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Research Advances

The First Discovery of Hadean Zircon in the Paleoproterozoic Rock

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Objective

The Hadean zircon and rock are critical to deepening our understanding of the developmental history of early Earth, making possible new avenues for the Pre-Archean Eon. However, the Hadean rock on Earth is only identified in Canada indeed. Comparatively, the Hadean zircon has attracted considerably more attention, as it is widespread and exhibits robust chemical and physical features that make it survive in extreme conditions, thereby providing a method of deciphering the evolution of the early Earth. It should be noted that most of the detrital or the xenocrystic zircons older than 4.0 Ga are found in Western Australia. Hadean zircon occurrences outside Western Australia have been also reported in Canada, west Greenland and China. For the first time, we report the occurrence of a 4.09 Ga zircon in the Paleoproterozoic meta-sedimentary rock (sample No. LHZ1) from the Dashiqiao Formation in the Dashiqiao magnesite deposit of Dashiqiao City, Liaoning Province (GPS location: 42°33′12″N, 129°40′37″E).

Methods

The zircon grains were extracted from the sample using heavy liquid and magnetic methods and were further purified by hand picking under a binocular microscope. The zircon grains were set in an epoxy mount that was polished and then vacuum coated with a layer of 50 nm high-purity gold. Cathodoluminescence (CL) images were taken to examine the internal structure of the individual grains. The zircon U–Pb analysis was performed using the LA-ICP-MS housed at Tianjin Institute of Geology and Mineral Resources.

Results

The staurolite-garnet-mica schist (sample No. LHZ1) is dark gray in color, with a lepido-granoblastic texture and schistosity. It contains staurolite (10%), garnet (15%), biotite (30%), muscovite (15%), plagioclase (20%) and quartz (10%), and accessory minerals of epidote, magnetite, apatite and zircon. The schist is intercalated with dolomitic marbles. The field relations are shown in Figs. 1a–e. Geochemically, the staurolite-garnet-mica schist consists of SiO_2 (55.77wt%), Al_2O_3 (15.30wt%), Fe_2O_3 (3.19wt%), FeO (7.20wt%) and K_2O (2.95wt%). Using a petrological and geochemical classification, its protolith is classified as shale. Thirty-six U–Pb analyses give a wide range of $^{207}Pb/^{206}Pb$ ages scattering between 2002 and 4087 Ma (Table 1). The youngest zircons in the sample yield ages of 2002±13 Ma, 2014 ± 13 Ma, and 2014 ± 13 Ma with concordances of 92.7%, 99.4% and 99.4%, respectively (Table 1; Fig. 1g). It is worthy to note that the 4087 Ma zircon with concordance of 99.9% appears as a dark-brown euhedral crystal with length/width ratios of 3:2 and without any cracks and inclusions in the reflection images (Figs. 1f–g; Appendix 1). A distinct core and a rim can be observed in the CL images. The core is dark-grey and has low luminescence and striped absorption, with a high Th/U ratio of 0.37, suggesting a magmatic origin and a likely acidic nature. The rim of the zircon is bright and has irregular shapes, which could be attributed to later overgrowth of the crystal, similar to the one with Archean age (see #21 in Fig. 1f). Unfortunately, the rim is too narrow to measure the U–Pb age data; therefore, we are not able to unequivocally distinguish whether the rim is igneous or metamorphic overgrowth. These characteristics indicate that the detrital and relatively broad core of the 4087 Ma

