Research Advances

New Zircon U-Pb Age of Tuff in the Third Section of the Tuchengzi Formation: Constraints on the Jurassic-Cretaceous Boundary of Continental Strata in Western Liaoning

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Citation: Chen et al., 2019. New Zircon U-Pb Age of Tuff in the Third Section of the Tuchengzi Formation: Constraints on the Jurassic-Cretaceous Boundary of Continental Strata in Western Liaoning. Acta Geologica Sinica (English Edition), 93(6): 1980–1982. DOI: 10.1111/1755-6724.14318

Objective

Western Liaoning has a large area of Mesozoic continental strata, which is unique for the study of Mesozoic continental strata in China and even all over the world. The Jurassic-Cretaceous boundary of Mesozoic continental strata in Western Liaoning has been controversial since 2013 when the Jurassic-Cretaceous boundary at 145 Ma was established in the international stratigraphic table. The Tuchengzi Formation is a key Mesozoic stratum in Western Liaoning, which is widely distributed and has a clear top and bottom. The determination of the age of the Tuchengzi Formation can provide important constraints on the Jurassic-Cretaceous boundary in Western Liaoning and even eastern China, as well as on the study of other major geological problems in eastern China. However, because of the domination of coarse clastic rocks and few fossils, paleontologists have been debating the age of the Tuchengzi Formation. At the same time, the geochronogical study is very difficult due to the lack of volcanic rocks in the Tuchengzi Formation. Rock assemblages can divide the Tuchengzi Formation into three sections from bottom to top. So far, several ages have been obtained from the first and second sections of the Tuchengzi Formation, but not yet in the third section. In this paper, three new ages have been reported for the first time for tuff interbeds within the third section of the Tuchengzi Formation. Combined with the analysis of sedimentary facies, the Jurassic-Cretaceous boundary of continental strata in Western Liaoning has been determined.

Methods

In this paper, three rhyolitic crystal tuff samples were collected from the third section of the Tuchengzi Formation for zircon U-Pb dating. Zircon grains were extracted from whole-rock samples and handpicked at the LangfangYuneng Mineral Separation Limited Company, Hebei Province, China. The cathodoluminescence (CL) imaging and the LA-ICP-MS zircon U-Pb analysis were undertaken at the Key Laboratory of Mineral Resources Evaluation in Northeast Asia, Ministry of Land and Resources, Jilin University, Changchun, China.

Results

In CL images, all the samples display striped absorption and fine-scale oscillatory zoning. Zircons of the samples are short or long column. Most zircons have high Th/U ratios (>0.4), indicating a magmatic origin. Therefore, the LA-ICP-MS U-Pb zircon ages can represent their crystallization ages.

Twenty analyses of zircons were carried out for sample PM205-31-1. All the data plot on the concordant line and can be divided into four groups. The first and second groups include six spots,yielding weighted mean ^{206}Pb/^{238}U ages of 355.9±5.4 Ma (n=3)and 233.9±7.8 Ma (n=3), respectively. The third group consists of only one spot with ^{206}Pb/^{238}U age of 156±2 Ma. These three groups of ages are older than the main population, implying that they represent inherited/xenocrystic zircons in this rhyolitic tuff. The forth group includes thirteen spots, yielding a weighted mean ^{206}Pb/^{238}U age of 133.4±2.7 Ma (MSDW=4.2), which is regarded as the crystallization age of this sample.

Twenty-three analyses of zircons were carried out for sample D1019. Four zircon data were eliminated because of high discordancy. The other nineteen spots can be divided into three groups. The weighted mean ^{206}Pb/^{238}U ages of the first and second groups are 238±3 Ma (n=1) and 162.5±2.0 Ma (n=3), respectively, which are interpreted as ages of inherited/xenocrystic zircons. The third group contains 15 zircon analyses plotted on or near the concordant line, defining a weighted mean ^{206}Pb/^{238}Uage of 126.9±2.0 Ma (MSDW=4.1), which is regarded as the crystallization age of sample D1019.

