U-Pb geochronology of the Mitchell deposit, northwestern British Columbia

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Front cover: Xenolith of Phase 1 diorite with internal stockwork in Phase 2 diorite at Mitchell, 423300 E, 6265575 N. **Photo by Gayle Febbo**.

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Abstract

Cross-cutting relationships separate three phases of plutonism at the Mitchell calc-alkalic porphyry Au-Cu-Ag-Mo deposit in Stikine terrane of northwestern British Columbia. A sample of porphyritic hornblende diorite from Phase 1 yielded a U-Pb zircon age of 196 ± 2.9 Ma. A second porphyritic hornblende diorite sample from Phase 1 yielded a U-Pb zircon age of 189.9 ± 2.8 Ma. A sample of hornblende diorite from Phase 2 yielded a U-Pb zircon age of 192.2 ± 2.8 Ma, which is within error of the younger Phase 1 determination.

Keywords: Sulphurets district, KSM property, KSM trend, Mitchell, porphyry, U-Pb zircon, Texas Creek suite

1. Introduction

The Mitchell calc-alkalic porphyry Au-Cu-Ag-Mo deposit, in Stikine terrane of northwestern British Columbia, is the largest undeveloped gold resource in Canada, with 40.72 Moz of total contained gold (Seabridge Gold, 2018). It is part of the KSM porphyry trend, a 12 km long linear array that also includes the Kerr, Sulphurets and Iron Cap porphyry Au-Cu deposits. The Mitchell deposit is genetically related to diorite, monzodiorite and graniodiorite intrusions, part of the regionally-extensive Texas Creek suite (Lower Jurassic; Fig. 1; Kirkham, 1963). These intrusions cut sedimentary and volcanic rocks of the Stuhini Group (Upper Triassic) and Hazelton Group (Upper Triassic to Lower Jurassic; Alldrick and Britten, 1988, 1991; Nelson and Kyba, 2014; Nelson et al., 2018). The results and interpretations of U-Pb zircon geochronologic work on samples taken from these intrusions were reported by Febbo et. al, (2015) and Febbo (2016); herein we provide sample descriptions and analytical data.

2. Sample descriptions

The relative ages of intrusive phases mapped at the Mitchell deposit (Fig. 1) are defined by cross-cutting relationships. Sample M-11-123 is representative of Phase 1, and sample M-07-49 is representative of Phase 2. Sample M-11-123 demonstrates a clear overlap with potassic alteration, which is one of the criteria for classification as Phase 1. Other criteria for Phase 1 classification include the overprint of high-volume quartz veins, which range from 20 to 90% by volume (e.g., sheeted vein body; Febbo, 2016). Sample M-07-49 contains clasts of the sheeted vein body, a criterion used in the field area to outline the extent of Phase 2 (Fig. 1), and has sparse quartz veins, which is typical of Phase 2.

The affinity of sample GF-13-02 is less clear. It has an ambiguous relationship to potassic alteration and the sheeted vein body, and contains only sparse quartz veins (~10%), more typical of Phase 2. However, domains of anomalously low quartz vein abundance have been mapped in Phase 1 outcrops (Fig. 2), and it is uncertain if sample GF-13-02 represents one of these anomalous Phase 1 domains or represents Phase 2. Nonetheless, the sampled intrusion lacks xenoliths of the sheeted veins despite being adjacent to a raft of the sheeted vein body, and despite being surrounded by Phase 2 rocks with abundant such xenoliths (Figs. 1, 2). Hence we interpret that sample GF-13-02 represents Phase 1.

2.1. Sample M-11-123

Sample M-11-123 is a medium-grained, potassic-altered, Phase 1 porphyritic hornblende diorite (sample from drill hole M-11-123, 621 m depth; location 422606 mE, 6265280 mN, 198 m asl elevation). The intrusion is synmineralization because it hosts irregularly shaped, disarticulated chalcopyrite-quartz veins and vein fragments with diffuse boundaries and is overprinted by pervasive and vein-controlled secondary K-feldspar, quartz, biotite, chlorite, magnetite, pyrite and chalcopyrite. It contains 35% sericitized plagioclase phenocrysts (0.5-2 mm in diametre), 7% K-feldspar phenocrysts (1-5 mm in diametre) and 10% hornblende phenocrysts (0.5-1 mm diametre) in an altered, fine-grained groundmass. This sample yielded a U-Pb zircon age of 196 ± 2.9 Ma (see below).

