Research Advances

New Zircon U-Pb Age of Granodiorite in Chifeng at the Northern Margin of North China Craton and Constraints on Plate Tectonic Evolution

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Objective

The North China Craton (NCC) is one of the oldest cratons in the world. The accretionary belt at its northern margin has been the focus of scholars both at home and abroad (Zhu Junbing and Ren Jishun, 2017). In recent years, a series of Late Paleozoic-Mesozoic intrusions trending E-W have been discovered within the northern margin of the NCC, forming a magmatic belt. The study on the origin and tectonic setting of this magmatic belt not only has important significance for understanding the Late Paleozoic-Mesozoic tectonic evolution history of the northern margin of the NCC, but also can provide key constraints on the evolution of its surrounding Xing'an-Mongolia orogenic belt and the Paleo-Asian Ocean. At present, no Devonian to early stage of Early Carboniferous intrusion has been reported within the northern margin of the NCC. A large volume of granites is distributed in the Chifeng area, and the exsiting datas show that they are mostly emplaced from the Permian to Mesozoic (Cui Yuliang et al., 2017). Are there any earlier intrusions within this region? In order to solve the problem, this paper reports a newly discovered Early Carboniferous granodiorite in the Chifeng area, which will provide evidence on the Early Carboniferous tectonic evolution of the northern margin of the NCC.

Methods

Four samples for zircons dating in this work were collected from the Xiaxinjing and Zhuanshanzi plutons in eastern Chifeng. Zircon grains were extracted from wholerock samples and handpicked at the Langfang Yuneng Mineral Separation Limited Company, Hebei Province, China. The cathodoluminescence (CL) images of zircons were completed at the electron microprobe Laboratory of the Institute of Geology and Geophysics, Chinese Academy of sciences. The LA-ICP-MS zircon U-Pb analysis was carried out at the Geologic Lab Center, China University of Geosciences (Beijing).

Results

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

The Th/U ratios of zircons from the sample PM205 range from 0.47 to 1.04. Twenty-four analyses of zircons were obtained from this sample. All the data points have small variation range and distribute in one group on the concordant line. Their weighted mean ²⁰⁶Pb/²³⁸U age is 354.3±1.1 Ma (MSDW=0.94), which is regarded as the magma crystallization age of this sample. The Th/U ratios of zircons from the sample D2710-1 range from 0.41 to 1.11. For this sample, twenty-five U-Pb analyses were obtained. All but two of the analyses data distribute in one group on or near the concordant line. Their weighted mean ²⁰⁶Pb/²³⁸U age is 351.1±1.7Ma (MSDW=0.67), which is regarded as the crystallization age of D2710-1. The Th/U ratios of zircons from the sample D2712-1 range from 0.53 to 1.55 except one inherited zircon (Th/U=0.13). Twenty-five analyses of zircons were obtained from this sample. Eleven of these data are inherited zircon, and the other 14 analyses data distribute in one group on the concordant line. Their weighted mean ²⁰⁶Pb/²³⁸U age is 355.3±3.1 Ma (MSDW=0.23), which is regarded as the crystallization age of this sample. The Th/U ratios of zircons from the sample D7274 range from 0.33 to 1.56. For this sample, twenty-five U-Pb analyses were obtained. Eight zircon data are eliminated in drawing concordia

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Fig. 1. U-Pb concordia diagrams of zircons from the granodiorites from the Yuanbaoshan and Zhuanshanzi area in eastern Chifeng.

diagram because of inherited age or high discordancy. The other 17 zircon analyses distribute in one group on or near the concordant line, with a weighted mean ²⁰⁶Pb/²³⁸U age of 358.7±2.9 Ma (MSDW=0.43), which is regarded as the crystallization age of D7274. The dating results of four granodiorite samples indicate they were emplaced in the Early Carboniferous with an age range of 351.1–358.7Ma.

Conclusions

A suite of granodiorite has been identified in the Yuanbaoshan and Zhuanshanzi area in eastern Chifeng at northern margin of NCC. The dating results of four granodiorite samples are 354.3 ± 1.1 Ma, 351.1 ± 1.7 Ma, 355.3 ± 3.1 Ma and 358.7 ± 2.9 Ma, respectively, indicating that their crystallization age is the Early Carboniferous. This is the first discovery of early stage of Early Carboniferous intrusion in the northern margin of the NCC. The identification of the granodiorite fills the gap of

the early stage of Early Carboniferous tectonic evolution of the northern margin of the NCC.

Acknowledgments

This study is financially supported by the China Geological Survey (grants No. DD20160048-05, 12120113053400 and 12120114055501).