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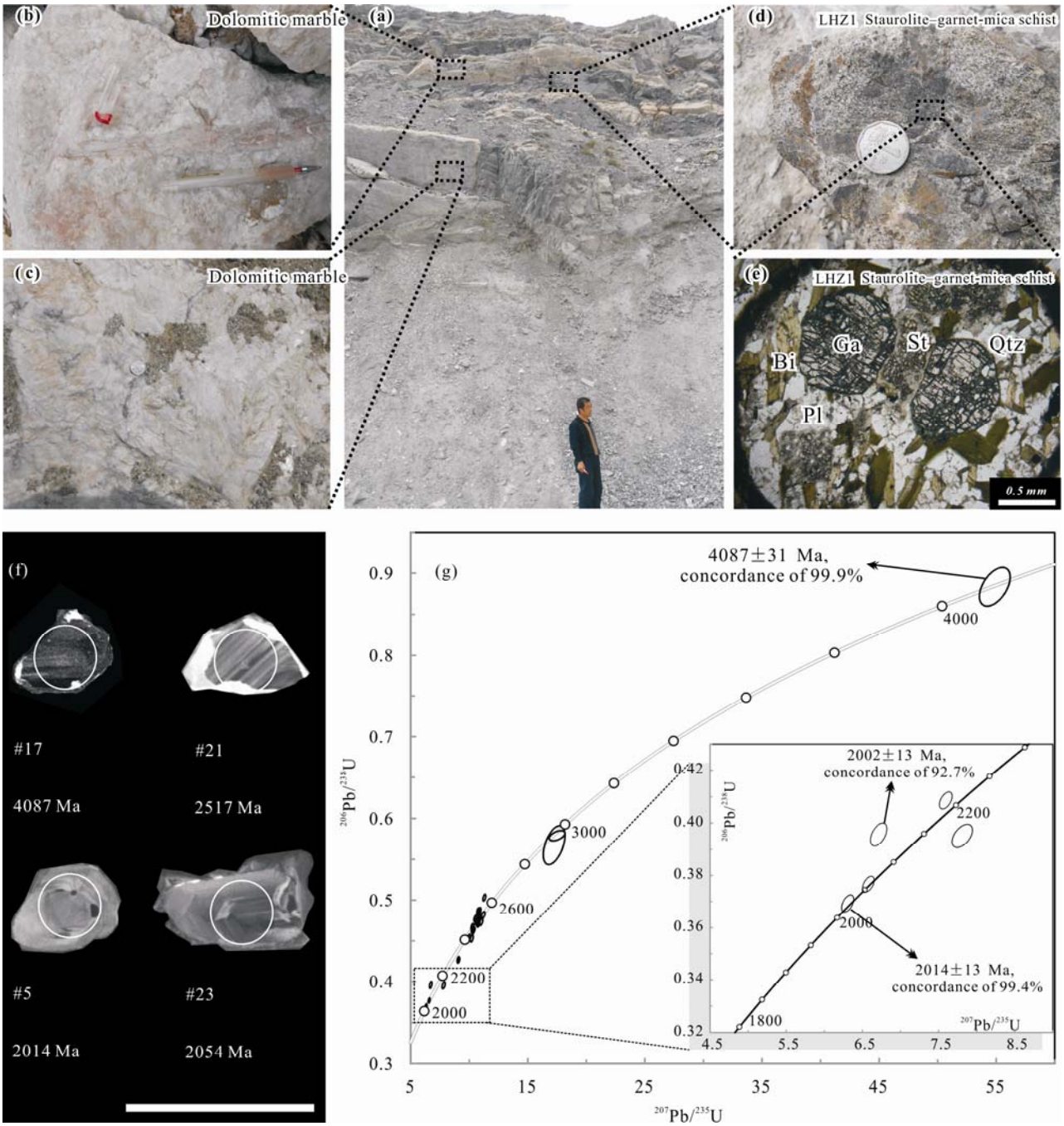

Fig. 1. (a), A field photo showing that the schist (d) is intercalated with dolomitic marbles (b) and (c); (e), Microphotograph of the staurolite-garnet-mica schist (LHZ1); (f), CL images of representative zircons, with a cartoon showing the Hadean zircon textures. The circles on the zircons represent analyzed spots, and the numbers below are the U–Pb ages and spot numbers; (g), Zircon U–Pb ages for the sample (LHZ1).

zircon is igneous in origin with a narrow rim probably overgrown during late-stage thermal events or metamorphism.

Conclusions

The presence of the Hadean detrital zircon in the metasedimentary rocks in the North China Craton is conspicuous and the 4087 Ma zircon is ~570 million years older than the oldest zircon previously identified in the Jiao–Liao–Ji belt. To our knowledge, this is the first report of Hadean crustal material identified in a Paleoproterozoic sedimentary rock all over the world. This study may also indicate that the possibility of obtaining additional Hadean material entrained in the Paleoproterozoic sedimentary rock in the North China Craton and other cratonic areas

may be greater than previously thought. The North China Craton, especially the Eastern Block, is an ideal geological environment for further exploration for the Hadean zircon or even rock.

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Appendix 1 Zircon U–Pb age data