Twenty analyses of zircons were obtained from sample D1013. Nine zircon data were eliminated in drawing

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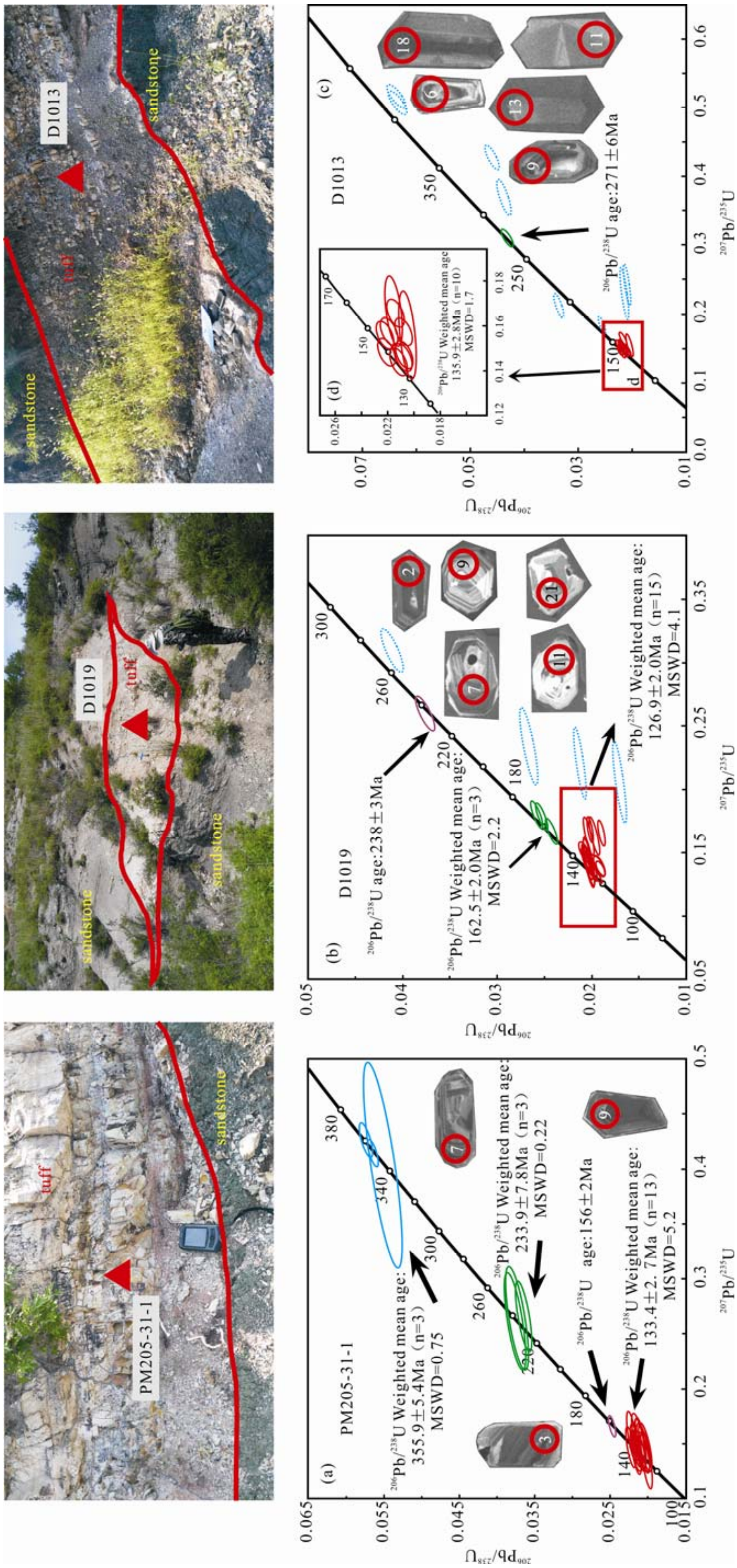

Fig. 1. U-Pb concordia diagrams of zircons from the rhyolitic crystal tuffs inthe third section of the Tuchengzi Formation in Western Liaoning.

concordia diagram because of high discordancy. One of the remaining eleven concordant data is an inherited age of 271±6 Ma (Fig. 2c), while the other ten zircon analyses concentrate in one group on the concordant line. Their weighted mean ^{206}Pb/^{238}Uage is 135.9±2.8 Ma (MSDW=1.7), which is regarded as the crystallization age of this sample.