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ACTA GEOLOGICA SINICA (English Edition) http://www.geojournals.cn/dzxben/ch/index.aspx http://mc.manuscriptcentral.com/ags

Feb. 2018

Appendix 1 LA-ICP-MS U-Pb data of zircons from the granodiorite in the	e Chifeng area
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Mon. pp Ta U PhpZe10	Spot No.	C	ontent (pp	n)	Th/II		omposition	Age (Ma)					
PM205-01 25 352 346 1.01 0.41574 0.01076 0.05681 0.00089 353 8 357 5 PM205-03 17 200 344 0.82 0.41754 0.0159 0.05656 0.00091 353 9 353 6 6 9 9 353 9 353 6 353	Spot No.	Pb	Th	U	- In/U	²⁰⁷ Pt	o/ ²³⁵ U	²⁰⁶ Pt	$0/^{238}$ U	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ
PM205-62 26 340 365 09 0.42947 0.01107 0.005847 0.00091 335 9 357 5 PM205-641 18 242 235 0.98 0.01127 0.005646 0.00091 335 9 355 6 PM205-66 12 157 199 0.77 0.44897 0.0110 0.05546 0.00092 351 19 355 6 PM205-68 84 123 0.68 0.44897 0.01610 0.05549 0.00092 351 11 355 6 PM205-69 8 84 123 0.68 0.44897 0.01649 0.00092 354 9 355 6 PM205-11 17 20 224 0.84 0.01491 0.01690 0.00091 355 13 35 6 PM205-11 17 20 235 68 0.44297 0.0117 0.05580 0.00094 355 9 355 <th< td=""><td>PM205-01</td><td>25</td><td>352</td><td>348</td><td>1.01</td><td>0.41574</td><td>0.01076</td><td>0.05631</td><td>0.00088</td><td>353</td><td>8</td><td>353</td><td>5</td></th<>	PM205-01	25	352	348	1.01	0.41574	0.01076	0.05631	0.00088	353	8	353	5
PM205-03 17 200 244 0.82 0.41754 0.0159 0.00091 355 8 8 6 PM205-04 12 111 185 0.61 0.41872 0.01218 0.00091 353 9 355 6 PM205-07 23 21 448 0.41872 0.01218 0.00096 353 9 353 6 PM205-07 23 21 348 0.61 0.41823 0.0100 0.00096 353 11 353 6 PM205-07 14 147 244 0.81 0.01200 0.05547 0.00091 327 10 353 6 PM205-10 14 147 244 0.84 0.01200 0.00097 357 11 357 6 PM205-15 16 196 223 0.84 0.42176 0.01164 0.00090 357 8 357 6 PM205-17 18 221 0.44	PM205-02	26	349	365	0.96	0.42047	0.01107	0.05687	0.00090	356	8	357	5
PM205-04 18 2409 255 09 0.41877 0.01272 0.015656 0.00091 355 09 355 6 PM205-06 30 224 445 0.65 0.04522 0.01001 355 12 353 6 PM205-07 13 157 19 0.75 0.04597 0.00094 355 11 355 6 PM205-07 8 34 123 0.05 0.00094 355 11 355 6 PM205-11 17 206 242 0.85 0.42823 0.01489 0.05094 0.00094 355 7 356 6 PM205-12 7 7.15 0.75 0.44923 0.01440 0.00489 355 8 353 5 PM205-13 10 109 150 0.72 0.4125 0.0116 0.00494 352 8 353 5 PM205-14 11 194 233 0.84 <	PM205-03	17	200	244	0.82	0.41754	0.01159	0.05640	0.00091	354	8	354	6
PM205-05 12 113 185 061 0.41520 0.0126 353 09 353 6 PM205-06 14 157 199 0.79 0.4209 0.0110 0.05645 0.0000 357 9 353 6 PM205-10 14 147 134 0.73 0.44174 0.0126 0.05529 0.00002 353 9 333 6 PM205-11 14 147 136 0.54 0.4225 0.01248 0.05529 0.000091 325 11 337 6 PM205-11 10 109 109 0.72 0.44252 0.01248 0.05560 0.00091 335 6 PM205-12 9 73 136 0.54 0.42210 0.1660 0.00091 355 9 355 6 PM205-12 18 321 238 8 331 5 9 335 6 0.00091 352 8 335 <th< td=""><td>PM205-04</td><td>18</td><td>249</td><td>255</td><td>0.98</td><td>0.41897</td><td>0.01272</td><td>0.05656</td><td>0.00091</td><td>355</td><td>9</td><td>355</td><td>6</td></th<>	PM205-04	18	249	255	0.98	0.41897	0.01272	0.05656	0.00091	355	9	355	6
PM205-66 30 296 485 0.65 0.14820 0.01677 0.05680 0.00006 355 12 353 6 PM205-08 23 261 348 0.1320 0.00006 355 11 353 6 PM205-08 23 241 343 0.68 0.0122 0.00007 355 11 353 6 PM205-11 14 14 234 0.68 0.0123 0.00007 355 9 0.00007 355 9 0.00007 157 11 357 6 PM205-14 16 196 223 0.48 0.42028 0.01078 0.05684 0.00097 357 8 353 5 PM205-14 18 221 223 0.48 0.01170 0.05584 0.00093 351 8 353 5 PM205-13 18 21 223 0.41276 0.01167 0.05584 0.00090 353 8 351	PM205-05	12	113	185	0.61	0.41522	0.01208	0.05623	0.00093	353	9	353	6
