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LOW-TEMPERATURE THERMAL HISTORY OF THE COAST PLUTONIC COMPLEX AND INTERMONTANE BELT, NORTHWEST BRITISH COLUMBIA (104M, N)

By Raymond A. Donelick and John R. Dickie
Dalhousie University

KEYWORDS: Geothermometry, Tagish Lake, fission-track age, apatite, zircon, Cache Creek Terrane, Whitehorse trough, Coast plutonic complex, Llewellyn fault.

INTRODUCTION

Fieldwork completed in 1990 focused on Laberge Group sediments along the shores of southern Tagish Lake, northwestern British Columbia (Figure 1-14-1). The objective of this study is to determine the low-temperature thermal evolution of this part of the Intermontane Belt, using apatite fission-track techniques and, if possible, place constraints on the timing of mineralization at the Engineer gold deposit. Sample analyses are currently underway, with new results forthcoming. The remainder of this paper focuses on previously unpublished fission-track data for northwestern British Columbia, reported and discussed in two graduate theses by the first author (Donelick, 1986; 1988; *see* also Donelick and Miller, 1986). These data constrain the regional low-temperature cooling pattern of the Coast plutonic complex and Intermontane Belt in the vicinity of Tagish Lake.

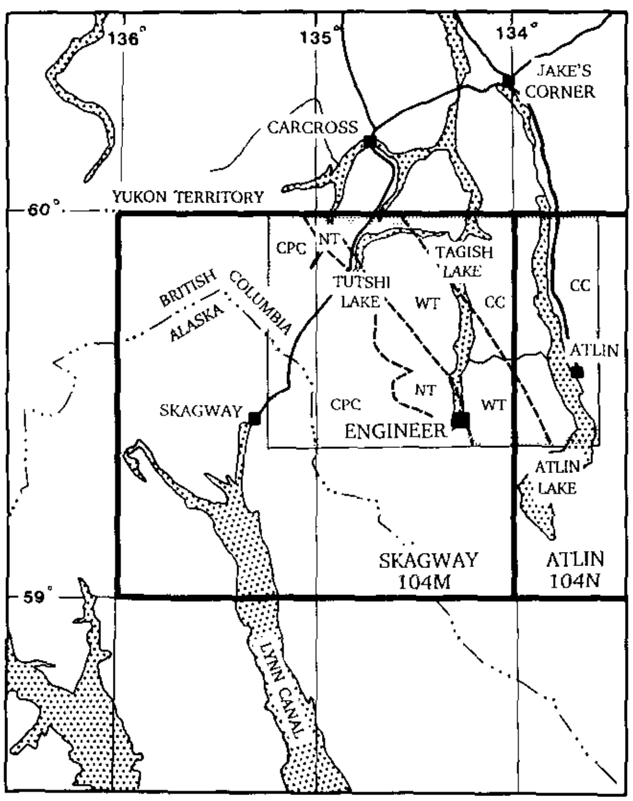

Figure 1-14-1. Location map of the study area (small box with dotted outline). CC = Cache Creek Terrane; WT = Whitehorse trough; NT = Nisling Terrane; CPC = Coast plutonic complex.

GENERAL GEOLOGY

The studied area is situated in the Cordillera of northwestern British Columbia between Atlin and the Alaska Panhandle (Figure 1-14-1; NTS 1:250 000 maps 104M and 104N). Geological mapping of this area was conducted by Christie (1957), Aitken (1959), Bultman (1979), Mihalynuk and Rouse (1988a, b), Mihalynuk *et al.* (1989a, b), Mihalynuk and Mountjoy (1990), and Mihalynuk *et al.* (1990). From east to west, the area crosses parts of (a) the Cache Creek Terrane, (b) the Whitehorse trough, (c) the Nisling Terrane, and (d) the Coast plutonic complex. The Cache Creek Terrane is composed of upper Paleozoic rocks of oceanic affinity and is inferred to have been metamorphosed no later than pre-Late Triassic time (Aitken, 1959; Eisbacher, 1974; Monger, 1977; Bultman, 1979). The Whitehorse trough is composed primarily of the Lower Jurassic Laberge Group fore-arc sequence which was folded and thrusted by Early Cretaceous time (*e.g.* Bultman, 1979; Dickie, 1989). The Nisling Terrane is composed of metamorphosed Proterozoic to Paleozoic volcanic arc and continental margin rocks (Mihalynuk and Mountjoy, 1990; Currie, 1990). Numerous Mesozoic to Cenozoic granitoid intrusions of the Coast plutonic complex form the western part of the study area and are present in all of the eastern assemblages.

