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Research Advances

Latest Zircon U-Pb Geochronology of the Qingshan GroupVolcanic rocks along the Tan-Lu Fault Zone of Shandong Province, Eastern China

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Objective

Shandong Province is divided into two parts by the Tan–Lu fault zone: the western part (Luxi) and the eastern part (Jiaodong). Large-scale volcanic activity occurred during the Late Mesozoic in Shandong Province, eastern China (Fig. 1b), and was controlled by the Tan–Lu fault zone and its secondary faults. Mesozoic volcanic rocks in Shandong Province mainly occur within the Cretaceous Qingshan group, overlying the Laiyang group and underlying the Wangsi group. The Qingshan group has been divided into four volcanic cycles, i.e., the Houkuang, Bamudi, Shiqianzhuang and Fanggezhuang formations from the oldest to the youngest. Although geochronology data indicate the volcanic activity occurred during the Early Cretaceous, the starting time and duration of volcanic activity are still equivocal. Two zircon U-Pb ages of volcanic rocks from strata at the lower base of the volcanic sequence along the Tan–Lu fault zone were reported in this paper, which provide new evidence for the discussion of the geological age.

Methods

Zircons were separated using standard heavy liquid and magnetic techniques, and were selected by hand picking under a binocular microscope according to color, shape, transparency and homogeneity. Together with standard zircon crystals (TEMORA), the selected zircons were mounted and polished to half of the grain thickness and then carbon-coated. Cathodoluminescence (CL) images were obtained using a scanning electron microscope (SEM) at the SEM Laboratory of Peking University in Beijing, China. Zircon U-Th-Pb analyses were performed on a laser ablation-inductively coupled plasma-mass spectrometer (LA-ICP-MS) at the Key Laboratory of Orogenic Belt and Crustal Evolution, Peking University in Beijing, China. The instrument configuration consists of an Agilent 7500ce ICPMS instrument equipped with a 193 nm ArF-excimer laser. Helium was used as the carrier gas. The laser beam was accelerated at 5 Hz, with an intensity of 5 J/cm^2. The diameter and depth of the laser analysis pit were 32 μm and 30–40 μm, respectively. Plešovice zircon was used as an external standard for all U-Th-Pb isotopic analyses, and NIST 610 was used as an external standard to calculate the concentrations of U–Th–Pb and other trace elements in zircon. U-Th-Pb isotopic ratios were calculated using the Glitter program. Data reduction was conducted using Isoplot.

Results

Two samples including trachyandensite (sample No. SD-54) and trachyte (sample No. SD-165) were collected from strata at the lower base of the volcanic sequence along the Tan–Lu fault zone in Shandong Province. Specific details and features of the results are as follows.

Zircons from trachyandensite sample No. SD-54 are euhedral–subhedral, prismatic, and range from 100 to 300 μm in diameter. They have length-to-width ratios of 2:1 to 1:1, with distinct oscillatory zoning and occasionally exhibit sector zoning (Fig. 1e). The zircons all have relatively high Th/U ratios (0.82–1.78), suggestive of a magmatic origin. All 25 zircons analyzed are concordant and yield a weighted mean $^{206}Pb/^{238}U$ age of 127.7±0.6Ma (MSWD = 0.26) (Fig. 1c). This age is interpreted as the crystallization age of the volcanic rocks.

Zircons from trachyte sample No. SD-165 are mostly euhedral–subhedral, prismatic, ranging from 150 to 400 μm in diameter, and have length-to-width ratios of 4:1 to 2:1, with distinct oscillatory zoning. However, a few of the inherited zircon grains have a core-rim structure, and the core shows oscillatory zoning. The rim shows thin and light-color rim (Fig. 1e), likely reflecting a metamorphic event. The high Th/U ratios (0.53–2.46) of all the zircons suggest a magmatic origin. Of the two inherited zircon analyses, two are concordant and produce $^{207}Pb/^{206}Pb$ ages