PM205-07 14 157 199 0.79 0.42699 0.0110 0.05866 0.00092 357 9 357 6 PM205-09 8 84 123 0.068 0.41640 0.01557 0.00092 355 11 355 6 PM205-10 11 123 0.04 0.01480 0.01430 0.05570 0.00092 355 11 335 6 PM205-11 10	PM205-06	30	296	458	0.65	0.41820	0.01677	0.05630	0.00102	355	12	353	6
PM205-48 23 241 348 0.75 0.4182 0.01272 0.05515 0.00093 354 9 352 6 PM205-10 14 147 244 0.0182 0.0184 0.05527 0.00093 354 9 353 6 PM205-11 17 264 0.242 0.01144 0.05527 0.00091 355 11 355 6 PM205-12 2 224 0.85 0.42253 0.01171 0.00991 355 7 355 5 PM205-12 12 242 1.04 0.42023 0.01078 0.05585 0.00089 351 8 355 5 PM205-12 18 140 221 0.64 0.0176 0.05585 0.00089 351 8 351 5 PM205-20 19 10 0.41210 0.0176 0.05573 0.0008 351 7 355 5 PM205-21 19 123 0.	PM205-07	14	157	199	0.79	0.42099	0.01310	0.05686	0.00096	357	9	357	6
PM208-10 8 84 123 0.06 0.01480 0.05857 0.00098 355 11 355 6 PM208-11 17 206 242 0.03 0.04823 0.00097 351 10 353 6 PM208-12 2 2 356 0.5 0.01097 0.05801 0.00097 355 7 355 6 PM208-13 10 10 350 0.8 0.02987 355 7	PM205-08	23	261	348	0.75	0.41674	0.01272	0.05615	0.00092	354	9	352	6
PM205-10 14 147 204 0.72 0.41283 0.01206 0.05529 0.00091 354 9 355 6 PM205-12 9 73 136 0.54 0.42125 0.01481 0.05520 0.00091 355 9 356 6 PM205-14 22 233 0.68 0.4203 0.01118 0.05844 0.00092 357 8 357 6 PM205-14 22 233 0.68 0.4207 0.01118 0.05824 0.00092 351 8 353 5 PM205-15 14 0.41276 0.0116 0.05824 0.00090 364 8 353 5 PM205-21 19 170 290 0.59 0.4214 0.01221 0.05728 0.00090 354 5 PM205-23 19 192 280 0.63 0.41241 0.01220 0.05738 0.00091 351 8 355 5 PM205-23 <td>PM205-09</td> <td>8</td> <td>84</td> <td>123</td> <td>0.68</td> <td>0.41882</td> <td>0.01490</td> <td>0.05657</td> <td>0.00098</td> <td>355</td> <td>11</td> <td>355</td> <td>6</td>	PM205-09	8	84	123	0.68	0.41882	0.01490	0.05657	0.00098	355	11	355	6
PM205-11 17 206 242 0.05 0.42106 0.0148 0.05524 0.00097 352 11 353 6 PM205-13 10 109 150 0.72 0.41201 0.01309 0.05580 0.00097 355 9 356 6 5 PM205-15 16 164 223 0.04491 0.01078 0.05580 0.00089 351 8 351 5 PM205-16 15 140 0.041491 0.01078 0.05580 0.00089 351 8 351 5 PM205-16 13 242 224 0.04 0.41210 0.00589 0.00090 352 8 351 5 PM205-21 19 170 249 249 0.04 0.42141 0.0157 0.00589 350 7 355 5 PM205-21 19 170 240 0.44141 0.01671 0.05621 0.00072 364 8 355	PM205-10	14	147	204	0.72	0.41689	0.01206	0.05629	0.00092	354	9	353	6
PM205-12 9 73 156 0.54 0.04181 0.05700 0.00097 355 9 356 6 PM205-14 222 335 0.68 0.42028 0.01018 0.05864 0.00099 355 9 355 5 PM205-16 16 16 223 0.88 0.42097 0.01078 0.05864 0.00099 352 8 353 5 PM205-17 18 202 10.41 0.41256 0.01078 0.05863 0.00090 354 8 355 5 PM205-20 24 349 349 100126 0.05863 0.00090 354 8 355 5 PM205-21 19 170 290 0.42114 0.0127 0.05864 0.00090 354 8 355 5 PM205-21 16 154 370 0.47 0.4270 0.00078 0.3521 0.00078 359 7 359 5 P	PM205-11	17	206	242	0.85	0.42825	0.01348	0.05624	0.00091	362	10	353	6
PM205-13 10 109 150 0.72 0.0120 0.05800 0.00094 355 7 356 5 PM205-15 16 196 223 0.08 0.42028 0.01118 0.05800 0.00092 357 8 357 6 PM205-15 16 196 223 0.0140 0.0523 0.00089 351 8 355 5 PM205-18 18 202 270 0.0126 0.05530 0.00089 351 8 350 5 PM205-12 18 221 288 0.3161 0.01270 0.05530 0.00089 359 7 359 5 PM205-21 19 192 231 0.47 0.4178 0.01070 0.05733 0.00089 355 8 355 5 PM205-21 19 192 231 0.48 0.41788 0.01710 0.00713 0.4371 0.0173 0.05733 0.00009 355 8 <	PM205-12	9	73	136	0.54	0.42106	0.01481	0.05700	0.00097	357	11	357	6
