DIFFERENTIAL UPLIFT ACROSS THE COAST PLUTONIC COMPLEX-NORTHERN STIKINE TERRANE CONTACT, YUKON: PRELIMINARY EVIDENCE FROM APATITE FISSION-TRACK THERMOCHRONOMETRY

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ABSTRACT

Six fission-track analyses were conducted on samples taken across a fault in the Takhini Hotsprings area, Yukon. The results indicate that samples taken on the east side of the fault cooled through 100°C at 104.4 ± 11.9 Ma, while the samples taken on the west side of the fault cooled through 100°C at 63.9 ± 8.5 Ma. Differential uplift and faster erosion on the west side of the fault between the mid-Cretaceous and the Early Paleocene could account for this difference in cooling history. This fault forms the approximate western edge of the Whitehorse Trough, and is marked by a dramatic change in the isopach of Jurassic and Triassic sedimentary and volcanic rocks which form a thin veneer over rocks of the Coast Plutonic Complex on the west side, and a very thick sedimentary sequence on the east side where basement rocks are not seen. Based on these observations, the fault is inferred to be a major zone of crustal weakness which could form the boundary between the Northern Stikine Terrane and the Coast Plutonic Complex in southern Yukon.

Similar results were obtained in a previous study of samples collected across the Llewellyn Fault Zone, which forms the boundary between the Northern Stikine Terrane and rocks of the Nisling Terrane and Coast Plutonic Complex in northwest B.C.

RÉSUMÉ

On a soumis à l'analyse des traces de fission dans l'apatite six échantillons recueillis le long d'un transect recoupant un prolongement septentrional de la zone faillée de Llewellyn au Yukon. Les échantillons recueillis dans la zone intramontagneuse présentaient une histoire de refroidissement différente de celle des échantillons recueillis dans l'acjacent complexe plutonique côtier. Les premiers se sont refroidis jusqu'à une température de 100 °C il y a 104,4 ±11,9 Ma et les derniers ont atteint cette même température il y a 63,9 ±8,5 Ma. Des résultats similaires obtenus pour des échantillons recueillis sur la zone faillée de Llewellyn dans le nord-ouest de la Colombie-Britannique indiquent une disparité régionale dans l'évolution thermique aux faibles températures de la zone intramontagneuse et du complexe plutonique côtier. Un soulèvement différentiel menant à une érosion plus rapide du côté occidental de la zone faillée pendant l'intervalle d'environ 104 à 64 Ma pourrait expliquer cette disparité dans les histoires thermiques. Sous forme d'une zone crustale affaiblie, la zone faillée de Llewellyn semble avoir facilité un soulèvement différentiel des roches du complexe plutonique côtier et des roches de l'adjacente zone intramontagneuse du Crétacé moyen au Crétacé tardif et au Paléocène précoce.

INTRODUCTION

Apatite fission-track techniques have revealed significantly different low-temperature cooling histories for rocks on either side of the Llewellyn Fault system in northwest British Columbia (e.g., Donelick and Dickie 1990). The Llewellyn Fault is a major crustal break which separates rocks of the Northern Stikine Terrane from the Nisling Terrane and the Coast Plutonic Complex (Fig. 1). The low-temperature thermal histories of samples taken across this structural boundary near the south end of Tagish Lake, British Columbia, are summarized by Donelick (1986, 1988), Donelick and Miller (1986), and Donelick and Dickie (1990). New results presented here show a similar change in low-temperature cooling history across a fault in southern Yukon. These results have important tectonic implications: we suggest that the observed difference in thermal history between rocks of the Northern Stikine Terrane and the Coast Plutonic Complex is due to differential uplift which occurred between the mid-Cretaceous and the Early Paleocene.

The study area lies approximately 20 km north of Whitehorse (Fig. 1). The samples were taken along a northeast-southwest transect across a north-trending fault zone which separates rocks of the Upper Triassic Lewes River Group from a thick sequence of Lower Jurassic Laberge Group clastics, east of Takhini Hotsprings (Fig. 2).

