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Research Advances

LA-ICPMS Zircon U-Pb Age of the Zhongchaye Vermiculite Deposit in Laiwu, Shandong Province

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Objective

The Zhongchaye vermiculite deposit is located north of Laiwu. Tectonically, it belongs to the Luxi Block, west of the Tan-Lu fault zone (Fig. 1a). The crystalline basement of this area consists of the Neoarchean Taishan Group and Paleoproterozoic Granitoid. The overlying strata are mainly Paleozoic carbonate rocks, Mesozoic clastic rocks, and Cenozoic sediments (Fig. 1b). The faults in the Luxi region are dominantly NWW-NW trending and are superimposed by multistage faults. The Zhongchaye vermiculite deposit exists within a thin layer of limestone and marlite in the Cambrian Mantou Formation. The ore bodies are found in weathered mica rocks. Vermiculite content is about 40–70 %, with a maximum of 95 %. The main ore body is ~2 m thick, 500–1000 m long, and is usually clustered in veins. The diagenetic age of an ultrabasic rock-alkaline rock assemblage, such as a carbonatite dyke and neighboring mica rock, has not been accurately determined in these areas. Determining this age has implications for the study of its genetic significance.

Methods

Zircon grains were separated from weathered mica rock (sample ZCY1) from the Zhongchaye vermiculite deposit with heavy liquid and magnetic separation techniques. Zircon grains were then mounted in epoxy and subsequently polished to expose internal structures. Transmitted light, reflected light, and cathodoluminescence (CL) images were taken to ensure that sites chosen for U-Pb analysis were free of fractures and inclusions. U-Pb dating of the zircons using laser ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS) was performed at Nanjing FocuMS Technology Co. Ltd. The instrument configuration consists of an Agilent 7700x ICP-MS instrument equipped with an ASI Resonetics 193 nm laser. Isotope ratios of the zircons were determined using ICPMSDataCal 7.0 and the ages of zircon were then calculated using Isoplot (Version 3.23).

Results

Zircon grains recovered from the weathered mica rock (sample ZCY1) are mostly prismatic, transparent, light gray to gray-black, and about 50–150 μm in size. All zircon grains show clear oscillatory zoning in CL images, indicating typical igneous zircons (Fig. 1c). Some inherited cores are surrounded by prismatic and transparent rims. Twenty-nine valid age data for sample ZCY1 were obtained. The U and Th concentrations of zircon grains range from 76–1627 ppm and 50–3157 ppm, respectively (Table 1). The Th/U ratios range from 0.32 to 5.25, which also indicates a magmatic origin. The zircon grains range in age from 121.1 Ma to 2525.7 Ma. There are three groups of older zircons, with inherited ages: one is 22.2–25.2 Ga (five spots yield ages of 22.2 Ga, 24.3 Ga, 25.0 Ga, 25.2 Ga and 25.2 Ga), another is 776 Ma, and the third is 446 Ma. The remaining zircon grains have ages ranging from 121.1 Ma to 132.7 Ma, with a weighted mean $^{206}Pb/^{238}U$ age of 125.4 ± 1.2 Ma (mean square weighted deviation MSWD = 0.79) (Fig. 1d; Appendix 1). This age may represent the diagenetic age of the mica rock, the weathering product of which is the Zhongchaye vermiculite deposit. In this paper, the age of the vermiculite deposit, 125.4 ±1.2 Ma, is reported for the first time. This age is consistent with the peak of the destruction of the North China Craton (NCC). Carbonatite and mica rocks are considered to be products of mantle-derived magma, so this study provides chronological constraints for the study of the destruction of the NCC.

Conclusions

An accurate U-Pb age of 125.4 ± 1.2 Ma (MSWD = 0.79), determined via LA-ICP-MS of zircon, for the Zhongchaye vermiculite deposit is reported for the first