PM205-14 22 229 335 0.68 0.42029 0.01017 0.05684 0.00089 335 7 356 5 PM205-16 21 344 222 0.48 0.0117 0.05503 0.00089 352 8 353 5 PM205-18 15 140 231 0.61 0.01176 0.05594 0.00090 352 8 353 5 PM205-19 17 206 0.33 0.01167 0.05590 0.00090 352 8 355 5 PM205-21 21 173 370 0.471 0.42210 0.0252 0.0008 359 7 359 5 PM205-21 19 172 248 0.68 0.41183 0.01090 0.05640 0.00090 355 8 355 5 PM205-21 19 122 238 0.62 0.41180 0.01310 0.0371 351 8 345 4 D2710-01<	PM205-13	10	109	150	0.72	0.41921	0.01309	0.05680	0.00094	355	9	356	6
PM205-15 16 196 223 0.88 0.4297 0.01177 0.05600 0.00092 352 8 353 5 PM205-17 18 202 270 0.75 0.41256 0.01078 0.00583 0.00089 351 8 350 5 PM205-18 15 140 0.1170 0.0553 0.00090 364 9 354 5 PM205-22 24 349 339 1.03 0.0126 0.05503 0.00090 359 7 359 5 PM205-22 17 370 0.47 0.4270 0.00050 0.3272 0.00090 352 8 355 5 PM205-22 16 154 377 0.41 0.01071 0.0564 0.00090 352 8 355 5 PM205-22 16 54 377 0.41 0.41678 0.01071 0.00071 341 7 352 4 12710.01 26 343 </td <td>PM205-14</td> <td>22</td> <td>229</td> <td>335</td> <td>0.68</td> <td>0.42028</td> <td>0.01018</td> <td>0.05684</td> <td>0.00089</td> <td>356</td> <td>7</td> <td>356</td> <td>5</td>	PM205-14	22	229	335	0.68	0.42028	0.01018	0.05684	0.00089	356	7	356	5
PM205-16 21 304 2270 0.75 0.01256 0.01078 0.05523 0.00089 352 8 353 5 PM205-18 15 140 231 0.61 0.01176 0.05554 0.00090 352 8 351 5 PM205-19 18 221 2268 0.83 0.0116 0.05590 0.00090 352 8 351 5 PM205-22 29 173 370 0.4214 0.01090 0.0564 0.00090 352 8 355 5 PM205-21 19 170 0.427 0.02120 0.05723 0.00090 352 8 355 5 PM205-21 16 154 249 0.01071 0.05622 0.00090 352 8 345 4 D2710-01 25 283 4 345 4 345 4 345 4 D2710-06 7 343 4 0.2213	PM205-15	16	196	223	0.88	0.42097	0.01177	0.05690	0.00092	357	8	357	6
PM205-17 18 202 270 0.75 0.41256 0.01116 0.05584 0.00080 351 8 350 5 PM205-19 18 221 268 0.83 0.41346 0.01267 0.05534 0.00090 352 8 351 5 PM205-20 24 349 339 1.03 0.4121 0.0126 0.05590 0.00090 359 9 359 5 PM205-21 19 170 290 0.59 0.42414 0.0122 0.05728 0.00090 352 8 355 5 PM205-21 16 154 249 0.62 0.41424 0.01071 0.05662 0.00090 352 8 355 5 D2110-02 26 244 377 0.911 0.42675 0.01184 0.00071 354 8 345 4 D2110-02 27 343 0.410216 0.00122 0.00518 0.00071 354 5	PM205-16	21	304	292	1.04	0.41491	0.01046	0.05623	0.00089	352	8	353	5
PM205-18 15 140 221 268 0.83 0.43146 0.01267 0.05533 0.00009 354 9 354 5 PM205-20 24 349 339 1.03 0.41211 0.01267 0.05533 0.00008 359 7 359 5 PM205-21 19 170 0.47 0.42370 0.01090 0.05664 0.00090 355 8 355 5 PM205-21 16 154 249 0.62 0.41424 0.01090 0.05664 0.00090 355 8 345 4 D2710-01 26 344 377 0.91 0.42075 0.01090 0.05610 0.00071 354 7 359 4 D2710-01 27 399 402 0.99 0.40055 0.01084 0.03072 3434 8 345 4 D2710-01 22 173 185 0.441 0.00122 0.05518 0.00072 359 <td>PM205-17</td> <td>18</td> <td>202</td> <td>270</td> <td>0.75</td> <td>0.41256</td> <td>0.01078</td> <td>0.05585</td> <td>0.00089</td> <td>351</td> <td>8</td> <td>350</td> <td>5</td>	PM205-17	18	202	270	0.75	0.41256	0.01078	0.05585	0.00089	351	8	350	5
PM205-19 18 221 268 0.83 0.413140 0.01026 0.05590 0.00098 359 7 351 5 PM205-21 19 170 290 0.59 0.42141 0.01025 0.00090 359 7 359 5 PM205-22 29 175 370 0.47 0.01005 0.05723 0.00090 355 8 355 5 PM205-24 16 154 249 0.68 0.41830 0.01071 0.00070 361 7 359 4 D2710-02 26 234 603 0.47 0.41676 0.00071 0.00071 354 8 345 4 D2710-03 37 406 578 0.7 0.41766 0.00072 0.05518 0.00072 343 4 343 4 D2710-06 73 384 14 1115 0.75 0.41071 0.00272 0.05518 0.00072 358 6 <t< td=""><td>PM205-18</td><td>15</td><td>140</td><td>231</td><td>0.61</td><td>0.41376</td><td>0.01116</td><td>0.05594</td><td>0.00090</td><td>352</td><td>8</td><td>351</td><td>5</td></t<>	PM205-18	15	140	231	0.61	0.41376	0.01116	0.05594	0.00090	352	8	351	5
