

Research Advances

LA-ICP-MS U-Pb Geochronology of Detrital Zircons in Eastern Liaoning Province: An Early Paleozoic Formation Associated with the Gondwana Supercontinent Event

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Objective

The Liao-Ji orogenic belt is a famous Paleoproterozoic orogenic belt in the East Block of the North China Craton (NCC), which extend in NE-SW direction. The geological mass in the Paleoproterozoic Liao-Ji belt is mainly composed of the Liaoji granites and metamorphic volcanic-sedimentary rocks of the Liaohe group (and its equivalents). Throughout the ages, the existence of Early Paleozoic strata has not been found in the Liao-Ji orogenic belt, and the strata we debate were always treated as part of the Liaohe group. In this study, we first identified a set of early Paleozoic sedimentary formation in Xiuyan County in the eastern Liaoning Province. And we found that the strata are not consistent with the Early Paleozoic sedimentary formation dominated by the carbonate rocks of the north China craton. Detrital zircon chronology suggests that the strata may be a geological body related to the evolution of the Gondwana supercontinent.

Methods

Based on the field geological survey, we selected the fresh quartz sandstone samples in the strata for zircon selection and dating. Zircons were separated at the Langfang Regional Geological Survey Institute in Hebei Province, China. U-Pb dating of zircons was performed by LA-ICP-MS at the Laboratory of Metallogeny and Mineral Assessment, Institute of mineral resources, Chinese academy of geological sciences.

Results

Field geological survey confirmed that there are significant differences between them and Liaohe group. The strata in the study area have the sequence characteristics of the interaction outputs of clastic rocks

and carbonate rocks, and they are not modified by regional metamorphism, only partially affected by dynamic metamorphism. The composition of the zircon chronology of the dating samples further proves that the sedimentary time of the strata is very different from that of the formation of the Liaohe group.

The sample of quartz sandstone (LD15) for dating was collected at the south of Chaoyang Town, Xiuyan County, Liaoning Province (E123°32'52.885", N40°25'09.036"). The zircons in the sample are subrounded to subangular and have characteristics of detrital zircons. We obtained 56 effective data and their age data ranged from 482 Ma to 2768 Ma (Fig. 1; Appendix 1).

(1) The age of the six zircons is 1880–2768 Ma. Cathodoluminescence (CL) images show that they are either the magmatic zircons with clear oscillation bands, or metamorphic zircons with a core-rim structure or uniform internal structure. These ages are consistent with important geologic events such as crustal growth, cratonization, rifting and orogenic in the NCC basement (Zhao Lei et al., 2016).

(2) The age of 17 zircons is between 1309 Ma and 1781 Ma. CL images show that most of these zircons are the magma zircons with clear rhythmic zoning, which correspond to the multi-stage cracking events occurred at the end of Paleoproterozoic to the Mesoproterozoic (Zhao Lei et al., 2016).

(3) The age of 26 zircons is 625–1292 Ma. These zircons exhibit complex CL features, some of them have core-rim structures, while others develop different types of oscillatory zoning, and the rest have a uniform internal structure. These ages correspond to the formation and breakup of the Rodinia Supercontinent. At present, the geological record of large-scale tectonic-thermal event relation to the Rodinia Supercontinent convergence and breakup in the NCC has not been found, but a large amount of the detrital zircons of this period are found in few sedimentary rocks with dynamic metamorphism (Luo et al., 2006).