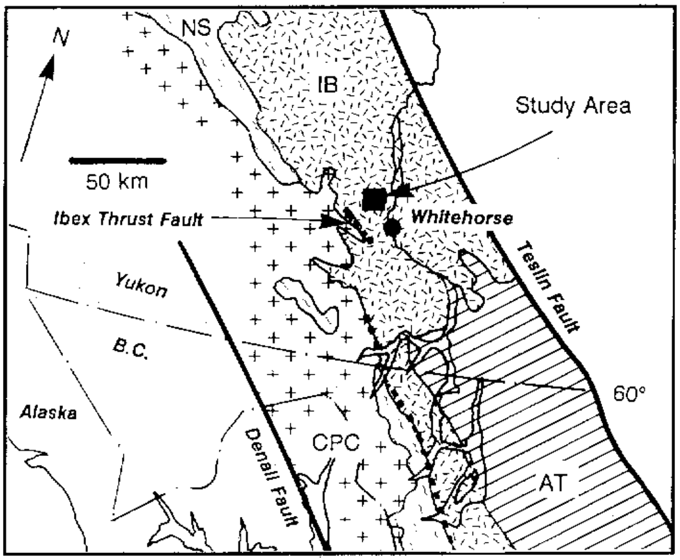

Figure 1. Study location map. The Northern Stikine Terrane (IB), Coast Plutonic Complex (CPC), Atlin Terrane (AT) and Nisling Terrane (NS) are depicted. The location of the Llewellyn Fault-Tally-Ho Shear system (dashed line) is based on data from Doherty and Hart (1988), Hart and Radloff (1990) and Mihalynuk and Mountjoy (1990).

GENERAL GEOLOGY

Two tectonic belts of the northern Cordillera are considered in this study. The Coast Plutonic Complex is a northwest-trending linear batholith comprised of Late Cretaceous to Eocene epizonal calc-alkaline plutons. It lies west of the Northern Stikine Terrane which, in southern Yukon, is predominantly represented by volcanic and sedimentary rocks of the Whitehorse Trough.

Mesozoic rocks of the Whitehorse Trough include (a) Carnian to Late Norian (to Hettangian?) calc-alkaline plagioclase- and augite-phyric volcanic flows, breccias and pyroclastics, volcanogenic sandstone, black argillite, and limestone of the Lewes River Group (e.g., Tozer 1958, Wheeler 1961, Hart and Radloff 1990), (b) Hettangian to Bajocian polymictic conglomerate, sandstone and argillite of the Laberge Group (e.g., Wheeler 1961, Dickie 1989, Hart and Radloff 1990, Dickie and Hein in press), (c) Oxfordian-Kimmeridgian (Hart and Radloff 1990) to Albian chert-pebble conglomerate, sandstone and coal of the Tantalus Formation (Lowey and Hills, 1988), and (d) Cretaceous andesitic to rhyolitic volcanic rocks.

The Whitehorse Trough sedimentary and volcanic rocks were deposited on the leading edge of the allochthonous Stikine Terrane during a Jurassic arc-continent collision (e.g., Tempelman-Kluit 1979, Dickie and Hein 1988, Dickie and Hein in press). They are now juxtaposed against quartzofeldspathic biotite-muscovite schist, quartzite, and marble of the Nisling Terrane (e.g., Wheeler and McFeely 1987, Hansen 1990, Hart and Radloff 1990) which form the basement to the Jurassic arc, but probably not to the forearc basin. Nisling rocks were originally classified by Cairnes (1916) as the Yukon Group and were later described as part of the Yukon Crystalline Terrane by Tempelman-Kluit (1976, 1979), and are intruded by igneous rocks of the Coast Plutonic Complex.

Whitehorse Trough developed as a fore-arc basin from Late Triassic to the Middle Jurassic (Tempelman-Kluit 1979, Dickie 1989, Dickie and Hein in press), and a plutonic belt formed along the western basin margin. These arc plutons range in composition from quartz diorite to granite and have yielded Late Triassic to Early Jurassic radiometric ages (e.g., Tempelman-Kluit and Wanless 1975, Morrison et al. 1979, Doherty and Hart 1988, Johnson 1988, Hart and Radloff 1990, Hart and Armstrong, unpublished data). Triassic-Jurassic radiometric dates (U/Pb method) from clasts of the Laberge Group conglomerate, and northeast to southeast-directed paleocurrents in the Jurassic basin-fill substantiate a link between this plutonic belt and the adjacent basin in the early Mesozoic (Hart, Dickie and Armstrong, unpublished data and in prep.). Plutons of the younger Coast Plutonic Complex follow the same trend as the Triassic-Jurassic plutons, but are much more numerous immediately west of the Triassic-Jurassic plutonic belt.