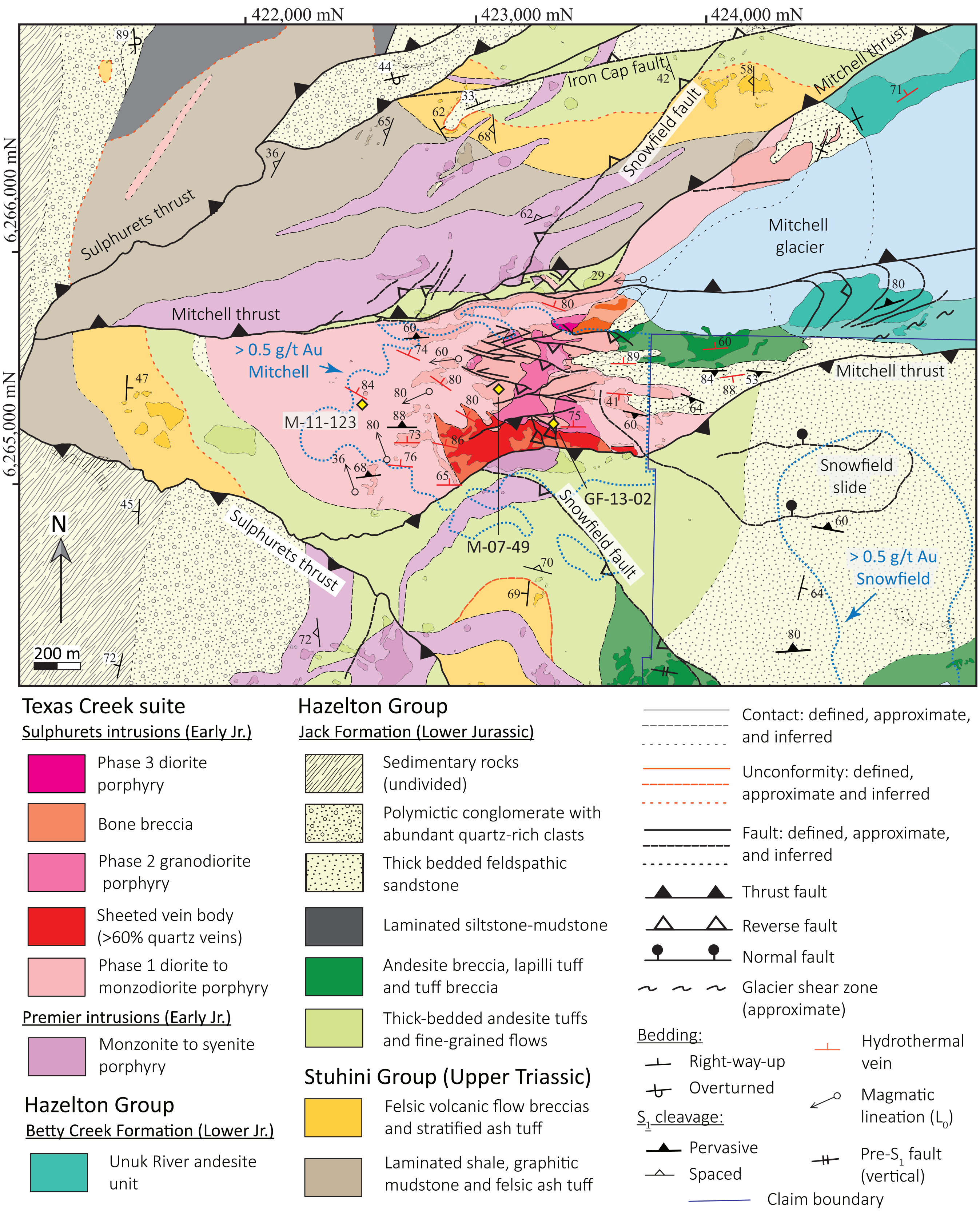

Fig. 1. Geological map of the Mitchell deposit showing locations of geochronologic samples.