The dating results of three rhyolitic crystal tuff samples are in a range of 126.9–135.9 Ma, indicating that the forming time of the third section of the Tuchengzi Formation is the Early Cretaceous.

Conclusions

Previous studies show that the first and second sections of the Tuchengzi Formation were formed in the Late Jurassic (146–147 Ma). This paper determines that the third section of the Tuchengzi Formation was formed in the Early Cretaceous (126.9–135.9 Ma). The sedimentary environment of the second and third sections of the Tuchengzi Formation was alluvial fan facies and eolian desert facies, respectively. There may be a sedimentary discontinuity between them. Taken together, it is concluded here that the Jurassic-Cretaceous boundary of continental strata in Western Liaoning occurred within the Tuchengzi Formation should be between the second and third sections.

Acknowledgments

This study is financially supported by the China Geological Survey (grants No. DD20190042, DD2016 0048-05, 12120113053400 and 12120114055501).

Appendix LA-ICP-MS U-Pb data of zircons from the rhyolitic crystal tuffs in the third section of the Tuchengzi Formation in Western Liaoning

Sample no.	Pb	Th	U	Th/U	$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$	
		ppm			ratio	1σ	ratio	1σ	ages	1σ	ages	1σ
PM205-31-1-1	7	142	221	0.64	0.15019	0.00427	0.02228	0.00027	142	4	142	2
PM205-31-1-2	50	2662	1481	1.80	0.14795	0.00249	0.02058	0.00023	140	2	131	1
PM205-31-1-3	19	364	702	0.52	0.14476	0.00313	0.02149	0.00025	137	3	137	2
PM205-31-1-4	14	172	177	0.97	0.42618	0.01229	0.05733	0.00072	360	9	359	4
PM205-31-1-5	9	223	337	0.66	0.14753	0.01562	0.02213	0.00054	140	14	141	3
PM205-31-1-6	17	453	697	0.65	0.16595	0.01001	0.02153	0.00039	156	9	137	2
PM205-31-1-7	19	592	732	0.81	0.15155	0.00901	0.02032	0.00035	143	8	130	2
PM205-31-1-8	13	297	498	0.60	0.14470	0.01273	0.02087	0.00047	137	11	133	3
PM205-31-1-9	5	177	140	1.26	0.14574	0.01355	0.02147	0.00046	138	12	137	3
PM205-31-1-10	23	411	859	0.48	0.14593	0.00266	0.02166	0.00024	138	2	138	2
PM205-31-1-11	3	58	126	0.47	0.13983	0.02452	0.02030	0.00080	133	22	130	5
PM205-31-1-12	17	101	262	0.39	0.26125	0.03695	0.03750	0.00114	236	30	237	7
PM205-31-1-13	13	245	548	0.45	0.16633	0.00693	0.02457	0.00035	156	6	156	2
PM205-31-1-14	38	467	507	0.92	0.41460	0.00955	0.05638	0.00067	352	7	354	4
PM205-31-1-15	12	172	170	1.01	0.26415	0.03934	0.03716	0.00125	238	32	235	8
PM205-31-1-16	18	179	287	0.62	0.40722	0.08037	0.05511	0.00200	347	58	346	12
PM205-31-1-17	108	74	133	0.56	0.13433	0.00805	0.01988	0.00034	128	7	127	2
PM205-31-1-18	20	557	708	0.79	0.13731	0.00510	0.02033	0.00027	131	5	130	2
PM205-31-1-19	18	438	789	0.55	0.13787	0.00540	0.02048	0.00024	131	5	131	2
PM205-31-1-20	27	361	373	0.97	0.26636	0.02661	0.03650	0.00092	240	21	231	6
D1019-01*	1	46	30	1.52	0.23392	0.02497	0.02658	0.00080	213	20	169	4
D1019-02	10	220	371	0.59	0.14105	0.00540	0.02035	0.00044	134	4	130	2
