Neogene and Quaternary Chilcotin Group Cover Rocks in the Interior Plateau, South-Central British Columbia: A Preliminary 3-D Thickness Model

by M.G. Mihalynuk

INTRODUCTION

Mineral exploration in the Interior Plateau region of British Columbia has been thwarted by lack of outcrop and a presumed 'great thickness' of Chilcotin Group cover. The plateau basalt of the Chilcotin Group has been considered a particularly severe impediment because it may mask underlying geochemical and geophysical signals. Thick cover also presents uncertainty for advanced exploration and development. If a mineral deposit was to be detected through thick basalt, would the extra exploration and development costs be prohibitive? What is the thickness of the overburden? Geological uncertainty is a principal source of exploration investment risk and, on the plateau, the principal geological unknown in many areas is depth of overburden.

To attract mineral exploration investment to underexplored parts of the Interior Plateau (*cf.* Mihalynuk, 2007), it is necessary to reduce investment risk. This paper is aimed at resolving uncertainty with respect to the cover thickness. It is an account of the methods and results of a first generation 3-D thickness model for Chilcotin Group cover over a large portion of the Interior Plateau.

The gently undulating plateau basalt flows that form the most conspicuous part of the Chilcotin Group range in age from Neogene[1] to Quaternary, *ca.* 16 to 1 Ma (Bevier, 1983; Mathews, 1989). These rocks are most extensive in NTS map sheets 092O and P, and 093B and C (Fig 1; Massey *et al.*, 2005). Accordingly, this area was chosen for the thickness model. Correlative rocks extend from the Okanagan Highlands, south of Vernon, to the Summit Lake area, north of Prince George (Mathews, 1989).

Most people are impressed by the thickness of the Chilcotin Group strata where they are best exposed along the incised flanks of major river valleys. However, these exposures may not to be representative of the largest expanses of the Chilcotin Group. For example, thicknesses along the Fraser River may be representative of infilling of a previous paleotopographic low. Immediately east of the Fraser River and south of the Highway 20 crossing, a narrow (less than approx. 200 m) basalt rampart clings to the pre-existing valley wall of Paleozoic strata (Fig 2). East of the Fraser River, K-Ar whole rock ages in this region average 4 Ma (N = 7), whereas those to the west average 16 Ma (N = 4; Mathews, 1989; Breitsprecher and Mortensen, 2004). In this same area, more than 180 m of glaciolacustrine strata have been incised by the Fraser River. Deposition of glaciolacustrine strata probably followed river damming by basalt flows (Mathews, 1989). An axis of glaciofluvial deposition near the Fraser River points to the precursor valley in Quaternary time, and the basalt ramparts built atop old valley walls point to an even older paleovalley (*cf.* Read, 2000; Mathews, 1989).

Neogene deformation has caused warping of the plateau basalt layers (Mathews, 1989). In addition, uplift of the Coast Ranges has been ongoing since at least Eocene time, with at least 2 km of uplift in the last 10 m.y. (Parrish, 1983). As a result, the base of the Chilcotin Group has been elevated to the west.

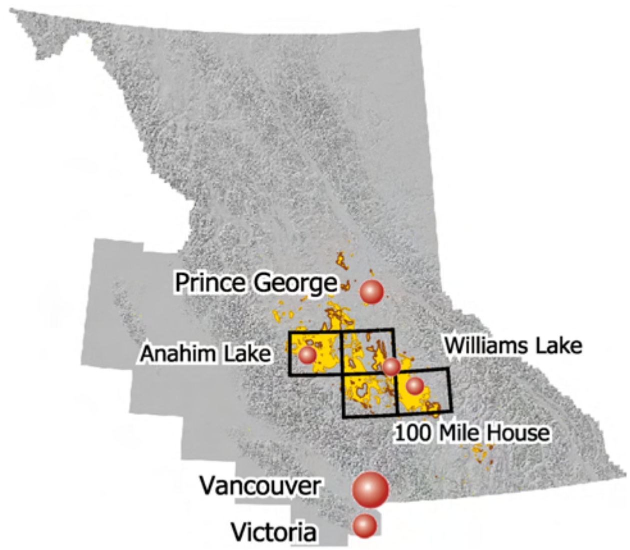

Figure 1. Provincial shaded relief map showing the location of the area considered for the Chilcotin thickness model. Map sheets, from northwest to southeast, are 093C, B; 092O, P. Chilcotin Group is highlighted in yellow.

[1] *Here we use the Neogene period and Quaternary period in the manner recommended by Clague (2006), with the base of the Quaternary at 2.588 Ma (including the Pleistocene and Gelasian). We have not adopted the recommendation of the International Commission on Stratigraphy to eliminate the Quaternary period, extending Neogene to the Present (*e.g.*, Gradstein et al., 2004).*

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the BC Ministry of Energy, Mines and Petroleum Resources website at http://www.em.gov.bc.ca/Mining/Geolsurv/Publications/catalog/cat_fldwk.htm

Figure 2. Rampart of nearly horizontal Chilcotin Group strata built upon the ancient Fraser River valley wall (just above the middle photo horizon). Strata thicken rapidly towards the valley axis (towards viewer). Note light-coloured basement rocks cropping out above and below the Chilcotin Group. View is to the east across the Fraser River (which is not visible in the deep valley bottom).