LOW-TEMPERATURE HISTORY OF NORTHWESTERN BRITISH COLUMBIA

No previous work is published concerning the low-temperature thermal history of northwestern British Columbia, however, relevant studies are reported for the southern part of the Coast plutonic complex (Harrison *et al.*, 1979; Parrish, 1982; 1983) and the Omineca crystalline belt (Parrish *et al.*, 1988; Sevigney *et al.*, 1990). These studies primarily document large-scale cooling of much of the Cordillera following latest Cretaceous to Eocene compressive orogeny. Of greatest significance to the present study is the 30-kilometre-wide belt of Late Cretaceous to Middle Eocene epizonal calcalkaline plutons situated along the International Boundary between Atlin, British Columbia

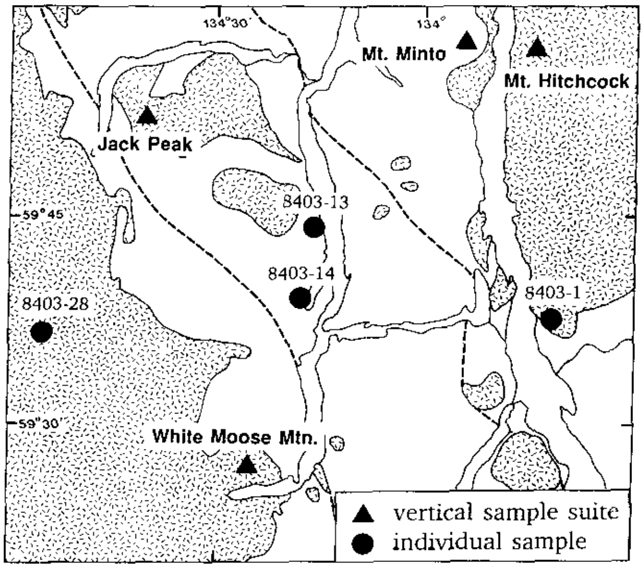

Figure 1-14-2. Sample location map. The patterned areas correspond to major granitoid intrusive bodies that were preferentially sampled; dashed lines indicate approximate terrane boundaries from Figure 1-14-1.

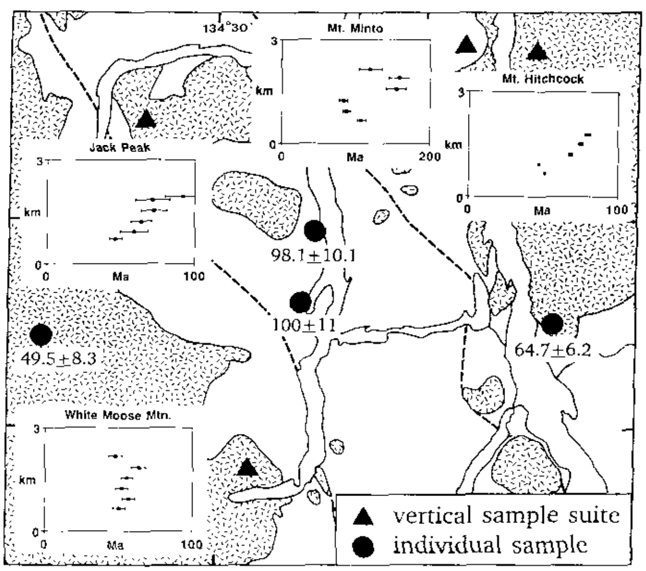

Figure 1-14-3. Summary of apatite fission-track ages (after Donelick, 1986). Errors given as one standard deviation.

and Juneau, Alaska (*e.g.* Bultman, 1979; Gehrels *et al.*, 1984; Brew, 1988), and several isolated plutons of the same age that intrude the Cache Creek Terrane to the east (Atlin Mountain, Birch Mountain; Aitken, 1959; Bultman, 1979). It is expected that the thermal histories recorded by these intrusions and adjacent country rock will reflect postintrusive cooling, no older than the age of the respective intrusive events.