In northwest B.C. the Llewellyn Fault system separates Nisling Terrane metamorphic rocks to the west from the Whitehorse Trough to the east (e.g., Hart and Radloff 1990). Dickie and Hein (in press) suggest that in the southernmost Yukon, the Tally-Ho Shear Zone forms a similar boundary between Nisling Terrane metamorphic basement rock and younger rift-related transitional to oceanic crust flooring the Whitehorse Trough. This transition between continental and oceanic crust in many island arcs is a zone of mechanical weakness, subject to failure in the form of fore-arc transform fault zones (Turcotte et al. 1977).

The Llewellyn Fault and Tally-Ho Shear Zone are described in detail by Hart and Radloff (1990) and Mihalynuk and Mountjoy (1990). Hart and Radloff (1990) and Radloff et al. (1990) described evidence for two phases of deformation along the Tally-Ho Shear Zone: (a) penetrative, semi-ductile structures, indicative of Triassic sinistral transcurrent motion at a mid-crustal level, and (b) non-penetrative, brittle structures, indicative of Late Cretaceous dextral transcurrent motion at a shallow crustal level. The Tally-Ho Shear Zone is inferred to represent a more deeply exposed part of the same fault system which provides a record of the more ductile Triassic deformation, whereas the Llewellyn Fault to the south exhibits late Cretaceous brittle deformation textures which overprinted the older, ductile fabrics. The Tally-Ho Shear Zone is offset from the Llewellyn Fault at the Yukon-B.C. border along a northeast-trending strike-slip fault (Hart and Radloff 1990). The Tally-Ho Shear Zone has been traced north as far as Fish Lake, where it is overridden by the Ibex Thrust.

Like the Llewellyn Fault and Tally-Ho Shear Zone, the fault near Takhini Hot Springs which forms the subject of this study appears to form the boundary between the Northern Stikine Terrane and the Nisling Terrane/Coast Plutonic Complex. The three faults show a number of similarities, including: (a) a north to northwest trend, (b) semi-ductile deformational features overprinted by brittle fractures within Triassic Lewes River Group sandstone and argillite (c) sheared black argillite containing veinlets of chalcopyrite with malachite, galena, tetrahedrite and argentite (Dickie, unpublished data), and (d) location along the western margin of the Whitehorse Trough, indicated by coastal deposits of the Lewes River and Laberge Groups (Dickie 1989) and a dramatic decrease in the thickness and extent of Laberge Group strata west of the fault.

Late Cretaceous volcanic rocks cap the Takhini Hotsprings fault at its north end (Wheeler 1961, Tempelman-Kluit 1984), and constrain the timing of its last significant lateral movement.

The Tally-Ho Shear Zone has been traced north as far as Fish Lake. A northeast-trending fault similar to the one which connects the Llewellyn Fault with the Tally-Ho Shear Zone would have to be invoked in order to link the Takhini Hotsprings-area fault with the north end of the Tally-Ho system.

METHODS

Six samples were collected for fission-track geochronology from an area near Takhini Hotspring (Fig. 2). All samples were collected at a constant elevation of 900 m above sea level. Sample locations are shown in Figure 2 and are summarized in Table 1. The sample suite represents: (a) two samples from sedimentary and pyroclastic Lewes River Group strata close to a late Cretaceous granitic pluton of the Coast Plutonic Complex (Wheeler 1961), (b) two samples from sedimentary Lewes River Group strata nearer to the west side of the fault, and (c) two samples from sedimentary Laberge Group strata on the east side of the structure depicted in Figures 2 and 3. 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 fission-track age is interpreted as the time when its sample cooled through the 100°C crustal isotherm. This interpretation results from the limited degree of fission-track annealing present in the apatites, revealed by relatively long mean etchable track lengths (e.g., Naeser and Forbes 1976, Green et al. 1986). Apatite fission-track ages were measured for all samples, which are labelled YT-1 to YT-6 (Fig. 2). It is convenient to consider the fission track data obtained for rocks exposed west and east of the fault in the study area separately (Fig. 2).