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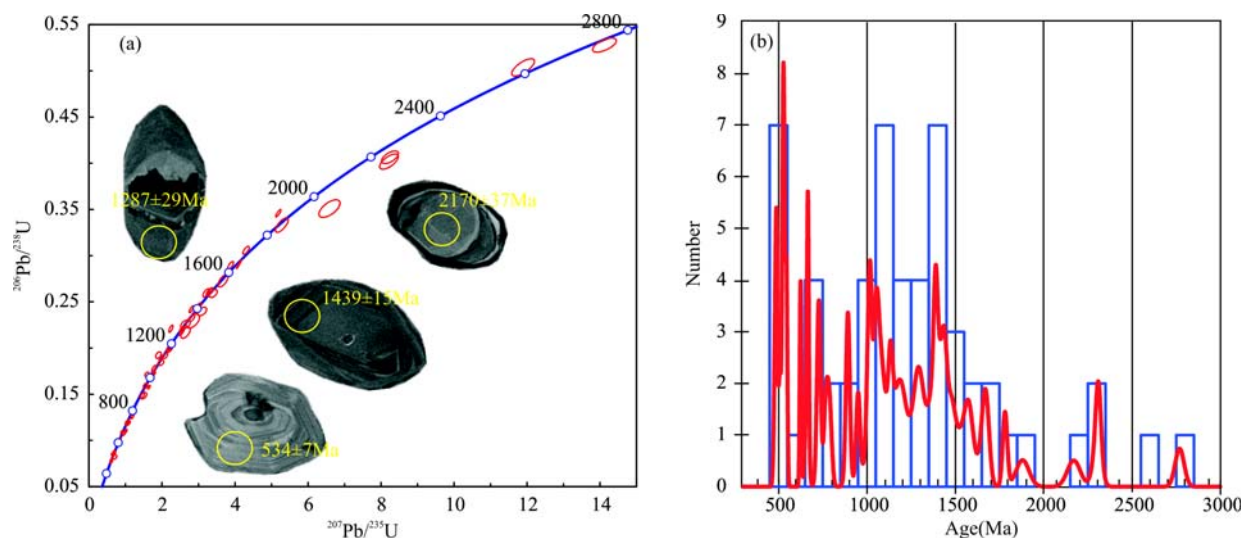


Fig. 1. U-Pb concordia diagrams for detrital zircons and cathodoluminescence images of typical zircon (a) and zircon U-Pb age histogram diagrams (b).

(4) The seven zircons with age of 482–546 Ma are mostly magma zircons with oscillatory zoning. The period coincided with the pan-African orogeny, which was represented by the convergence of Gondwana continent. However, 600–500 Ma magmatism is absent from or insignificant in the northern margins of the NCC. The arc-related magmatism occurred at ca. 500 Ma in the northern margins of the NCC, but the high pressure metamorphism of the same period is absent. The reason may be related to the convergence of the southern margin of the NCC with the northern margin of Australia which can be reflected by the high pressure metamorphism of 510–470 Ma in the northern Qinling area of the NCC (Han et al., 2016).

Conclusion

Our study confirmed for the first time that the strata in the Xiuyan area of Liao-Ji orogenic belt was formed in the Early Paleozoic, rather than part of the Liaohe group. It may not be a set of autochthonous deposits, but rather a set of construction related to orogenic effects. Detrital zircon chronology evidence shows that the composition of the rocks in source region contains huge amounts of products of magmatism and metamorphism which is

absent in the NCC in Greenville period and pan-African period. The results provide a basis for further discussion on the relationship between the NCC and Gondwana continent.

Acknowledgments

This research was supported by the National Science Foundation of China (grant No. 41272223) and China Geological Survey (grants No. DD20160049, 1212011220247 and 12120110300015).

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Appendix 1 LA-ICP-MS zircon U-Pb isotopic dating data for the quartz sandstone (LD15) in the Xiuyan area of eastern Liaoning Province