Twenty-seven samples were collected from throughout the study area for fission-track analysis; sample locations

TABLE 1-14-1
SAMPLE LOCATIONS

Sample	Rock type	Elevation above m.s.l. (km)	Longitude	Latitude
		Cache Creek Terrane		
Como Lake				
8403-1	intrusive	0.92	133°40′ 0″	59°36′40″
Mount Hitchcock				
8403-2	intrusive	0.67	133°48′10″	59°55′20″
8403-3	intrusive	0.92	133°47′20″	59°55′10″
8403-4	intrusive	1.22	133°46′20″	59°55′40″
8403-5	intrusive	1.53	133°46′ 0″	59°56′ 0″
8403-6	intrusive	1.80	133°45′ 0″	59°56′20″
Mount Minto				
8403-7	intrusive	0.67	133°50′50″	59°56′20″
8403-8	intrusive	0.92	133°51′ 0″	59°56′50″
8403-9	intrusive	1.22	133°51′50″	59°56′50″
8403-10	volcanic	1.53	133°52′50″	59°56′20″
8403-11	volcanic	1.84	133°53′50″	59°56′40″
8403-12	volcanic	2.11	133°53′50″	59°57′ 0″
		Whitehorse Trough		
Tagish Lake				
8403-13	sedimentary	0.92	134°16′20″	59°45′20″
8403-14	sedimentary	0.66	134°17′40″	59°37′30″
Jack Peak				
8403-21	intrusive	0.71	134°44′10″	59°55′30″
8403-22	intrusive	0.92	134°44′30″	59°55′10″
8403-23	intrusive	1.22	134°44′ 0″	59°54′50″
8403-24	intrusive	1.53	134°43′10″	59°54′40″
8403-25	intrusive	1.84	134°42′20″	59°54′40″
8403-26	intrusive	1.94	134°42′10″	59°52′50″
		Coast Plutonic Complex		
White Moose Mountain				
8403-15	intrusive	0.66	134°27′40″	59°25′ 0″
8503-16	intrusive	0.92	134°27′50″	59°25′20″
8403-17	intrusive	1.22	134°27′10″	59°25′30″
8403-18	intrusive	1.53	134°27′10″	59°25′50″
8403-19	intrusive	1.84	134°26′50″	59°26′ 0″
8403-20	intrusive	2.17	134°26′50″	59°26′30″
White Pass				
8403-28	intrusive	0.92	135° 7′10″	59°39′50″

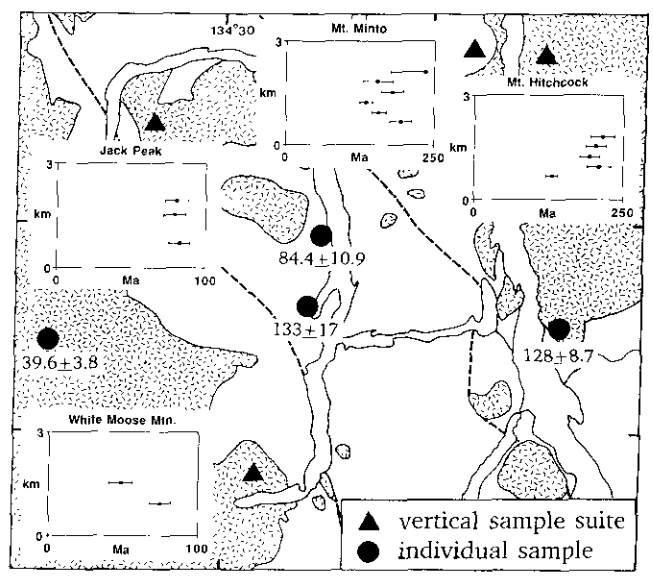

Figure 1-14-4. Summary of zircon fission-track ages (after Donelick, 1988). Errors given as one standard deviation.