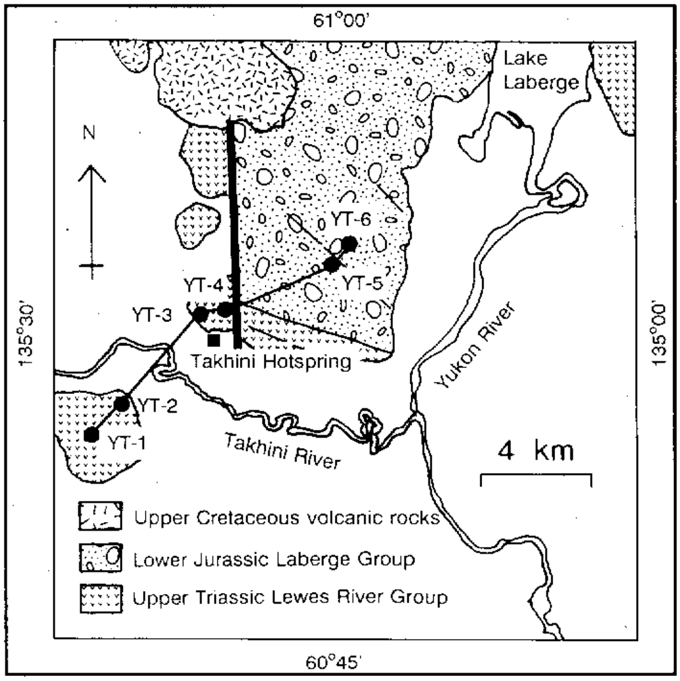

Figure 2. Detailed study location map showing the generalized outcrop patterns in the vicinity of Takhini Hotspring. The large solid line is the fault under study, which is believed to form the east boundary of the Coast Plutonic Complex, similar to the Llewellyn Fault in Northern B.C. Sample localities at 900 m elevation above sea level are depicted as YT-1 to YT-6.

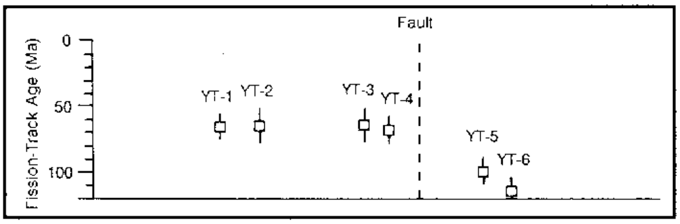

Figure 3. Summary cross-section of the sampling transect. Fission-track ages for samples YT-1 to YT-6, with error bars of one standard deviation, are plotted against relative distance from the fault (refer to Fig. 2 for localities). Notice that rocks on either side of the fault return significantly different cooling ages.

RESULTS

Although no previous work has been published on the low-temperature thermal history of the Coast Plutonic Complex in southern Yukon, relevant studies on the southern part of the Coast Plutonic Complex exist (e.g., Harrison et al. 1979; Parrish 1982, 1983; Donelick and Dickie 1991). These studies primarily document the large-scale cooling of much of the Cordillera following latest Cretaceous to Eocene compressive orogeny. Donelick and Dickie (1991) published the first detailed low-temperature history of this plutonic belt in the northern Cordillera. These results from northwestern British Columbia show cooling ages through the 100°C crustal isotherm of 63.7 ± 4.9 Ma to 48.3 ± 4.6 Ma with a mean age of 53.9 ± 4.6 Ma. No plutons of the Coast Plutonic Complex were sampled for fission-track thermochronometry in southern Yukon. It is expected, however, that rocks of the Lewes River Group directly overlying rocks of the Coast Plutonic Complex would have experienced a very similar low-temperature cooling history, whereas rocks separated from the Coast Plutonic Complex by a major fault might have a different low-temperature cooling history.