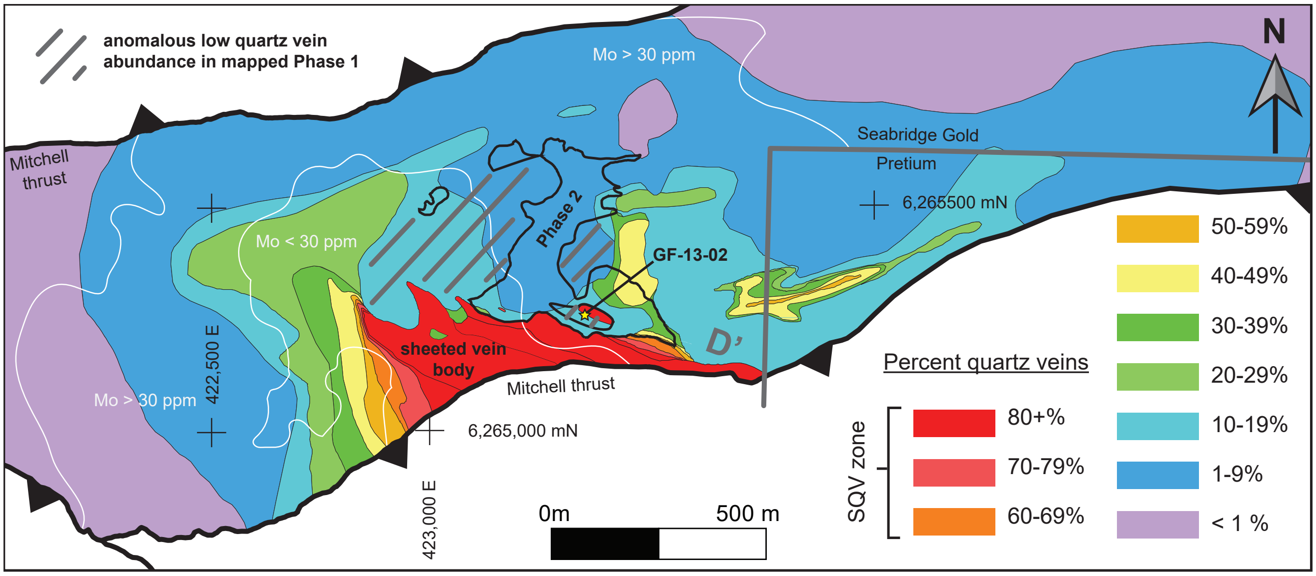

Fig. 2. Quartz vein abundance map and molybdenum grade contours for the Mitchell deposit.

2.2. Sample GF-13-02

Sample GF-13-02 is a medium-grained, phyllic-altered Phase 1 porphyritic hornblende diorite that crops out adjacent to a sheeted vein body (location 423312 mE, 6265278 mN, 990 m asl elevation). It is interpreted as host to the sheeted vein body because it contains no clasts of the nearby sheeted quartz veins. The sampled intrusion is diorite in composition from whole rock geochemistry (Febbo, 2016), consisting of 35% muscovite-altered laths interpreted to be replaced plagioclase (1-2 mm in diametre), 8% chlorite aggregates in rhombohedral domains interpreted to be replaced hornblende (0.5-1 mm in diametre) and 5% equant anhedral K-feldspar partially replaced to muscovite (2-3 mm diametre) in an altered, fine-grained groundmass. It is overprinted by muscovite-chlorite-pyrite-magnetite alteration with trace chalcopyrite, 2% pyrite and ~10% quartz-chalcopyrite-pyrite veins by volume. This sample yielded a U-Pb zircon age of 189.9 ± 2.8 Ma (see below).

2.3. Sample M-07-49

Sample M-07-49 is a Phase 2 intermineralization hornblende diorite from drill hole M-07-49 at a depth of 320m (423123 mE, 6265474 mN, 619 m asl elevation). The sample is a fine-grained, Phase 2 hornblende diorite plug that cuts the sheeted quartz vein body and is overprinted by quartz-muscovite-illite-pyrite pervasive alteration and planar veins. The sheeted veins that are cut by the plug contain ~90% quartz-pyrite-chalcopyrite veins in the contact area. The intensely altered sampled intrusion is diorite in composition from whole rock geochemistry (Febbo, 2016) and overlaps temporally with granodiorite dikes in drill core. Due to the alteration intensity, it was not possible to identify primary quartz that was used to characterize a granodioritic composition in other Phase 2 intrusions. The intrusion contains 1-10% quartz vein xenoliths that are most abundant in the contact areas and is overprinted by ~5% quartz-pyrite-chalcopyrite veins. The porphyry contains 30% muscovite-altered laths (~1 mm long) interpreted to be replaced plagioclase, 5% chlorite aggregates interpreted to be replaced hornblende, and 5% anhedral inclusion-rich K-feldspar in a fine-grained groundmass. The intrusion is overprinted by muscovite-illite-chlorite-pyrite alteration with 1% secondary magnetite and stringers of anhydrite and calcite. This sample yielded a U-Pb zircon age of 192.2 ± 2.8 Ma (see below).