Spot	Th (ppm)	U (ppm)	Th/U	Isotopic ratios						Corrected ages (Ma)						Disc (%)
				$^{207}Pb/^{206}Pb$	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	
LHZ1-1	2	21	0.09	0.21932	0.00494	17.50904	0.44473	0.57900	0.00406	2976	36	2963	75	2945	21	1.0
LHZ1-2	403	536	0.75	0.16118	0.00113	10.29901	0.07665	0.46343	0.00259	2468	12	2462	18	2455	14	0.5
LHZ1-3	18	63	0.29	0.14347	0.00149	7.81766	0.08846	0.39519	0.00289	2270	18	2210	25	2147	16	5.4
LHZ1-4	633	1185	0.53	0.15943	0.00111	10.27226	0.07372	0.46729	0.00245	2450	12	2460	18	2472	13	−0.9
LHZ1-5	97	152	0.64	0.12395	0.00091	6.31126	0.05268	0.36930	0.00217	2014	13	2020	17	2026	12	−0.6
LHZ1-6	290	341	0.85	0.15991	0.00115	10.52261	0.07971	0.47726	0.00260	2455	12	2482	19	2515	14	−2.5
LHZ1-7	202	279	0.73	0.16418	0.00121	10.79624	0.08421	0.47691	0.00266	2499	12	2506	20	2514	14	−0.6
LHZ1-8	608	404	1.51	0.16254	0.00120	10.36599	0.08454	0.46255	0.00280	2482	12	2468	20	2451	15	1.3
LHZ1-9	120	725	0.17	0.16376	0.00117	10.22079	0.08477	0.45266	0.00289	2495	12	2455	20	2407	15	3.5
LHZ1-10	1	10	0.14	0.22059	0.00373	17.25645	0.61271	0.56736	0.01567	2985	27	2949	105	2897	80	3.0
LHZ1-11	102	123	0.83	0.16641	0.00123	10.79111	0.08239	0.47032	0.00249	2522	12	2505	19	2485	13	1.5
LHZ1-12	118	284	0.41	0.15478	0.00108	9.09160	0.07002	0.42600	0.00236	2399	12	2347	18	2288	13	4.7
LHZ1-13	151	759	0.20	0.16283	0.00114	10.75341	0.09008	0.47897	0.00313	2485	12	2502	21	2523	16	−1.5
LHZ1-14	64	111	0.57	0.16898	0.00128	11.03117	0.09128	0.47346	0.00310	2548	13	2526	21	2499	16	1.9
LHZ1-15	95	301	0.32	0.16293	0.00114	10.86149	0.08213	0.48350	0.00278	2486	12	2511	19	2542	15	−2.3
LHZ1-16	1228	1730	0.71	0.15958	0.00107	9.99962	0.07000	0.45447	0.00239	2451	11	2435	17	2415	13	1.5
LHZ1-17	2	5	0.37	0.45060	0.00952	54.88397	0.86824	0.88339	0.01546	4087	31	4085	65	4081	71	0.1
LHZ1-18	24	384	0.06	0.16286	0.00105	11.29461	0.07910	0.50297	0.00280	2486	11	2548	18	2627	15	−5.7
LHZ1-19	105	230	0.46	0.16039	0.00104	10.75849	0.07357	0.48649	0.00256	2460	11	2502	17	2555	13	−3.9
LHZ1-20	139	255	0.54	0.16591	0.00113	10.91824	0.07882	0.47730	0.00260	2517	11	2516	18	2515	14	0.1
LHZ1-21	106	373	0.29	0.16220	0.00115	10.88400	0.08402	0.48668	0.00273	2479	12	2513	19	2556	14	−3.1
LHZ1-22	158	416	0.38	0.12676	0.00093	6.58380	0.05020	0.37669	0.00200	2054	13	2057	16	2061	11	−0.4
LHZ1-23	269	1185	0.23	0.16218	0.00115	10.61962	0.07981	0.47491	0.00259	2479	12	2490	19	2505	14	−1.1
LHZ1-24	224	546	0.41	0.16539	0.00116	10.78571	0.08603	0.47297	0.00279	2512	12	2505	20	2497	15	0.6
LHZ1-25	75	643	0.12	0.12316	0.00092	6.71942	0.07098	0.39571	0.00287	2002	13	2075	22	2149	16	−7.3
LHZ1-26	275	1067	0.26	0.15394	0.00108	9.06807	0.06533	0.42724	0.00224	2390	12	2345	17	2293	12	4.1
LHZ1-27	196	468	0.42	0.13491	0.00095	7.60108	0.05548	0.40862	0.00214	2163	12	2185	16	2209	12	−2.1
LHZ1-28	31	129	0.24	0.16872	0.00132	11.21041	0.09599	0.48188	0.00262	2545	13	2541	22	2535	14	0.4
LHZ1-29	442	723	0.61	0.16343	0.00120	10.65186	0.08171	0.47271	0.00255	2491	12	2493	19	2495	13	−0.2
LHZ1-30	45	518	0.09	0.21932	0.00494	17.50904	0.44473	0.57900	0.00406	2976	36	2963	75	2945	21	1.0
LHZ1-31	1512	2011	0.75	0.16118	0.00113	10.29901	0.07665	0.46343	0.00259	2468	12	2462	18	2455	14	0.5
LHZ1-32	123	426	0.29	0.14347	0.00149	7.81766	0.08846	0.39519	0.00289	2270	18	2210	25	2147	16	5.4
LHZ1-33	88	165	0.53	0.15943	0.00111	10.27226	0.07372	0.46729	0.00245	2450	12	2460	18	2472	13	−0.9
LHZ1-34	235	369	0.64	0.12395	0.00091	6.31126	0.05268	0.36930	0.00217	2014	13	2020	17	2026	12	−0.6
LHZ1-35	544	641	0.85	0.15991	0.00115	10.52261	0.07971	0.47726	0.00260	2455	12	2482	19	2515	14	−2.5
LHZ1-36	208	286	0.73	0.16418	0.00121	10.79624	0.08421	0.47691	0.00266	2499	12	2506	20	2514	14	−0.6