Samples YT-1 to YT-4 were collected from the Lewes River Group on the west side of the fault zone. These revealed latest Cretaceous to early Paleocene cooling ages, ranging from 67.7 ± 6.9 Ma to 61.8 ± 12.1 Ma (Table 2), providing a mean fission-track age of 63.9 ± 8.5 Ma. These results are slightly older than, but similar to, the results of Donelick (1986, 1988) and Donelick and Dickie (1990) for northwestern British Columbia.

Samples YT-5 and YT-6 are clasts collected from Laberge Group conglomerate east of the fault. These samples yielded 100°C cooling ages of 113.0 ± 10.0 Ma and 95.8 ± 10.5 Ma respectively (Table 2), providing a mean fission-track age of 104.4 ± 11.9 Ma. As a comparison, two conglomerate samples collected from the Laberge Group beside Tagish Lake and analysed by Donelick (1986, 1988) yielded apatite fission-track ages of 98.1 ± 10.1 Ma and 100.0 ± 11.0 Ma.

DISCUSSION AND CONCLUSIONS

The fission-track results are consistent with west-side up displacement across the fault in the study area between about 100 Ma and 60 Ma. This coincides with the intrusion of the Coast Plutonic Complex in this part of the Cordillera (e.g., Tempelman-Kluit and Wanless 1975, Hart and Radloff 1990) and may reflect a mechanical response to inhomogeneous thermal expansion across an existing crustal weakness. Uppermost Cretaceous volcanic rocks capping the northern part of the fault are consistent with this model. We believe that uplift across this boundary ceased immediately prior to the emplacement of those volcanic flows.

These fission-track results suggest that both in Yukon and in Northern British Columbia, the Whitehorse Trough and the adjacent Coast Plutonic Complex experienced significantly different low-temperature cooling histories. If the interpreted vertical movement on the major terrane-bounding faults between about 100 Ma and 60 Ma is related to the intrusion of the Coast Plutonic Complex, then these faults and associated splays are of interest for their economic potential, as the faults would have acted as conduits for hot fluids associated with the intrusions. Many hydrothermal fluids would contain sufficient heat to anneal fission tracks in wall-rock apatite. Because rocks east of the fault consistently return 100 Ma fission-track ages, post-100 Ma mineralizing events could be modelled on the basis of "reset" fission-track ages.

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Table 1. Summary of Sample Lithologies and Locations

Sample	Lithology	Longitude	Latitude
YT-1	unwelded andesite tuff	135°28'	60°49'
YT-2	aphyric andesite[1]	135°27'	60°50'
YT-3	granite[1]	135°24'	60°51'
YT-4	volcanogenic sandstone	135°22'	60°51'
YT-5	hornblende granodiorite[2]	135°15'	60°52'
YT-6	augite-phyric andesite[2]	135°13'	60°53'

[1] Clasts in the uppermost Lewes River Group conglomerate

[2] Clasts in the Laberge Group conglomerate

Table 2. Summary of Apatite Fission-track Results

Sample	ρ_s[a]	N	ρ_i[a]	N	ρ_d[a]	N	GrainsChi^{2}Test[b]	Fission-track Age (Ma)
YT-1	3.06E+05	129	1.12E+06	474	4.25E+06	5300	169.0289PASS	63.3 ± 6.6
YT-2	2.13E+05	73	7.92E+05	271	4.25E+06	5300	153.0931PASS	62.7 ± 8.5
YT-3	1.17E+05	34	4.40E+05	128	4.25E+06	5300	121.1447PASS	61.8 ± 12.1
YT-4	2.13E+05	137	7.33E+05	471	4.25E+06	5300	226.0711PASS	67.7 ± 6.9
YT-5	4.49E+05	75	1.19E+06	199	4.21E+06	3450	123.9354PASS	95.8 ± 13.9
YT-6	5.23E+05	282	1.17E+06	632	4.21E+06	3450	2010.5127PASS	113 ± 10.0

[a] in units of 10^6 tracks/cm^2

[b] pass or fail at the 95% confidence level for Chi^2

[c] zeta calibration factor 110 ± 3.0 (samples YT-1 to YT-4) and 121.8 ± 6.0 (samples YT-5 and YT-6) relative to neutron dosimeter glass standard CN1.

Error given is 1 standard deviation.