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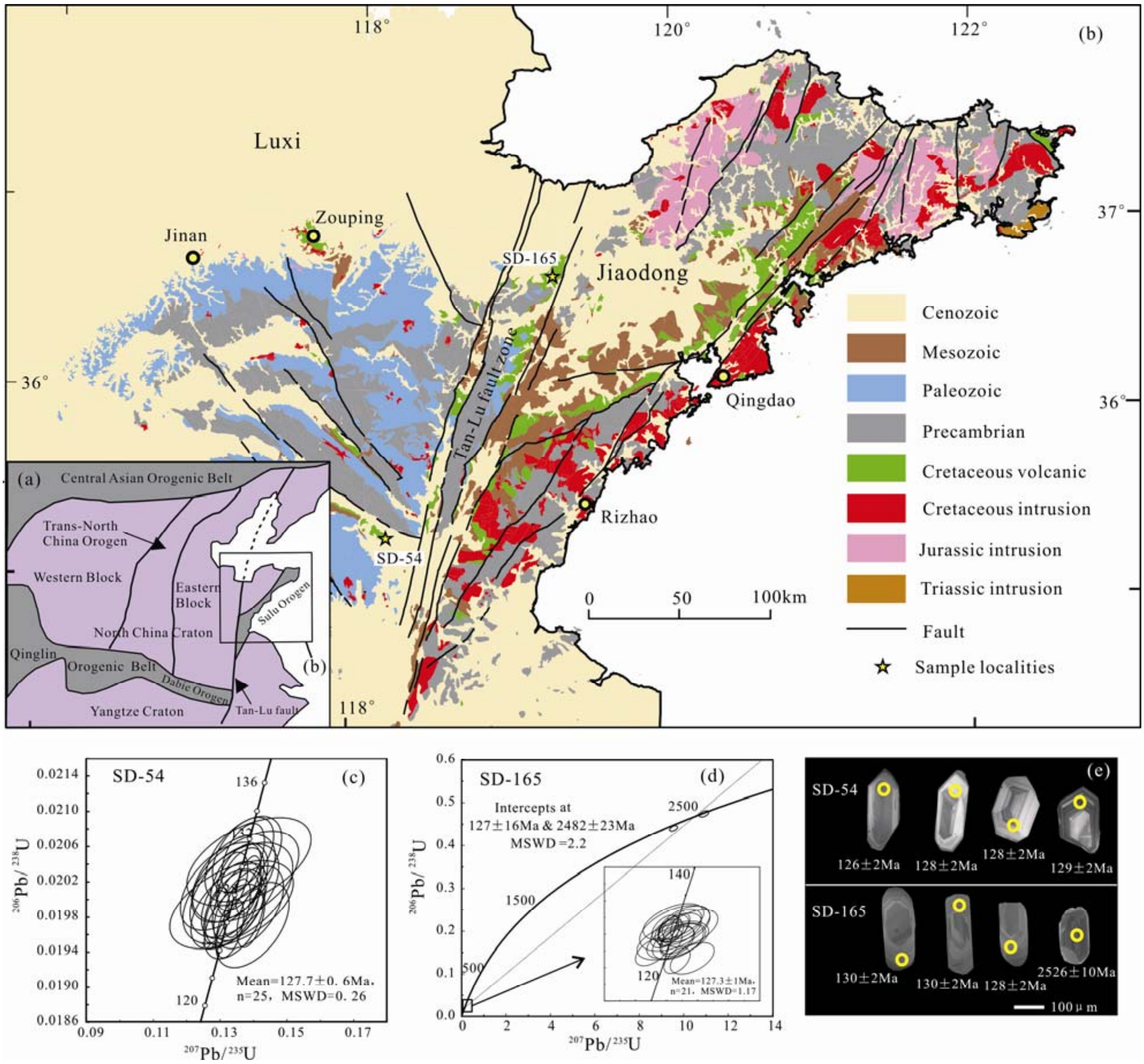

Fig. 1. (a), Generalized geological map of the North China Craton (NCC), showing the main cratonic blocks and orogenic belts; (b), Simplified geological map of Shandong Province, eastern China, showing the locations of samples obtained during this study; (c–d), Concordia diagrams of zircon U-Pb for the volcanic rocks from Qingshan group; (e), Cathodoluminescence (CL) images of zircons from the volcanic rocks.

of 2526 Ma and 2425 Ma, respectively. All the analyses define a discordia with lower and upper intercepts at 127±16 Ma and 2482±23 Ma (MSWD=2.2), respectively (Fig. 1d). Excluding analyses of inherited zircons, the 21 young zircons analyzed are concordant and yield a weighted mean $^{206}Pb/^{238}U$ age of 127.3±1 Ma (MSWD=1.17) (Fig. 1d) which is interpreted as the age of volcanism.