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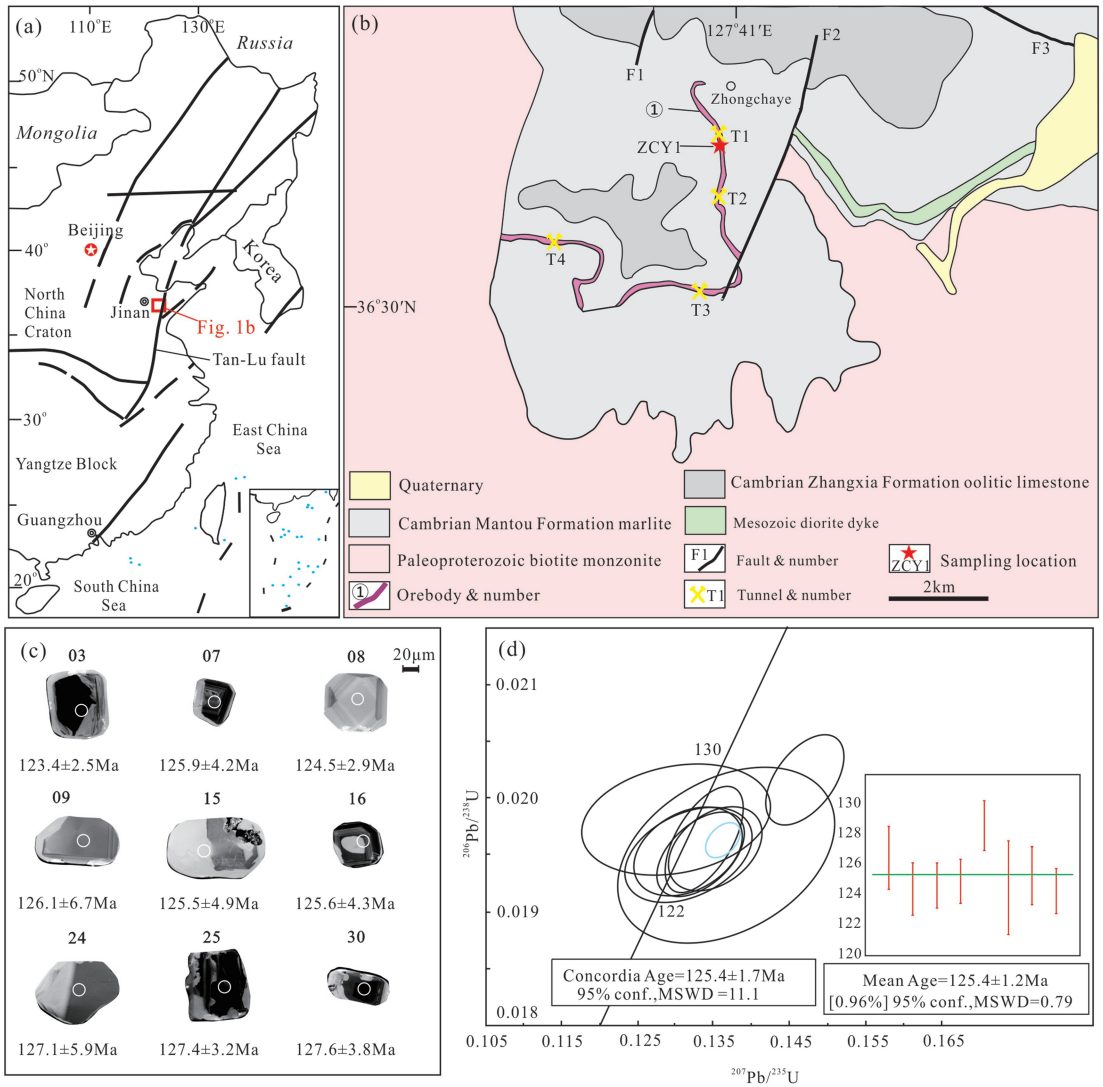

Fig. 1. (a) Sketch geotectonic map of Eastern China; (b) Regional geological map of Zhongchaye vermiculite deposit; (c) Cathodoluminescence images of typical zircons; (d) Concordia and weighted mean U-Pb age of zircons.

time. This age is consistent with the peak period of destruction of the NCC, which was the product of the late Yanshanian magmatic activity. In the Late Mesozoic, a large-scale lithospheric thinning occurred in eastern China. A large number of crust-mantle mixed granites and basic-ultrabasic-alkaline dykes were formed as a result of upwelling of mantle-derived materials. The vermiculite deposit reported in this paper is the product of mica weathering, and its age coincides with the peak period of Mesozoic magmatic activity. Therefore, the deposit may be the product of the destruction of the NCC.

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Appendix 1 LA-ICPMS zircon U-Pb analytical results of sample ZCY1 from Zhongchaye vermiculite deposit in Laiwu, Shandong Province