3. Zircon analysis

Zircon analysis was done by laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) at the University of British Columbia's Pacific Centre for Isotopic and Geochemical Research; detailed methods are described by Tafti et al. (2009). All three samples contain similar zircons: well-zoned, clear to pale pink, euhedral to subhedral prisms with length-width ratios of 1 to 3 (Fig. 3).

Fig. 3. CL images of representative grains dated using LA-ICP-MS. White lines show outlines oflaser tracks. **a).** Sample M-11-123, analysis 14. **b).** Sample GF-13-02, analysis 9. **c).** Sample M-07-49, analysis 12.

4. Results

Cross-cutting relationships separate three phases of plutonism at Mitchell. Phase 1, defined by multiple pulses of diorite, hosts all of the copper-gold bearing potassic alteration. A medium grained, potassic- and phyllic-altered, synmineralization Phase 1 hornblende diorite (sample M-11-123) returned a U-Pb zircon age of 196 ± 2.9 Ma (Figs. 4a, b; Table 1). A second Phase 1 hornblende diorite (sample GF-13-02), which hosts a copper-gold mineralized sheeted vein body, returned a U-Pb zircon age of 189.9 ± 2.8 Ma (Figs. 4c, d, Table 1). A Phase 2 phyllic-altered, hornblende diorite cuts Phase 1 rocks and the sheeted vein body. Sample M-07-49 from Phase 2 returned a U-Pb zircon age of 192.2 ± 2.8 Ma (Figs. 4e, f; Table 1), an age that overlaps, within error, with the younger of the Phase 1 ages.