Sample No.	²⁰⁶ Pb*	Th	U	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	
	(ppm)	(ppm)	(ppm)	Ratio	Ratio	1σ	Ratio	1σ	Ratio	1σ	Age(Ma)	1σ	Age(Ma)	1σ	Age(Ma)	1σ
LD15-1	59.82	176.94	278.66	0.63	0.07786	0.00209	1.97146	0.05301	0.18398	0.00194	1144	48	1106	18	1089	11
LD15-2	18.25	160.11	170.93	0.94	0.05813	0.00248	0.68984	0.03006	0.08631	0.00123	600	97	533	18	534	7
LD15-3	102.96	480.14	357.19	1.34	0.09412	0.00251	3.09808	0.08232	0.23953	0.00304	1510	51	1432	20	1384	16
LD15-4	332.52	271.33	904.57	0.30	0.11502	0.00227	5.28612	0.11541	0.33304	0.00521	1881	36	1867	19	1853	25
LD15-5	75.27	228.77	571.69	0.40	0.06634	0.00180	1.18658	0.03845	0.13019	0.00214	817	56	794	18	789	12
LD15-6	51.34	286.70	180.72	1.59	0.08056	0.00196	2.20928	0.05487	0.19933	0.00248	1211	48	1184	17	1172	13
LD15-7	146.62	367.30	438.04	0.84	0.09831	0.00222	3.67920	0.09141	0.27291	0.00455	1592	43	1567	20	1556	23
LD15-8	30.29	257.28	288.06	0.89	0.05559	0.00174	0.65127	0.02058	0.08536	0.00101	435	70	509	13	528	6
LD15-9	74.65	143.24	289.06	0.50	0.08474	0.00236	2.64437	0.08476	0.22552	0.00307	1309	54	1313	24	1311	16
LD15-10	104.54	413.07	417.48	0.99	0.07901	0.00140	2.09327	0.04130	0.19158	0.00205	1172	35	1147	14	1130	11
LD15-11	194.90	521.68	804.15	0.65	0.08520	0.00159	2.55484	0.04734	0.21859	0.00325	1320	42	1288	14	1274	17
LD15-12	155.74	405.17	493.40	0.82	0.08976	0.00146	3.20906	0.05573	0.23954	0.00291	1420	30	1459	13	1487	15
LD15-13	45.53	98.94	265.77	0.37	0.07058	0.00166	1.54409	0.03785	0.15885	0.00198	946	48	948	15	950	11
LD15-14	18.66	51.79	148.21	0.35	0.06533	0.00259	1.06287	0.04448	0.11905	0.00187	785	84	735	22	725	11
LD15-15	126.51	50.00	340.04	0.15	0.13547	0.00286	6.59079	0.19062	0.35087	0.00629	2170	37	2058	26	1939	30
LD15-16	121.55	387.87	632.30	0.61	0.07244	0.00105	1.69089	0.02724	0.16926	0.00187	998	30	1005	10	1008	10
LD15-17	191.07	192.94	610.15	0.32	0.10276	0.00101	4.11441	0.04675	0.29068	0.00323	1676	19	1657	9	1645	16
LD15-18	258.54	337.09	535.44	0.63	0.14685	0.00166	8.21979	0.16864	0.40168	0.00545	2310	14	2256	19	2177	25
LD15-19	158.30	426.29	955.48	0.45	0.07546	0.00094	1.64311	0.02320	0.15770	0.00131	1081	24	987	9	944	7
LD15-20	121.56	185.64	435.02	0.43	0.09250	0.00104	3.32536	0.04302	0.26114	0.00279	1477	21	1487	10	1496	14
LD15-21	44.95	315.81	454.24	0.70	0.05728	0.00126	0.69759	0.01588	0.08834	0.00088	502	48	537	10	546	5
LD15-22	119.89	238.72	366.85	0.65	0.09740	0.00118	3.88050	0.05226	0.28929	0.00285	1576	22	1610	11	1638	14
LD15-23	82.15	354.06	421.49	0.84	0.07456	0.00125	1.76993	0.03402	0.17228	0.00195	1057	33	1034	12	1025	11
LD15-24	35.04	296.46	399.05	0.74	0.05647	0.00142	0.61032	0.01570	0.07880	0.00089	472	56	484	10	489	5
LD15-25	62.55	518.83	496.32	1.05	0.06855	0.00114	1.19663	0.02750	0.12652	0.00205	887	35	799	13	768	12
LD15-26	56.12	296.16	506.45	0.58	0.06420	0.00133	0.96451	0.02765	0.10802	0.00167	750	43	686	14	661	10
LD15-27	65.90	156.32	290.48	0.54	0.07411	0.00108	2.24745	0.03638	0.22090	0.00257	1056	29	1196	11	1287	14