PM205-20 24 349 339 1.03 0.41211 0.01221 0.025728 0.00008 359 7 359 5 PM205-22 29 175 370 0.47 0.42370 0.01090 0.05728 0.00090 355 8 355 5 PM205-24 16 154 249 0.62 0.41424 0.01070 0.05664 0.00090 352 8 351 5 D2710-01 26 344 377 0.4176 0.01030 0.00721 354 7 359 4 D2710-02 36 63 0.47 0.41678 0.01030 0.00721 354 7 352 4 D2710-04 27 399 402 0.99 0.40055 0.01084 0.03540 0.00072 354 7 343 4 D2710-06 12 173 185 0.4104215 0.0122 0.03518 0.00070 355 6 352 4	PM205-19	18	221	268	0.83	0.43146	0.01267	0.05653	0.00090	364	9	354	5
PM205-21 19 170 290 0.59 0.42144 0.01272 0.00090 359 9 359 5 PM205-23 19 192 281 0.68 0.41833 0.01005 0.02733 0.00090 355 8 355 5 D2710-01 26 344 377 0.911 0.42675 0.01071 0.05602 0.00090 352 8 345 4 D2710-02 36 283 603 0.477 0.41676 0.01071 0.05602 0.00072 354 8 345 4 D2710-03 37 406 578 0.77 0.41766 0.00072 0.05511 0.00071 344 7 352 4 D2710-06 73 384 1115 0.75 0.41071 0.002518 0.00072 354 8 349 4 D2710-06 12 173 185 0.94 0.40235 0.01184 0.035518 0.00071 3556	PM205-20	24	349	339	1.03	0.41211	0.01026	0.05590	0.00088	350	7	351	5
PM205-22 29 175 370 0.47 0.42370 0.01005 0.05664 0.00090 355 8 355 5 PM205-24 16 154 249 0.62 0.41424 0.01071 0.05664 0.00090 352 8 351 5 D2710-01 26 344 377 0.0103 0.01631 0.00071 354 8 345 4 D2710-04 27 399 402 0.99 0.41678 0.01184 0.05511 0.00071 354 8 345 4 D2710-04 27 399 402 0.99 0.40055 0.01184 0.05560 0.00072 342 9 346 5 D2710-07 22 138 0.94 0.40235 0.01610 0.05550 0.00071 343 9 346 5 D2710-07 22 23 58 0.61 0.42353 0.00071 356 7 348 4	PM205-21	19	170	290	0.59	0.42414	0.01221	0.05728	0.00090	359	9	359	5
PM205-23 19 192 281 0.68 0.41833 0.01090 0.05602 0.00900 352 8 355 5 D2710-01 26 283 603 0.412675 0.01030 0.05731 0.00072 354 8 345 4 D2710-02 36 283 603 0.47 0.41766 0.00992 0.05511 0.00071 354 7 352 4 D2710-04 27 399 402 0.99 400355 0.01232 0.05518 0.00072 342 9 346 5 D2710-046 12 173 185 0.94 0.40255 0.01232 0.05518 0.00072 359 8 349 4 D2710-04 13 102 122 0.04235 0.00072 359 7 348 4 D2710-10 44 429 705 0.61 0.42363 0.00071 350 4 10 344 5 10	PM205-22	29	175	370	0.47	0.42370	0.01005	0.05723	0.00089	359	7	359	5
PM05-24 16 154 249 0.62 0.41424 0.0071 0.05701 0.000073 351 7 359 4 D2710-02 36 283 603 0.47 0.41678 0.01186 0.05711 0.00072 354 8 345 4 D2710-04 27 399 402 0.99 0.40055 0.01640 0.00071 354 8 345 4 D2710-04 27 399 402 0.99 0.40055 0.01844 0.05560 0.00072 342 9 343 4 D2710-06 12 173 185 0.94 0.40235 0.01921 0.05550 0.00072 359 8 349 4 D2710-07 21 22 358 0.61 0.41918 0.005570 0.00070 355 6 352 4 D2710-10 44 429 705 0.61 0.42363 0.00071 366 7 348 <td< td=""><td>PM205-23</td><td>19</td><td>192</td><td>281</td><td>0.68</td><td>0.41883</td><td>0.01090</td><td>0.05664</td><td>0.00090</td><td>355</td><td>8</td><td>355</td><td>5</td></td<>	PM205-23	19	192	281	0.68	0.41883	0.01090	0.05664	0.00090	355	8	355	5
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	PM205-24	16	154	249	0.62	0.41424	0.01071	0.05602	0.00090	352	8	351	5
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-01	26	344	377	0.91	0.42675	0.01030	0.05731	0.00073	361	7	359	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-02	36	283	603	0.47	0.41678	0.01186	0.05491	0.00072	354	8	345	4