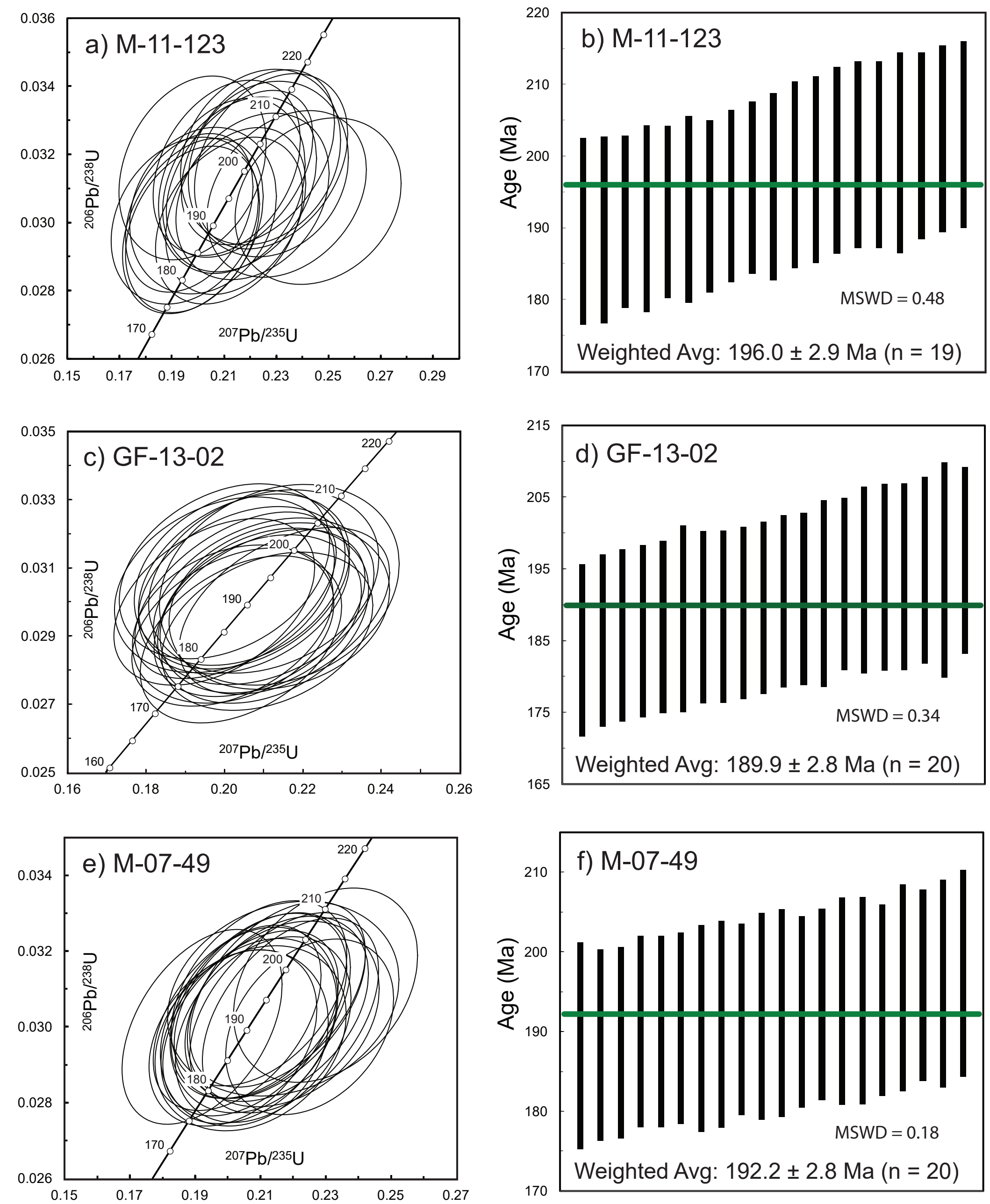

Fig. 4. Concordia diagrams (a, c, e) and $^{206}Pb/^{238}U$ age histograms, (b, d, f). All errors are shown at 2σ.

Table 1. Zircon U-Pb laser ablation ICP-MS analytical data.

Sample no. Analysis ID	Isotopic Ratios							Isotopic Ages					
	$^{207}Pb/^{235}U$	2σ (abs)	$^{206}Pb/^{238}U$	2σ (abs)	ρ[1]	$^{207}Pb/^{206}Pb$	2σ (abs)	$^{207}Pb/^{235}U$	2σ (Ma)	$^{206}Pb/^{238}U$	2σ (Ma)	$^{207}Pb/^{206}Pb$	2σ (Ma)
GF-13-02													
1	0.204	0.022	0.0307	0.0021	0.26	0.048	0.003	188	18	195	13	137	130
2	0.214	0.025	0.0305	0.0024	0.21	0.052	0.005	194	21	195	15	240	180
3	0.205	0.022	0.0306	0.0021	0.32	0.050	0.004	188	19	194	13	170	140
4	0.210	0.022	0.0296	0.0021	0.30	0.052	0.004	193	19	188	13	198	130
5	0.210	0.023	0.0300	0.0020	0.33	0.050	0.004	192	19	191	12	200	130
6	0.209	0.022	0.0297	0.0020	0.42	0.051	0.003	191	18	188	12	186	120
7	0.200	0.023	0.0305	0.0021	0.29	0.049	0.004	186	19	193	13	150	140
8	0.205	0.022	0.0303	0.0020	0.33	0.050	0.003	188	18	193	12	173	120
9	0.210	0.024	0.0306	0.0022	0.25	0.052	0.004	190	20	194	13	180	150
10	0.200	0.022	0.0309	0.0021	0.33	0.047	0.004	184	19	196	13	70	130
11	0.197	0.021	0.0300	0.0020	0.41	0.049	0.003	183	18	191	12	148	120
12	0.214	0.023	0.0299	0.0020	0.19	0.053	0.004	194	19	190	12	331	140
13	0.203	0.021	0.0302	0.0020	0.51	0.051	0.003	188	18	192	13	214	120
14	0.204	0.021	0.0289	0.0020	0.40	0.051	0.003	188	18	184	12	238	130
15	0.215	0.022	0.0297	0.0020	0.45	0.053	0.003	197	18	189	12	273	120
16	0.211	0.022	0.0291	0.0019	0.33	0.054	0.004	193	19	185	12	343	130
17	0.209	0.021	0.0297	0.0019	0.28	0.051	0.003	192	18	188	12	227	120
18	0.204	0.021	0.0295	0.0019	0.22	0.050	0.003	188	18	187	12	233	130
19	0.202	0.021	0.0294	0.0019	0.27	0.050	0.003	187	18	186	12	197	120
20	0.202	0.021	0.0293	0.0019	0.40	0.050	0.003	185	18	186	12	198	130
M-07-49													
1	0.215	0.022	0.0309	0.0020	0.45	0.049	0.003	197	19	196	12	167	120
2	0.207	0.022	0.0301	0.0020	0.44	0.049	0.004	188	19	191	13	152	130
3	0.225	0.021	0.0300	0.0019	0.32	0.053	0.003	207	18	190	12	310	120
4	0.205	0.021	0.0297	0.0019	0.19	0.049	0.003	188	17	188	12	175	120
5	0.211	0.022	0.0306	0.0020	0.41	0.050	0.003	193	19	194	13	189	120
6	0.211	0.022	0.0299	0.0020	0.34	0.052	0.003	194	18	190	12	270	120
7	0.203	0.021	0.0302	0.0020	0.46	0.048	0.003	189	17	192	13	132	110
8	0.219	0.022	0.0303	0.0021	0.46	0.053	0.003	200	19	192	13	271	120
9	0.210	0.022	0.0306	0.0020	0.41	0.050	0.003	192	19	194	13	184	120