LD15-28	231.45	107.62	666.31	0.16	0.10889	0.00077	5.18883	0.04642	0.34588	0.00264	1781	13	1851	8	1915	13
LD15-29	66.43	302.37	410.09	0.74	0.07173	0.00164	1.46652	0.03474	0.14857	0.00172	989	51	917	14	893	10
LD15-30	24.77	231.08	250.20	0.92	0.05521	0.00173	0.64916	0.02215	0.08512	0.00099	420	75	508	14	527	6
LD15-31	31.00	229.36	143.00	1.60	0.07241	0.00197	1.90480	0.05035	0.19230	0.00230	998	54	1083	18	1134	12
LD15-32	70.73	190.30	634.27	0.30	0.05938	0.00080	0.89287	0.01278	0.10896	0.00079	589	30	648	7	667	5
LD15-33	124.76	228.85	345.44	0.66	0.10209	0.00116	4.30579	0.05711	0.30570	0.00284	1663	21	1694	11	1720	14
LD15-34	42.69	104.62	224.70	0.47	0.06708	0.00147	1.59038	0.03801	0.17149	0.00158	840	46	966	15	1020	9
LD15-35	174.93	298.59	642.63	0.46	0.08398	0.00085	2.80420	0.03614	0.24186	0.00244	1292	25	1357	10	1396	13
LD15-36	210.02	460.47	676.08	0.68	0.09062	0.00067	3.26244	0.03381	0.26071	0.00246	1439	15	1473	8	1493	13
LD15-37	80.95	186.44	367.84	0.51	0.08784	0.00196	2.64728	0.08444	0.21645	0.00393	1389	11	1314	24	1263	21
LD15-38	100.22	89.13	420.09	0.21	0.08372	0.00124	2.54582	0.03863	0.21952	0.00161	1287	29	1285	11	1279	9
LD15-39	90.18	145.40	328.35	0.44	0.08877	0.00111	3.01864	0.04267	0.24556	0.00225	1399	29	1412	11	1416	12
LD15-40	12.34	128.78	130.67	0.99	0.05824	0.00242	0.61357	0.02428	0.07760	0.00123	539	86	486	15	482	7
LD15-41	80.32	382.63	326.98	1.17	0.07548	0.00124	1.97305	0.03463	0.18898	0.00199	1081	33	1106	12	1116	11
LD15-42	209.27	641.40	734.47	0.87	0.08777	0.00141	2.82463	0.04838	0.23251	0.00233	1377	31	1362	13	1348	12
LD15-43	162.49	195.02	1602.67	0.12	0.06132	0.00094	0.86559	0.01328	0.10184	0.00080	650	33	633	7	625	5
LD15-44	55.81	162.35	176.12	0.92	0.09510	0.00190	3.41050	0.07081	0.25896	0.00282	1531	38	1507	16	1485	14
LD15-45	72.98	285.24	363.59	0.78	0.07312	0.00145	1.74077	0.03584	0.17165	0.00160	1017	41	1024	13	1021	9
LD15-46	201.06	276.30	291.61	0.95	0.19312	0.00296	14.12158	0.21456	0.52781	0.00505	2769	25	2758	14	2732	21
LD15-47	202.98	271.80	319.56	0.85	0.17035	0.00277	11.89311	0.20514	0.50368	0.00616	2561	-6	2596	16	2630	26
LD15-48	111.07	434.52	363.08	1.20	0.08906	0.00160	2.96897	0.05420	0.24092	0.00283	1406	34	1400	14	1391	15
LD15-49	129.55	629.37	1101.18	0.57	0.06588	0.00168	1.00700	0.02594	0.11028	0.00128	1200	52	707	13	674	7
LD15-50	14.45	257.38	136.90	1.88	0.06482	0.00387	0.71030	0.03708	0.08194	0.00144	769	131	545	22	508	9
LD15-51	104.81	430.43	429.42	1.00	0.07979	0.00145	2.21811	0.04132	0.20079	0.00212	1192	31	1187	13	1180	11
LD15-52	95.77	125.59	639.66	0.20	0.07196	0.00205	1.49760	0.05713	0.14843	0.00231	985	58	929	23	892	13
LD15-53	25.40	99.16	100.73	0.98	0.08931	0.00307	2.84750	0.12090	0.22924	0.00506	1411	66	1368	32	1331	27
LD15-54	74.38	525.78	525.97	1.00	0.06394	0.00136	1.06206	0.02503	0.12000	0.00161	739	44	735	12	731	9
LD15-55	82.53	296.39	406.61	0.73	0.07244	0.00133	1.77809	0.03718	0.17747	0.00240	998	37	1037	14	1053	13
LD15-56	409.04	358.89	887.02	0.40	0.14604	0.00206	8.24696	0.15268	0.40637	0.00451	2302	24	2259	17	2198	21