TABLE 1-14-2
SUMMARY OF APATITE FISSION-TRACK ANALYSES

Sample	ρ_s^a	N	ρ_i^a	N	ρ_d^a	N	Grains	Chi²	Test[b]	Fission Track Age[c] (Ma)	Track Lengths[d]	Mean Track Length (μm)	Std. Dev. (μm)
							Cache Creek Terrane						
Como Lake													
8403-1	0.660	145	2.45	539	1.36	6520	15	7.48	PASS	64.7±6.2	301	13.24±0.10	1.70
Mount Hitchcock													
8403-2	0.674	220	4.03	1316	1.70	10719	15	32.9	FAIL	51.2±6.6	301	13.02±0.10	1.65
8403-3	0.674	169	4.17	1044	1.63	11025	15	16.5	PASS	47.0±4.0	306	13.48±0.11	1.90
8403-4	2.75	339	12.3	1516	1.71	10719	15	12.8	PASS	68.0±4.3	306	13.24±0.09	1.49
8403-5	2.33	287	9.39	1157	1.72	10719	15	4.30	PASS	75.7±5.2	313	13.24±0.09	1.56
8403-6	2.69	332	9.83	1211	1.65	11025	15	9.46	PASS	79.9±5.2	310	12.93±0.11	1.88
Mount Minto													
8403-7	4.17	548	11.3	1486	1.66	11025	15	15.1	PASS	108 ±5.8	311	12.73±0.11	2.01
8403-8	2.50	441	6.92	1222	1.38	6520	15	11.3	PASS	88.0±5.2	n.m.		
8403-9	1.57	328	5.51	1154	1.67	11025	15	17.1	PASS	83.8±5.5	n.m.		
8403-10	4.87	220	9.87	446	1.77	10719	15	17.4	PASS	154 ±13	n.m.		
8403-11	0.900	194	1.69	365	1.69	11025	16	18.9	PASS	158 ±14	n.m.		
8403-12	0.634	86	1.59	216	1.70	11025	15	22.6	PASS	119 ±15	n.m.		
							Whitehorse Trough						
Tagish Lake													
8403-13	0.480	131	1.48	403	1.72	11025	15	19.6	PASS	98.1±10.1	n.m.		
8403-14	0.346	106	0.850	260	1.39	6520	15	13.3	PASS	100 ±11	n.m.		
Jack Peak													
8403-21	0.752	142	4.75	897	1.66	11025	15	7.90	PASS	46.7±4.3	n.m.		
8403-22	0.564	51	2.31	209	1.36	6520	10	7.97	PASS	59.1±9.3	110	13.88±0.19	1.99
8403-23	0.730	117	3.38	541	1.68	11025	15	11.6	PASS	64.4±6.7	n.m.		
8403-24	0.571	88	2.49	382	1.78	10719	15	7.20	PASS	72.6±8.7	n.m.		
8403-25	0.905	119	4.15	546	1.70	10719	13	27.5	FAIL	71.6±11.5	n.m.		
8403-26	0.771	76	2.50	246	1.69	11025	15	13.0	PASS	92.4±12.3	n.m.		
							Coast Plutonic Complex						
White Moose Mountain													
8403-15	0.884	198	5.06	1132	1.63	11025	15	16.4	PASS	50.8±4.0	n.m.		
8403-16	1.31	244	5.66	1058	1.40	6520	15	14.4	PASS	57.2±4.2	306	13.79±0.09	1.55
8403-17	0.798	195	4.44	1085	1.64	11025	15	15.8	PASS	52.4±4.2	n.m.		
8403-18	1.16	233	6.11	1230	1.65	11025	15	4.99	PASS	55.5±4.1	n.m.		
8403-19	0.703	215	3.39	1037	1.73	10719	15	17.9	PASS	63.7±4.9	n.m.		
8403-20	0.632	131	4.09	848	1.76	10719	15	11.1	PASS	48.3±4.6	n.m.		
White Pass													
8403-28	0.273	41	1.64	246	1.63	11025	22	16.0	PASS	49.5±8.3	n.m.		

[a] in units of 10^6 tracks/cm²
[b] pass or fail at the 95% confidence level for Chi² calculated using the method of Galbraith (1981)
[c] zeta calibration factor 357.0±6.3 relative to neutron dosimeter glass standard SRM-612; ages determined using the criteria of Green (1981); error given as 1 standard deviation
[d] confined horizontal fission tracks as recommended by Laslett *et al.* (1982); n.m. = not measured