Table 1. continued.

Sample no. Analysis ID	Isotopic Ratios							Isotopic Ages					
	$^{207}Pb/^{235}U$	2σ (abs)	$^{206}Pb/^{238}U$	2σ (abs)	ρ[1]	$^{207}Pb/^{206}Pb$	2σ (abs)	$^{207}Pb/^{235}U$	2σ (Ma)	$^{206}Pb/^{238}U$	2σ (Ma)	$^{207}Pb/^{206}Pb$	2σ (Ma)
10	0.207	0.024	0.0297	0.0020	0.26	0.050	0.004	186	20	188	13	170	140
11	0.215	0.022	0.0306	0.0020	0.53	0.052	0.003	197	18	194	12	256	110
12	0.206	0.022	0.0299	0.0020	0.35	0.050	0.003	189	18	190	12	173	120
13	0.230	0.023	0.0311	0.0021	0.30	0.055	0.003	209	19	197	13	320	120
14	0.202	0.021	0.0297	0.0019	0.33	0.050	0.003	186	18	189	12	199	120
15	0.215	0.023	0.0305	0.0020	0.38	0.052	0.004	196	19	193	12	210	130
16	0.217	0.024	0.0303	0.0020	0.27	0.050	0.004	197	19	193	12	170	130
17	0.208	0.021	0.0302	0.0020	0.25	0.049	0.003	191	17	192	12	151	120
18	0.217	0.029	0.0307	0.0021	0.20	0.051	0.005	199	22	196	13	250	140
19	0.210	0.022	0.0309	0.0020	0.41	0.050	0.003	192	18	196	13	190	120
20	0.192	0.020	0.0300	0.0021	0.44	0.047	0.003	178	18	190	13	86	110
M-11-123													
1	0.211	0.023	0.0316	0.0021	0.32	0.049	0.004	192	19	200	13	110	130
2	0.216	0.023	0.0314	0.0020	0.45	0.049	0.003	197	19	199	13	173	130
4	0.202	0.023	0.0304	0.0020	0.17	0.049	0.004	185	19	193	13	120	140
5	0.198	0.022	0.0299	0.0021	0.34	0.049	0.004	183	18	190	13	150	140
6	0.197	0.020	0.0303	0.0019	0.32	0.048	0.003	183	17	192	12	123	110
7	0.198	0.021	0.0298	0.0020	0.30	0.050	0.004	182	18	190	13	190	140
8	0.213	0.023	0.0311	0.0021	0.24	0.051	0.004	196	19	198	13	186	130
9	0.198	0.023	0.0316	0.0022	0.27	0.047	0.004	183	19	200	14	100	150
10	0.195	0.023	0.0301	0.0020	0.24	0.048	0.004	179	19	191	13	80	140
11	0.216	0.024	0.0311	0.0021	0.30	0.050	0.004	198	19	197	13	193	130
12	0.246	0.026	0.0306	0.0020	0.21	0.057	0.004	222	21	194	12	450	140
13	0.228	0.024	0.0318	0.0021	0.31	0.052	0.004	210	20	201	13	256	140
14	0.223	0.024	0.0319	0.0021	0.39	0.051	0.003	202	19	202	13	221	120
15	0.224	0.025	0.0319	0.0021	0.19	0.050	0.004	204	21	203	13	190	150
16	0.227	0.025	0.0316	0.0021	0.13	0.052	0.004	206	20	200	13	240	140
17	0.234	0.025	0.0308	0.0020	0.29	0.053	0.004	211	21	196	13	330	140
18	0.221	0.024	0.0308	0.0020	0.28	0.052	0.004	202	20	196	12	266	130
19	0.212	0.023	0.0301	0.0020	0.34	0.049	0.003	194	19	191	12	148	130
20	0.215	0.022	0.0303	0.0020	0.33	0.050	0.003	197	19	193	12	189	120