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-03	37	406	578	0.7	0.41766	0.00992	0.05611	0.00071	354	7	352	4
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-04	27	399	402	0.99	0.40055	0.01184	0.05460	0.00072	342	9	343	4
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-05	73	834	1115	0.75	0.41071	0.00828	0.05560	0.00069	349	6	349	4
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-06	12	173	185	0.94	0.40235	0.01292	0.05518	0.00074	343	9	346	5
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-07	22	223	358	0.62	0.42352	0.01141	0.05559	0.00072	359	8	349	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-08	57	549	897	0.61	0.41918	0.00897	0.05608	0.00070	355	6	352	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-09	13	102	212	0.48	0.45911	0.01465	0.05637	0.00074	384	10	354	5
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-10	44	429	705	0.61	0.42363	0.00916	0.05542	0.00069	359	7	348	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-11	24	205	386	0.53	0.41924	0.01019	0.05550	0.00071	356	7	348	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-12	34	351	540	0.65	0.41228	0.00942	0.05586	0.00070	351	7	350	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-13	35	246	581	0.42	0 40397	0.00928	0.05576	0.00071	345	7	350	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-14	44	692	623	1.11	0.40709	0.00934	0.05517	0.00070	347	7	346	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-15	62	746	942	0.79	0 40307	0.00871	0.05568	0.00070	344	6	349	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-16	56	793	826	0.96	0.40747	0.00876	0.05556	0.00070	347	6	349	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-17	49	462	795	0.58	0.40230	0.00869	0.05501	0.00069	343	6	345	4
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	D2710-18	32	469	463	1.01	0.41457	0.00981	0.05585	0.00071	352	7	350	4
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	D2710-19	78	922	1197	0.77	0.40760	0.00866	0.05587	0.00070	347	6	350	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-20*	81	1172	1229	0.95	0.51462	0.01079	0.05610	0.00070	422	7	352	4
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-21	25	340	378	0.9	0.40663	0.01019	0.05564	0.00071	346	, 7	349	4
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2710-22	26	237	432	0.55	0.40542	0.00978	0.05507	0.00070	346	7	346	4
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	D2710-23	37	394	588	0.67	0.41206	0.00978	0.05593	0.00071	350	7	351	4
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	D2710-24*	17	249	233	1.07	0 47974	0.01554	0.05922	0.00080	398	11	371	5
$\begin{array}{ c c c c c c c c c c c c c c c c c c c$	D2710-25	40	522	584	0.89	0 44040	0.01240	0.05575	0.00073	371	9	350	4
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2712-1-01*	348	92	701	0.13	10 1891	0.25852	0.45644	0.00674	2452	23	2424	30
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2712-1-02	15	274	201	1 36	0 42430	0.02386	0.05742	0.00106	359	17	360	6
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	D2712-1-03	20	309	278	1.11	0.41666	0.02281	0.05629	0.00099	354	16	353	6
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2712-1-04	16	184	235	0.78	0.43767	0.02315	0.05662	0.00095	369	16	355	6
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2712-1-05	21	253	310	0.82	0.42629	0.01801	0.05662	0.00091	361	13	355	6