are shown in Figure 1-14-2 and listed in Table 1-14-1. The samples represent: (a) vertical suites from four mountains collected over their accessible elevation ranges and (b) four additional samples collected from selected sites interspersed among the vertical suites. Apatite fission-track ages were measured for all 27 samples (Table 1-14-2 and Figure 1-14-3); etchable fission-track length distributions in apatite for nine samples (Table 1-14-2); and zircon fission-track ages for twenty samples (Table 1-14-3 and Figure 1-14-4). Full details regarding the mineral separation techniques, sample preparation procedures and analytical methods employed for the fission-track analyses are presented in Donelick (1986; 1988). In this paper, each apatite fission-track age is interpreted as the time when its sample cooled through the 100°C crustal isotherm. This interpretation is appropriate due to the limited degree of fission-track annealing present in the apatites as evidenced by the relatively long, mean etchable track lengths (*e.g.* Naeser and Forbes, 1976; Green *et al.*, 1986). Furthermore, we interpret each zircon fission-track age as a minimum age of formation of the igneous rock samples (either intrusive or volcanic), as each age probably reflects the time when its rock cooled through the 200°C crustal isotherm (*e.g.* Harrison *et al.*, 1979). It is convenient to consider separately, the data obtained for the Cache Creek Terrane, the Whitehorse trough, and the Coast plutonic complex.

Cache Creek Terrane

Figure 1-14-3 shows all apatite fission-track ages measured in this study, including plots of apatite fission-track age versus sample elevation for Mount Hitchcock, on the eastern shore of Atlin Lake, and Mount Minto, 5 kilometres from Mount Hitchcock on the western shore. It is apparent

TABLE 1-14-3
SUMMARY OF ZIRCON FISSION-TRACK ANALYSES

Sample	ρ_s^a	N	ρ_i^a	N	ρ_d^a	N	Grains	Chi²	Test[b]	Fission Track Age[c] (Ma)
					Cache Creek Terrane					
Como Lake										
8403-1	35.2	650	25.6	474	1.46	15879	7	9.78	PASS	128±8.7
Mount Hitchcock										
8403-2	24.4	501	17.4	358	1.48	15879	8	7.60	PASS	132±10
8403-3	22.7	467	10.2	210	1.49	15879	10	6.72	PASS	210±19
8403-4	26.6	546	13.2	271	1.52	15879	10	9.78	PASS	194±16
8403-5	22.3	549	10.6	261	1.53	15879	10	12.2	PASS	204±17
8403-6	25.8	424	11.7	192	1.53	15879	8	10.5	PASS	215±20
Mount Minto										
8403-7	24.6	405	11.9	195	1.46	15879	8	10.3	PASS	193±18
8403-8	29.7	549	17.6	325	1.47	15879	8	11.1	PASS	158±12
8403-9	28.5	410	19.8	284	1.48	15879	7	10.1	PASS	136±11
8403-10	34.3	282	18.3	150	1.51	15879	2	0.29	PASS	180±19
8403-11	30.5	438	17.1	246	1.52	15879	5	14.4	FAIL	155±25
8403-12	28.2	58	11.2	23	1.47	15879	2	3.11	PASS	235±58
					Whitehorse Trough					
Tagish Lake										
8403-13	11.6	119	13.0	134	1.48	15879	4	0.35	PASS	84.4±10.9
8403-14	15.0	154	10.7	110	1.49	15879	4	0.49	PASS	133±17
Jack Peak										
8403-21	22.6	278	26.9	331	1.53	15879	6	1.60	PASS	82.5±7.2
8403-22										n.m.
8403-23										n.m.
8403-24	23.4	240	28.1	289	1.48	15879	4	1.29	PASS	79.0±7.3
8403-25										n.m.
8403-26	20.7	213	25.2	259	1.52	15879	4	0.90	PASS	80.1±7.8
					Coast Plutonic Complex					
White Moose Mountain										
8403-15										n.m.
8403-16	8.15	201	10.6	261	1.52	15879	6	2.72	PASS	75.0±7.4
8403-17										n.m.
8403-18	15.3	63	29.9	123	1.48	15879	2	1.98	PASS	48.6±7.7
8403-19										n.m.
8403-20										n.m.
White Pass										
8403-28	13.8	170	33.0	407	1.48	15879	6	4.77	PASS	39.6±3.8

