6	417	5
D3690-N1-04	192	331	0.58	0.05497	0.00108	0.50144	0.01070	0.06622	0.00090	0.64	409	44	413	7	413	5
D3690-N1-05	370	514	0.72	0.05604	0.00100	0.50755	0.00987	0.06566	0.00076	0.60	454	41	417	7	410	5
D3690-N1-06	121	274	0.44	0.05645	0.00139	0.50771	0.01317	0.06520	0.00083	0.49	478	56	417	9	407	5
D3690-N1-07	231	336	0.69	0.05719	0.00185	0.50425	0.01533	0.06403	0.00103	0.53	498	68	415	10	400	6
D3690-N1-08	331	445	0.74	0.05638	0.00123	0.49929	0.01353	0.06415	0.00117	0.67	478	53	411	9	401	7
D3690-N1-09	295	422	0.70	0.05682	0.00103	0.51289	0.00964	0.06559	0.00114	0.93	483	41	420	6	410	7
D3690-N1-10	170	287	0.59	0.05527	0.00115	0.51276	0.01229	0.06728	0.00111	0.69	433	51	420	8	420	7
D3690-N1-11	666	594	1.12	0.05600	0.00105	0.50315	0.01100	0.06504	0.00085	0.60	454	43	414	7	406	5
D3690-N1-12	344	944	0.36	0.05554	0.00072	0.50978	0.00909	0.06642	0.00097	0.82	435	28	418	6	415	6
D3690-N1-13	229	611	0.38	0.05447	0.00098	0.51041	0.01035	0.06785	0.00092	0.67	391	41	419	7	423	6
D3690-N1-14	196	359	0.54	0.05632	0.00114	0.51167	0.01036	0.06587	0.00078	0.59	465	44	420	7	411	5
D3690-N1-15	297	308	0.96	0.20573	0.01721	1.13941	0.23008	0.03824	0.00614	0.80	2872	136	772	109	242	38
D3690-N1-16	209	324	0.65	0.05634	0.00127	0.50058	0.01248	0.06431	0.00089	0.56	465	50	412	8	402	5
D3690-N1-17	163	286	0.57	0.05503	0.00131	0.49910	0.01177	0.06578	0.00089	0.57	413	49	411	8	411	5
D3690-N1-18	139	239	0.58	0.11430	0.00785	1.11663	0.10095	0.06688	0.00194	0.32	1869	124	761	48	417	12
D3690-N1-19	178	315	0.56	0.05907	0.00115	0.53288	0.01147	0.06531	0.00092	0.66	569	43	434	8	408	6
D3690-N1-20	266	396	0.67	0.05764	0.00131	0.52850	0.01320	0.06640	0.00107	0.64	517	50	431	9	414	6
D3690-N1-21	241	403	0.60	0.06005	0.00181	0.54304	0.01871	0.06525	0.00078	0.35	606	97	440	12	407	5
D3690-N1-22	281	325	0.87	0.06013	0.00301	0.50058	0.03208	0.06419	0.00358	0.87	609	112	412	22	401	22
D3690-N1-23	182	322	0.56	0.05441	0.00144	0.48730	0.01283	0.06508	0.00095	0.56	387	64	403	9	406	6
D3690-N1-24	368	708	0.52	0.05547	0.00088	0.50883	0.01098	0.06636	0.00098	0.68	432	35	418	7	414	6
D3690-N1-25	203	326	0.62	0.05742	0.00109	0.53252	0.01205	0.06721	0.00102	0.67	509	43	433	8	419	6
D3690-N1-26	428	789	0.54	0.05519	0.00084	0.50963	0.00950	0.06694	0.00103	0.82	420	33	418	6	418	6
D3690-N1-27	183	444	0.41	0.05555	0.00096	0.50929	0.01034	0.06644	0.00092	0.68	435	39	418	7	415	6
D3690-N1-28	212	368	0.58	0.05381	0.00108	0.48706	0.01045	0.06573	0.00102	0.72	365	46	403	7	410	6
D3690-N1-29	259	348	0.75	0.05014	0.00430	0.05208	0.00499	0.00751	0.00015	0.21	211	180	52	5	48	1
D3690-N1-30	230	377	0.61	0.05397	0.00144	0.48134	0.01527	0.06475	0.00157	0.76	369	59	399	10	404	9

Appendix 2 LA-MC-ICP-MS Zircon Hf isotopic data for the Gecaiyong amphibolite in the Zhikong-Songduo subduction complex

Spot	Age (Ma)	$^{176}Yb/^{177}Hf$	2σ	$^{176}Lu/^{177}Hf$	2σ	$^{176}Hf/^{177}Hf$	2σ	$(^{176}Hf/^{177}Hf)_{initial}$	$\varepsilon_{Hf}(0)$	$\varepsilon_{Hf}(t)$	2σ	T_{DM}	T_{DM}^{C}	$f_{Lu/Hf}$
D3690-N1, amphibolite														
1	403	0.044082	0.001536	0.001546	0.000045	0.282544	0.000015	0.282533	−8.5	0.0	0.5	1017	1374	−0.95
3	417	0.039924	0.000414	0.001481	0.000016	0.282538	0.000014	0.282526	−8.7	0.1	0.5	1025	1380	−0.96
4	413	0.083000	0.004945	0.002822	0.000146	0.282537	0.000015	0.282515	−8.8	−0.3	0.5	1064	1407	−0.92
9	410	0.050750	0.000789	0.001882	0.000033	0.282570	0.000021	0.282555	−7.6	1.0	0.7	990	1319	−0.94
10	420	0.066303	0.001356	0.002282	0.000043	0.282530	0.000014	0.282512	−9.0	−0.3	0.5	1058	1409	−0.93
13	423	0.059281	0.001729	0.002122	0.000057	0.282535	0.000023	0.282518	−8.8	0.0	0.8	1047	1395	−0.94
14	411	0.035835	0.000265	0.001308	0.000009	0.282548	0.000015	0.282538	−8.4	0.4	0.5	1005	1357	−0.96
17	411	0.035512	0.000246	0.001324	0.000009	0.282530	0.000014	0.282520	−9.0	−0.2	0.5	1032	1398	−0.96
19	408	0.018842	0.000191	0.000706	0.000006	0.282516	0.000014	0.282511	−9.5	−0.6	0.5	1034	1420	−0.98
20	414	0.048711	0.000224	0.001820	0.000006	0.282514	0.000015	0.282500	−9.6	−0.9	0.5	1068	1441	−0.95
23	406	0.027527	0.000260	0.001028	0.000009	0.282511	0.000014	0.282504	−9.7	−0.9	0.5	1049	1438	−0.97
24	414	0.045183	0.000390	0.001613	0.000011	0.282523	0.000013	0.282510	−9.3	−0.5	0.4	1050	1417	−0.95
25	419	0.062700	0.002610	0.002151	0.000073	0.282549	0.000030	0.282532	−8.4	0.4	1.1	1028	1366	−0.94
30	404	0.040096	0.000582	0.001496	0.000021	0.282536	0.000024	0.282525	−8.8	−0.2	0.8	1027	1391	−0.96