Spot	Pb (ppm)	Th (ppm)	U (ppm)	Th/U	Isotopic ratios								Age (Ma)			
					$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	$^{208}Pb/^{232}Th$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ
ZCY1-01	10.35	1101.32	209.85	5.25	0.048859	0.002831	0.12738	0.006138	0.018967	0.000319	0.005622	0.000113	121.7	5.5	121.1	2.0
ZCY1-03	39.38	1255.28	1627.24	0.77	0.048626	0.001014	0.130203	0.002827	0.01933	0.000222	0.005989	0.000107	124.3	2.5	123.4	1.4
ZCY1-04	12.18	641.07	427.78	1.50	0.047649	0.001862	0.128847	0.005276	0.019459	0.000238	0.005837	0.000123	123.1	4.7	124.2	1.5
ZCY1-05	451.5	411.37	774.65	0.53	0.167402	0.002298	10.661343	0.162571	0.458788	0.004627	0.116978	0.002149	2494.1	14.3	2434.2	20.5
ZCY1-07	18.86	1581.54	487.7	3.24	0.048578	0.002025	0.131998	0.004706	0.019671	0.000252	0.005745	0.000112	125.9	4.2	125.6	1.6
ZCY1-08	1.85	108.95	60.65	1.80	0.057916	0.005999	0.146801	0.012892	0.019495	0.000456	0.006051	0.000255	139.1	11.4	124.5	2.9
ZCY1-09	4.18	170.95	156.37	1.09	0.048891	0.002949	0.130513	0.007463	0.019751	0.000295	0.006279	0.000211	124.6	6.7	126.1	1.9
ZCY1-10	1.65	103.73	51.91	2.00	0.056836	0.004645	0.137981	0.009587	0.01932	0.00043	0.006115	0.000188	131.2	8.6	123.4	2.7
ZCY1-11	151.1	174.55	233.65	0.75	0.168234	0.002439	11.047249	0.173175	0.47387	0.004533	0.138219	0.002485	2527.1	14.7	2500.5	19.9
ZCY1-12	6.4	567	160.26	3.54	0.048803	0.003332	0.129972	0.008132	0.019813	0.000328	0.005775	0.000122	124.1	7.3	126.5	2.1
ZCY1-13	7.62	570.58	150.75	3.78	0.047827	0.003064	0.146164	0.009307	0.021953	0.000411	0.007126	0.000205	138.5	8.2	140	2.6
ZCY1-15	5.94	401.64	179.01	2.24	0.049136	0.002241	0.131585	0.005495	0.019486	0.000272	0.006096	0.000127	125.5	4.9	124.4	1.7
ZCY1-16	9.33	359.81	358.44	1.00	0.04917	0.001882	0.131642	0.004842	0.019526	0.000236	0.006182	0.000135	125.6	4.3	124.7	1.5
ZCY1-18	15.81	883.32	521.08	1.70	0.050096	0.00159	0.135026	0.004108	0.019568	0.000231	0.006309	0.000119	128.6	3.7	124.9	1.5
ZCY1-19	2.98	191.04	92.71	2.06	0.050071	0.004039	0.13083	0.010686	0.019042	0.000358	0.006276	0.00018	124.8	9.6	121.6	2.3
ZCY1-20	55.46	442.34	625.37	0.71	0.056345	0.000948	0.560135	0.010777	0.071666	0.000709	0.0226	0.000357	451.6	7.0	446.2	4.3
ZCY1-21	39.97	3088.07	1116.6	2.77	0.053239	0.001286	0.147032	0.003463	0.020153	0.000258	0.006753	0.000127	139.3	3.1	128.6	1.6
ZCY1-22	39.06	3157.37	1027.31	3.07	0.057136	0.001338	0.154558	0.003562	0.019719	0.000256	0.006135	0.000089	145.9	3.1	125.9	1.6
ZCY1-23	2.83	220.86	76.43	2.89	0.05551	0.005756	0.136855	0.0095	0.019501	0.00049	0.005978	0.000314	130.2	8.5	124.5	3.1
ZCY1-24	8.67	351.97	325.39	1.08	0.046954	0.002302	0.133292	0.006592	0.020748	0.000306	0.007053	0.000244	127.1	5.9	132.4	1.9
ZCY1-25	37.29	2848.77	1062.6	2.68	0.049417	0.001152	0.13371	0.003538	0.019628	0.000305	0.006192	0.000114	127.4	3.2	125.3	1.9
ZCY1-26	4.38	303.51	129.07	2.35	0.044799	0.002906	0.117536	0.007124	0.019537	0.000327	0.006049	0.000126	112.8	6.5	124.7	2.1
ZCY1-27	32.39	219.63	189.72	1.16	0.065196	0.001374	1.135426	0.025764	0.125964	0.001381	0.040559	0.000659	770.3	12.3	764.8	7.9
ZCY1-29	42.54	50	81.52	0.61	0.163741	0.002444	9.311087	0.216304	0.410688	0.007855	0.132925	0.002375	2369.1	21.4	2218.1	35.9
ZCY1-30	19.97	1967.64	452.35	4.35	0.049896	0.001557	0.133849	0.004288	0.019463	0.000239	0.005803	0.000079	127.6	3.8	124.3	1.5
ZCY1-32	9.22	646.51	248.05	2.61	0.055604	0.002293	0.15191	0.005916	0.019861	0.000262	0.006588	0.00011	143.6	5.2	126.8	1.7
ZCY1-33	112.29	110.97	178.01	0.62	0.170807	0.002252	11.347267	0.169742	0.479648	0.005114	0.137876	0.002081	2552.1	14.1	2525.7	22.3
ZCY1-34	20.24	1850.46	428.2	4.32	0.052751	0.001858	0.151038	0.005297	0.020803	0.000266	0.006606	0.0001	142.8	4.7	132.7	1.7
ZCY1-35	226.55	120.24	375.81	0.32	0.164003	0.001848	10.886695	0.145486	0.479245	0.004759	0.186723	0.004471	2513.5	12.5	2524	20.8