CHILCOTIN THICKNESS MODEL

The regional thickness model for the Chilcotin Group was produced for 1:250 000 scale NTS sheets 092O and P, and 093B and C (Fig 1). Computational limitations necessitated splitting the area into two. For each half of the map area, the following six procedures were employed:

1) A digital elevation model (DEM) was produced from the existing digital 1:20 000 scale topographic base maps. Due to computational limitations, the DEM was generalized from 20 m to 100 m contour intervals (Fig 3).
2) Digital geology was gathered from the BC Geological Survey digital geology map (compiled at 1:100 000 scale to create a 1:250 000 scale product; Massey *et al.*, 2005). Boundary problems were rectified where appropriate.
3) Chilcotin Group basal contacts were spatially overlain on the digital 1:20 000 contour maps and elevation points generated at their intersections.
4) Intersection point elevation data was kriged using the 100 nearest neighbours to generate a Chilcotin basal contact surface in 3-D. Resolution of the 3-D surface is 0.01° pixels. An error surface can be generated to show how the distribution of point data affects the spatial uncertainty of the kriged surface.
5) The Chilcotin Group surface was subtracted from the DEM surface. The residual is a 3-D representation of the Chilcotin Group thickness (similar to Fig 4). An example of this process is shown in 2-D profiles in Figure 5 (profile location shown of Fig 4).
6) The two contoured thickness maps were reassembled to produce a product similar to Figure 4.

Four additional procedures were performed on the combined thickness maps:

1) The thickness data were converted to 0.01° gridded data.
2) Data points falling outside Chilcotin Group polygons were removed.
3) A 0.01° buffer was created around all Chilcotin Group polygons and broken into segments 0.01° long. Segment endpoints were assigned a zero value and these points added to the 0.01° grid of remaining thickness values.
4) The new grid of thickness values was kriged using 100 nearest neighbours and a resolution of 0.01°.
5) The resultant output was thematically formatted to produce a usable representation of the 3-D model (*e.g.*, Fig 4 legend).

MODEL HIGHLIGHTS

Thin Chilcotin Group is Widespread

Thickness distributions shown by the model indicate that, in more than 80% of the area covered by the Chilcotin Group, it is less than 25 m thick. According to the model, more than a third of the Chilcotin Group is less than 5 m thick. However, this figure is considered unreliable because the imprecise geological map data (1:250 000), as well as a maximum 20 m resolution of the digital elevation data, do not permit such precise thickness estimates.

Chilcotin Group Thickens towards Major Drainages

Increases in Chilcotin Group thickness towards major drainages are shown by the model. This is consistent with observations and inferences of previous workers (*e.g.,* Read, 2000) and contributors to this volume (Andrews and Russell, 2007). Good examples occur along the Fraser River west of Williams Lake, and along the Chilcotin River south of Alexis Creek. Best sections of Chilcotin Group — those exposed along major drainages — do appear to over-represent the thickness of the unit, creating a false impression of the exploration obstacle that they pose.

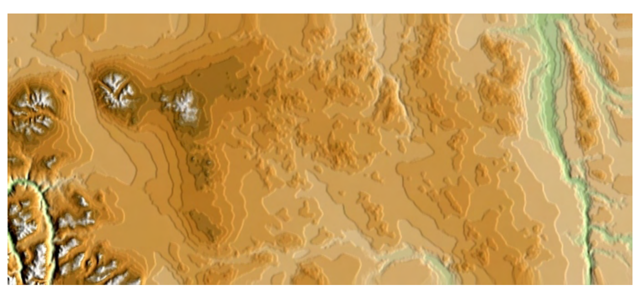

Figure 3. Digital elevation model for map sheets 093B (east half of figure) and C (west), derived from 20 m contour elevation data generalized to 100 m. Fraser River (east margin), Chilcotin River (south centre) and the three peralkaline Anahim Belt volcanoes of the Ilgachuz Range are prominent. Note steps in elevation model are emphasized in low-relief areas. Far Mountain is on the north side of the middle Anahim Belt volcano.