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2712-1-06*	26	390	342	1 14	0.46618	0.04062	0.05578	0.00106	389	28	350	6
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2712-1-00	13	125	170	0.74	0.45790	0.05464	0.05359	0.00100	383	38	337	7
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2712-1-08*	13	195	178	1.09	0.54077	0.02517	0.05999	0.00122	439	17	376	6
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2712-1-00	16	196	246	0.8	0.41815	0.02034	0.05628	0.00093	355	15	353	6
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$D2712_{-1}10$	23	244	310	0.76	0.47371	0.02051	0.06263	0.00106	30/	14	302	6
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	D2712-1-10	23	218	354	0.70	0.42548	0.01715	0.05709	0.00092	360	12	358	6
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2712-1-11*	34	167	218	0.77	0.42340	0.1/007	0.03707	0.00092	518	01	281	0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	D2712-1-12	47	887	570	1.55	0.41997	0.01397	0.05688	0.00149	356	10	357	5
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	D2712-1-13	11	88	167	0.53	0.41916	0.03265	0.05507	0.00117	355	22	351	7
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	D2712-1-14	50	886	646	1 37	0.42118	0.03203	0.05700	0.000117	357	10	357	5
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	D2712-1-16*	13	215	146	1.57	0.81568	0.04050	0.06177	0.00121	606	22	386	7
D2712-1-18* 17 145 146 0.99 0.50635 0.08254 0.0522 0.00120 356 24 355 7 D2712-1-18* 17 145 146 0.99 0.50635 0.08250 0.05557 0.00124 416 56 349 8 D2712-1-19* 29 455 348 1.31 0.50585 0.04377 0.05630 0.00105 416 30 353 6 D2712-1-20 12 142 182 0.78 0.42142 0.01849 0.05720 0.00096 357 13 359 6 D2712-1-21 16 209 229 0.92 0.41713 0.01942 0.05642 0.00096 354 14 354 6 D2712-1-22* 10 143 151 0.95 0.54403 0.03415 0.05684 0.00119 441 22 356 7 D2712-1-23* 20 191 201 0.95 0.54403 0.03415 0.06671 0.00149 615 49 380 9	$D_{2712-1-10}$	8	74	178	0.58	0 41027	0.04039	0.05622	0.00121	356	23 24	353	7
D2712-1-10 17 145 140 0.00 0.00000 0.00124 410 30 349 8 D2712-1-19* 29 455 348 1.31 0.50585 0.04377 0.05630 0.00105 416 30 353 6 D2712-1-20 12 142 182 0.78 0.42142 0.01849 0.05720 0.00096 357 13 359 6 D2712-1-21 16 209 229 0.92 0.41713 0.01942 0.05642 0.00096 354 14 354 6 D2712-1-22* 10 143 151 0.95 0.54403 0.03415 0.05684 0.00119 441 22 356 7 D2712-1-23* 20 191 201 0.95 0.83251 0.08755 0.06071 0.00149 615 49 380 9	$D2712_{1}18*$	17	1/15	1/6	0.00	0.50625	0.03274	0.05557	0.00120	/16	27 56	3/0	, Q
D2712-1-20 12 142 182 0.78 0.42142 0.01849 0.05720 0.00096 357 13 359 6 D2712-1-21 16 209 229 0.92 0.41713 0.01942 0.05642 0.00096 354 14 354 6 D2712-1-22* 10 143 151 0.95 0.54403 0.03415 0.05684 0.00119 441 22 356 7 D2712-1-23* 20 191 201 0.95 0.83751 0.08765 0.06149 615 49 380 9	D2712-1-10*	20	455	348	1 3 1	0.50055	0.03230	0.05537	0.00124	416	30	252	6
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$D_2 / 1_2 - 1 - 1_2 / 1_2 - 1_2 - 1_2 / 1_2 - 1_2 - 1_2 / 2_2 / $	12	1/2	182	0.79	0.20202	0.019/0	0.05050	0.00105	357	12	350	6
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	D2712-1-20	14	200	220	0.70	0.42142	0.01049	0.05720	0.00090	35/	1/	357	6
$D_{2712-1-22}$ 10 145 151 0.75 0.54405 0.05415 0.05064 0.00119 441 22 550 / $D_{2712-1-23}$ * 20 191 201 0.95 0.83251 0.08765 0.06071 0.00149 615 40 380 0	D2712-1-21	10	1/2	151	0.92	0.5//02	0.01742	0.05694	0.00090	774 771	22	354	7
	D2712-1-22*	20	145	201	0.95	0.83251	0.03415	0.05084	0.00119	615	22 40	380	ý