[a] in units of 10^6 tracks/cm²
[b] pass or fail at the 95% confidence level for Chi² calculated using the method of Galbraith (1981)
[c] zeta calibration factor 129.0±3.8 relative to neutron dosimeter glass standard CN-1; ages determined using the criteria of Green (1981); error given as 1 standard deviation; n.m. = not measured

from these data that opposite sides of northern Atlin Lake experienced markedly different Mesozoic to Cenozoic cooling histories. Apatite fission-track ages for Mount Hitchcock range from 47.0±4.0 Ma to 79.9±5.2 Ma (one standard deviation). Mount Minto, however, exhibits significantly older apatite fission-track ages, ranging from 83.8±5.5 Ma to 158±14 Ma. The Mount Hitchcock samples and the three lowest elevation samples from Mount Minto (samples 8403-7, 8, 9) are from the Black Mountain body, as mapped by Aitken (1959). The zircon fission-track ages for these samples range from 132±10 Ma to 215±20 Ma (Figure 1-14-4), indicating this intrusion is no younger than Triassic. The volcanic rocks that cap Mount Minto (samples 8403-10, 11, 12) exhibit zircon fission-track ages that range from 155±25 Ma to 235±58 Ma (Figure 1-14-4) indicating that these rocks are at least Mesozoic in age.

WHITEHORSE TROUGH

Figure 1-14-3 also contains a plot of apatite fission-track age versus sample elevation for Jack Peak, an intrusion into Whitehorse trough stata for which Bultman (1979) reports a K-Ar biotite age of 90±3.0 Ma. The fission-track ages range from 46.7±4.3 Ma to 92.4±12.3 Ma, similar to those observed for Mount Hitchcock in the Cache Creek Terrane. In contrast, two Lower Jurassic Laberge Group samples from the western shore of Tagish Lake (samples 8403-13 and 14; Figure 1-14-2) yield apatite fission-track ages of 98.1±10.1 Ma and 100±11 Ma respectively (Figure 1-14-3), significantly older than those for Jack Peak. The zircon fission-track ages for the Jack Peak samples range from 79.0±7.3 Ma to 82.5±7.2 Ma (Figure 1-14-4). The Laberge Group samples yield zircon fission-track ages of 84.4±10.9 Ma and 133±17 Ma respectively (Figure

1-14-4), significantly younger than their depositional ages indicating that these rocks experienced postdepositional temperatures in excess of approximately 200°C.

Coast Plutonic Complex

The apatite fission-track age versus sample elevation plot for White Moose Mountain is included in Figure 1-14-3. The ages range from 48.3±4.6 Ma to 63.7±4.9 Ma, representing the youngest age range of the vertical suites analyzed. The zircon fission-track ages for these samples range from 39.6±3.8 Ma to 75.0±7.4 Ma (Figure 1-14-4).

DISCUSSION

The results summarized above, in particular the apatite fission-track ages, indicate that the Whitehorse trough in the vicinity of Tagish Lake, and part of the Cache Creek Terrane near Mount Minto, experienced a different cooling history relative to surrounding areas. The differential cooling, evidenced by the zone of 100 Ma fission-track ages at low elevations along Tagish Lake and at Mount Minto (at or below 920 metres above m.s.l.; Table 1-14-1), most likely resulted from differential vertical motion in the region between approximately 100 Ma and 50 Ma. It appears that an as yet unrecognized structure beneath the northern part of Atlin Lake forms the eastern boundary of this zone of 100 Ma apatite-cooling ages. The western boundary may be the Llewellyn fault, but this has yet to be proven. Mihalynuk and Hart (in press) document at least 100 kilometres of dextral motion on the Llewellyn fault zone – Tally Ho shear zone coincident with the boundary between Stikine Terrane to the east and Nisling Terrane to the west. Furthermore, these authors state that "thick accumulations of coarse clastic sedimentary rocks of the Lower Jurrasic Whitehorse trough overlie the Stikine Terrane, but are thin and discontinuously exposed west of the fault zone on the Nisling Terrane." Greater erosion on the west side of the Llewellyn fault zone between 100 Ma and 50 Ma would account for both the fission track data summarized here and the greater preservation of Whitehorse Trough strata on the east side.

Our current research in this region is aimed at delimiting the zone of 100 Ma apatite fission-track ages along southern Tagish Lake. If this zone includes the Engineer mine, it may be possible to determine the timing of mineralization at this historically important deposit. Preliminary fluid-inclusion data from the Engineer deposit indicate homogenization temperatures of approximately 185°C, sufficient to completely anneal fission tracks in apatite (M. Mihalynuk, personal communication, 1990). If the hydrothermal activity was localized near the Engineer deposit and occurred post-100 Ma, apatites from country rocks heated by these fluids will yield fission-track ages less than 100 Ma, indicating the timing of mineralization.

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