Conclusion

The weighted mean $^{206}Pb/^{238}U$ age of the volcanic rocks from the strata at the lower base of the volcanic sequence Qingshan group along the Tan–Lu fault zone range from 127.7 to 127.3 Ma, match with the reported starting age (126.4 Ma) of the volcanic activity in the Jiaodong area, suggesting that the Qingshan group volcanic activity in Jiaodong and Tan–Lu fault zone began contemporaneously.

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Appendix 1 LA-ICP-MS zircon U-Pb isotope dating for the volcanic rocks along the Tan–Lu fault zone in Shandong Province

Analysis	W_B (ppm)			Th/U	$^{207}Pb/^{206}Pb$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$		$^{207}Pb/^{206}Pb$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$	
	Th	U	Pb		ratios	1σ	ratios	1σ	ratios	1σ	Age	1σ	Age	1σ	Age	1σ
Sample SD-54 trachyandensite (E118°8.285′ N36°34.806′)																
SD-54-01	153	163	4.49	0.93	0.0485	0.0032	0.1343	0.0088	0.0201	0.0004	121	114	128	8	128	2
SD-54-02	261	247	6.80	1.06	0.0484	0.0022	0.1334	0.0059	0.0200	0.0003	119	75	127	5	128	2
SD-54-03	382	465	12.40	0.82	0.0477	0.0014	0.1327	0.0037	0.0202	0.0002	85	44	127	3	129	2
SD-54-04	310	352	9.53	0.88	0.0489	0.0017	0.1362	0.0046	0.0202	0.0003	145	55	130	4	129	2
SD-54-05	98	94	2.68	1.05	0.0493	0.0038	0.1377	0.0105	0.0203	0.0003	162	141	131	9	129	2
SD-54-06	352	285	8.44	1.23	0.0485	0.0016	0.1355	0.0044	0.0203	0.0003	126	54	129	4	129	2
SD-54-07	140	136	3.81	1.02	0.0480	0.0030	0.1340	0.0083	0.0202	0.0003	100	107	128	7	129	2
SD-54-08	286	188	5.98	1.52	0.0484	0.0022	0.1369	0.0061	0.0205	0.0003	119	76	130	5	131	2
SD-54-09	294	353	9.55	0.83	0.0485	0.0015	0.1368	0.0042	0.0205	0.0003	123	49	130	4	131	2
SD-54-10	202	149	4.40	1.36	0.0514	0.0027	0.1397	0.0072	0.0197	0.0003	259	89	133	6	126	2
SD-54-12	87	79	2.30	1.10	0.0555	0.0032	0.1538	0.0088	0.0201	0.0003	125	211	127	11	127	2
SD-54-16	148	100	3.14	1.48	0.0472	0.0032	0.1312	0.0086	0.0202	0.0003	61	114	125	8	129	2
SD-54-17	647	671	18.41	0.96	0.0472	0.0009	0.1289	0.0025	0.0198	0.0002	58	27	123	2	127	1
SD-54-19	118	100	3.02	1.18	0.0486	0.0027	0.1370	0.0076	0.0205	0.0003	127	95	130	7	131	2
SD-54-20	509	590	15.85	0.86	0.0493	0.0010	0.1351	0.0026	0.0199	0.0002	160	26	129	2	127	1
SD-54-21	174	185	5.09	0.94	0.0487	0.0020	0.1336	0.0053	0.0199	0.0003	133	67	127	5	127	2
SD-54-22	626	634	17.55	0.99	0.0510	0.0010	0.1392	0.0028	0.0198	0.0002	242	26	132	2	126	1
SD-54-23	236	133	4.33	1.78	0.0493	0.0022	0.1341	0.0058	0.0198	0.0003	160	75	128	5	126	2
SD-54-24	161	101	3.17	1.60	0.0483	0.0027	0.1323	0.0073	0.0199	0.0003	112	95	126	7	127	2