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Appendix 1 Continued

Spot No.	Content (ppm)			Isotopic composition				Age (Ma)				
	Pb	Th	U	Th/U	²⁰⁷ Pb/ ²³⁵ U		²⁰⁶ Pb/ ²³⁸ U		²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ
D2712-1-24*	16	209	184	1.13	0.83296	0.06666	0.05903	0.00128	615	37	370	8
D2712-1-25	15	192	215	0.89	0.42029	0.01906	0.05674	0.00096	356	14	356	6
D7274-01*	112	94	253	0.37	4.80470	0.10326	0.30645	0.00491	1786	18	1723	24
D7274-02	77	451	1079	0.42	0.45318	0.01005	0.05781	0.00093	380	7	362	6
D7274-03	70	412	1081	0.38	0.42455	0.00960	0.05738	0.00093	359	7	360	6
D7274-04	58	292	713	0.41	0.41778	0.00951	0.05649	0.00091	354	7	354	6
D7274-05	45	225	543	0.41	0.42150	0.00993	0.05695	0.00093	357	7	357	6
D7274-06	101	715	1680	0.43	0.41822	0.00941	0.05647	0.00091	355	7	354	6
D7274-07*	102	90	212	0.43	5.73748	0.12582	0.34679	0.00560	1937	19	1919	27
D7274-08*	74	155	373	0.42	2.70238	0.06021	0.18952	0.00307	1329	17	1119	17
D7274-09	11	234	150	1.56	0.44275	0.01640	0.05690	0.00101	372	12	357	6
D7274-10	85	496	1432	0.35	0.42384	0.00993	0.05739	0.00094	359	7	360	6
D7274-11	24	189	389	0.48	0.41825	0.01107	0.05650	0.00095	355	8	354	6
D7274-12*	245	163	374	0.44	5.00940	0.11135	0.30946	0.00500	1821	19	1738	25
D7274-13	30	225	500	0.45	0.41723	0.01070	0.05647	0.00093	354	8	354	6
D7274-14	80	874	1217	0.72	0.42833	0.01011	0.05774	0.00094	362	7	362	6
D7274-15	48	436	743	0.59	0.48257	0.01172	0.05845	0.00097	400	8	366	6
D7274-16*	123	191	307	0.62	3.46932	0.07870	0.23533	0.00383	1520	18	1362	20
D7274-17	88	610	1460	0.42	0.42435	0.00991	0.05830	0.00095	359	7	365	6
D7274-18	89	449	1191	0.38	0.41958	0.00987	0.05675	0.00093	356	7	356	6
D7274-19	74	534	1254	0.43	0.42802	0.01033	0.05711	0.00094	362	7	358	6
D7274-20*	47	297	653	0.46	0.52031	0.01813	0.06812	0.00112	425	12	425	7
D7274-21	71	520	1024	0.51	0.41298	0.00995	0.05682	0.00094	351	7	356	6
D7274-22	104	565	1726	0.33	0.43056	0.01031	0.05798	0.00095	364	7	363	6
D7274-23*	117	886	1793	0.49	0.57966	0.02268	0.05801	0.00099	464	15	364	6
D7274-24*	86	747	1270	0.59	0.43899	0.01071	0.06139	0.00101	370	8	384	6
D7274-25	45	393	716	0.55	0.42578	0.01104	0.05748	0.00096	360	8	360	6

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