D1019-03*	3	48	87	0.55	0.18138	0.00866	0.02524	0.00056	169	7	161	2
D1019-04	2	88	79	1.12	0.16259	0.01268	0.02015	0.00053	153	11	129	3
D1019-05	10	266	349	0.76	0.14124	0.00565	0.02039	0.00044	134	5	130	2
D1019-06*	6	209	162	1.29	0.18280	0.00880	0.02551	0.00058	170	7	162	2
D1019-07	14	639	389	1.64	0.14252	0.01582	0.02028	0.00050	135	10	129	2
D1019-08	14	393	490	0.80	0.14690	0.01084	0.02021	0.00046	139	7	129	2
D1019-09	21	522	788	0.66	0.14924	0.00418	0.02019	0.00042	141	3	129	2
D1019-10	12	394	416	0.95	0.14322	0.00688	0.01992	0.00045	136	6	127	2
D1019-11	16	896	441	2.03	0.17529	0.00466	0.02000	0.00042	146	9	127	2
D1019-12	8	282	291	0.97	0.13987	0.00648	0.01915	0.00043	133	5	122	2
D1019-13*	5	159	115	1.38	0.21986	0.02315	0.02115	0.00057	202	13	135	2
D1019-14*	7	112	129	0.87	0.30983	0.01393	0.04111	0.00093	274	10	260	4
D1019-15*	10	248	299	0.83	0.16834	0.00844	0.02382	0.00055	158	7	152	2
D1019-16	4	185	132	1.40	0.13899	0.00728	0.01994	0.00046	132	6	127	2
D1019-17	20	743	667	1.11	0.16260	0.01244	0.01964	0.00047	153	6	125	2
D1019-18	13	374	463	0.81	0.15268	0.00453	0.02080	0.00044	144	3	133	2
D1019-19*	5	124	124	1.00	0.19598	0.02680	0.01782	0.00054	182	18	114	2
D1019-20*	7	121	136	0.89	0.25867	0.01112	0.03768	0.00084	234	8	238	3
D1019-21	7	255	277	0.92	0.13764	0.00478	0.01902	0.00041	131	4	121	2
D1019-22	16	834	487	1.71	0.18016	0.00464	0.01941	0.00041	168	3	124	1
D1019-23	21	713	776	0.92	0.13077	0.00444	0.01932	0.00042	125	3	123	2
D1013-01	19	218	338	0.64	0.31013	0.00920	0.04298	0.00091	274	7	271	6
D1013-02*	8	130	121	1.07	0.36980	0.02033	0.04370	0.00105	320	15	276	6
D1013-03	14	649	388	1.68	0.14903	0.00455	0.02208	0.00047	141	4	141	3
D1013-04*	39	240	472	0.51	0.51716	0.01362	0.06367	0.00134	423	9	398	8
D1013-05	27	1052	836	1.26	0.16571	0.00491	0.02146	0.00046	156	4	137	3
D1013-06	19	695	575	1.21	0.15746	0.00437	0.02200	0.00046	148	4	140	3
D1013-07	23	981	680	1.44	0.15568	0.00429	0.02220	0.00047	147	4	142	3
D1013-08*	18	430	341	1.26	0.21257	0.01325	0.03348	0.00073	196	11	212	5
D1013-09	24	1045	740	1.41	0.14610	0.00408	0.02088	0.00044	138	4	133	3
D1013-10*	9	230	123	1.86	0.43058	0.01308	0.04398	0.00095	364	9	277	6
D1013-11	26	1159	796	1.46	0.14371	0.00392	0.02122	0.00045	136	3	135	3
D1013-12	21	872	620	1.41	0.19088	0.00479	0.02117	0.00045	177	4	135	3
D1013-13	67	4519	1599	2.83	0.15937	0.00417	0.02087	0.00044	150	4	133	3
D1013-14	27	1012	857	1.18	0.15574	0.01310	0.02052	0.00049	147	12	131	3
D1013-15*	43	198	557	0.36	0.50669	0.01342	0.06330	0.00135	416	9	396	8
D1013-16*	7	276	194	1.43	0.18417	0.00816	0.02538	0.00057	172	7	162	4
D1013-17*	40	1655	1018	1.63	0.24075	0.02404	0.02092	0.00057	219	20	133	4
D1013-18	70	3135	2222	1.41	0.14691	0.00390	0.02076	0.00044	139	3	132	3
D1013-19*	6	132	130	1.01	0.42852	0.01917	0.02652	0.00066	362	14	169	4
D1013-20*	66	3935	1409	2.79	0.23060	0.03112	0.02137	0.00064	211	26	136	4

*Representing the abandoned points because of discordance when calculating weighted average age.