SD-54-25	240	262	7.17	0.92	0.0493	0.0020	0.1358	0.0054	0.0200	0.0003	164	65	129	5	127	2
SD-54-26	111	95	2.90	1.17	0.0581	0.0029	0.1654	0.0080	0.0207	0.0003	158	204	132	11	130	2
SD-54-27	77	70	2.01	1.11	0.0489	0.0040	0.1353	0.0109	0.0201	0.0004	144	145	129	10	128	2
SD-54-28	970	550	17.65	1.76	0.0490	0.0011	0.1329	0.0028	0.0197	0.0002	149	28	127	2	126	1
SD-54-29	209	156	4.61	1.34	0.0505	0.0026	0.1386	0.0069	0.0199	0.0003	217	86	132	6	127	2
SD-54-30	706	729	20.55	0.97	0.0498	0.0009	0.1385	0.0025	0.0202	0.0002	187	23	132	2	129	1
Sample SD-165 trachyte （E119°7.87′ N36°16.504′）																
SD165-01	106	88	2.61	1.20	0.0479	0.0046	0.1345	0.0129	0.0204	0.0004	93	180	128	12	130	2
SD165-02	134	118	3.42	1.13	0.0523	0.0042	0.1455	0.0116	0.0202	0.0004	298	147	138	10	129	2
SD165-03	260	149	4.68	1.75	0.0551	0.0036	0.1465	0.0093	0.0193	0.0003	417	114	139	8	123	2
SD165-04	104	74	2.22	1.40	0.0491	0.0056	0.1341	0.0152	0.0198	0.0004	153	219	128	14	126	2
SD165-06	239	168	5.09	1.43	0.0502	0.0027	0.1370	0.0073	0.0198	0.0003	206	96	130	7	126	2
SD165-08	106	147	95.52	0.72	0.1669	0.0022	10.9141	0.1383	0.4745	0.0049	2526	10	2516	12	2503	21
SD165-09	130	112	3.39	1.16	0.0505	0.0040	0.1412	0.0110	0.0203	0.0004	216	143	134	10	130	2
SD165-10	164	137	4.02	1.20	0.0500	0.0030	0.1398	0.0083	0.0203	0.0003	194	109	133	7	129	2
SD165-11	328	196	6.23	1.67	0.0500	0.0027	0.1366	0.0072	0.0198	0.0003	194	96	130	6	127	2
SD165-13	332	173	5.58	1.92	0.0449	0.0026	0.1205	0.0070	0.0195	0.0003	-24	97	116	6	124	2
SD165-14	275	475	11.92	0.58	0.0497	0.0015	0.1388	0.0041	0.0203	0.0002	180	46	132	4	129	2
SD165-15	158	126	3.67	1.26	0.0495	0.0036	0.1374	0.0099	0.0202	0.0003	170	132	131	9	129	2
SD165-16	194	188	5.14	1.04	0.0472	0.0026	0.1304	0.0070	0.0200	0.0003	60	91	124	6	128	2
SD165-17	237	223	6.21	1.06	0.0484	0.0023	0.1346	0.0063	0.0202	0.0003	118	82	128	6	129	2
SD165-18	591	352	11.18	1.68	0.0476	0.0017	0.1311	0.0045	0.0200	0.0002	77	56	125	4	128	2
SD165-19	222	118	3.81	1.89	0.0504	0.0040	0.1374	0.0108	0.0198	0.0004	212	146	131	10	126	2
SD165-20	668	284	9.81	2.35	0.0516	0.0022	0.1368	0.0056	0.0192	0.0003	270	69	130	5	123	2
SD165-21	130	92	2.70	1.42	0.0487	0.0055	0.1353	0.0150	0.0202	0.0005	131	206	129	13	129	3
SD165-22	211	258	6.85	0.82	0.0465	0.0021	0.1292	0.0057	0.0202	0.0003	22	70	123	5	129	2
SD165-23	274	513	295.72	0.53	0.1572	0.0020	9.5418	0.1180	0.4404	0.0044	2425	10	2392	11	2352	19
SD165-24	128	93	2.71	1.37	0.0499	0.0046	0.1362	0.0125	0.0198	0.0004	191	174	130	11	126	2
SD165-27	376	347	9.73	1.08	0.0475	0.0018	0.1320	0.0050	0.0201	0.0003	76	62	126	4	129	2
SD165-29	939	382	13.82	2.46	0.0490	0.0016	0.1335	0.0043	0.0198	0.0002	147	53	127	4	126	2