Table 1. continued.

Sample no. Analysis ID	Isotopic Ratios							Isotopic Ages					
	$^{207}Pb/^{235}U$	2σ (abs)	$^{206}Pb/^{238}U$	2σ (abs)	ρ[1]	$^{207}Pb/^{206}Pb$	2σ (abs)	$^{207}Pb/^{235}U$	2σ (Ma)	$^{206}Pb/^{238}U$	2σ (Ma)	$^{207}Pb/^{206}Pb$	2σ (Ma)
Plesovice reference zircon													
1	0.394	0.038	0.0537	0.0034	0.71	0.053	0.003	337	28	337	21	338	110
2	0.404	0.040	0.0546	0.0037	0.74	0.054	0.003	344	29	342	22	343	120
3	0.393	0.038	0.0535	0.0033	0.52	0.053	0.003	336	28	336	20	316	110
4	0.395	0.040	0.0541	0.0035	0.54	0.053	0.003	337	29	339	21	314	120
5	0.396	0.040	0.0546	0.0037	0.77	0.053	0.003	338	29	342	23	321	120
6	0.385	0.040	0.0525	0.0036	0.71	0.053	0.003	332	28	330	22	323	120
7	0.393	0.039	0.0530	0.0036	0.74	0.053	0.003	335	28	333	22	324	110
8	0.392	0.039	0.0533	0.0037	0.80	0.053	0.003	336	28	334	23	349	120
9	0.395	0.039	0.0545	0.0037	0.70	0.053	0.003	338	28	342	22	298	120
10	0.391	0.039	0.0547	0.0035	0.68	0.053	0.003	334	28	343	22	298	120
11	0.383	0.042	0.0527	0.0042	0.59	0.052	0.003	329	31	331	25	277	140
12	0.389	0.040	0.0526	0.0036	0.61	0.053	0.003	332	29	330	22	341	120
13	0.394	0.041	0.0540	0.0043	0.81	0.053	0.003	337	30	338	26	316	120
14	0.391	0.042	0.0526	0.0040	0.75	0.054	0.003	334	30	330	24	361	130
15	0.391	0.040	0.0537	0.0036	0.65	0.053	0.003	334	29	337	22	320	120
16	0.397	0.039	0.0537	0.0034	0.46	0.054	0.003	339	28	337	21	334	120
17	0.395	0.040	0.0543	0.0035	0.43	0.053	0.003	340	28	341	21	308	130
18	0.392	0.039	0.0530	0.0034	0.67	0.053	0.003	335	28	333	21	336	120
19	0.395	0.039	0.0539	0.0035	0.62	0.053	0.003	337	28	338	21	322	120
20	0.394	0.039	0.0538	0.0036	0.89	0.053	0.003	336	28	337	22	330	110
Temora2 reference zircon													
1	0.492	0.059	0.0679	0.0052	0.49	0.053	0.005	401	39	425	31	260	160
2	0.487	0.050	0.0665	0.0043	0.35	0.054	0.003	401	34	415	26	323	120
3	0.564	0.068	0.0687	0.0057	0.44	0.058	0.005	453	43	434	35	490	180
4	0.477	0.049	0.0652	0.0043	0.44	0.054	0.003	396	33	407	26	355	120
5	0.480	0.049	0.0650	0.0043	0.45	0.054	0.003	400	34	405	26	340	120

[1] correlation coefficient

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