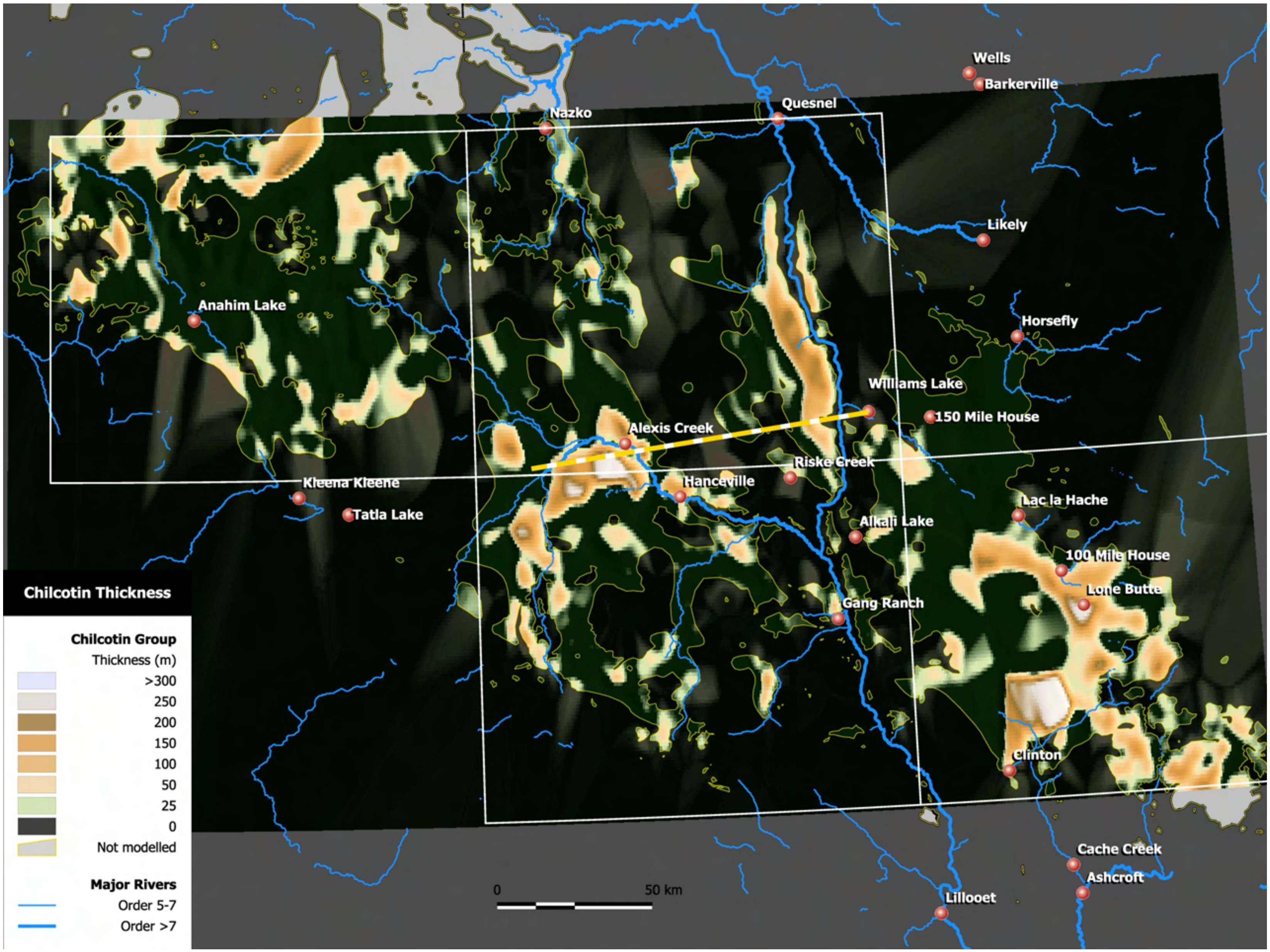

Figure 4. Chilcotin Group thickness model and section line for the profiles shown in Figure 5. Note that areas outside of the Chilcotin Group are shown as semitransparent so that the model shortcomings can be assessed. In these areas, some of the Chilcotin Group is shown by the model where none has been mapped (*see* text for discussion).

Major Thicknesses in Ilgachuz Range and 100 Mile House Areas

In addition to main river valleys, thicknesses of Chilcotin Group greater than 200 m are shown by the model in the Ilgachuz Range and near 100 Mile House. Peralkaline Anahim Group volcanic rocks in the Ilgachuz Range are mantled by the Chilcotin Group strata. The contact has significant topographic relief (400 m over 5 km) and possible flow structures on the north slope of Far Mountain. These features point to a centre of Chilcotin Group volcanism in the Ilgachuz Range (*cf*. Souther, 1986).

Atypical thicknesses of Chilcotin Group rocks are known in the 100 Mile House area, where they occur over an elevation range of 350 m according to (Mathews, 1989). Maximum thicknesses (>300 m) are shown by the model in the Lone Butte area, 13 km south-southeast of 100 Mile House, in concert with the observations of Mathews (1989).

MODEL LIMITATIONS

As is the case for most models, the quality of the input data and assumptions made in the generation of the model are key determinants of the quality of the model. Geological data used in this model do not include a measure of uncertainty (*e.g.,* defined, approximate or assumed contacts). Thus, all contacts were treated as defined at 1:250 000 scale. This is clearly not correct, and future models should take contact location uncertainty into consideration when generating an error surface. An example of an error surface is shown in Figure 5. It includes only that component of error that is introduced by the kriging process.

In some areas, the Chilcotin lavas were confined and ponded by paleotopographic highs. In such instances, the kriging algorithm used to determine the 3-D basal Chilcotin surface may under-represent the true thickness. In other areas, the contour surface clearly overestimates the thickness of Chilcotin basalt. One of the clearest and most drastic examples occurs about 20 km north of Hanceville, where the highest point in the area, Mount Alex Graham, is underlain by Eocene to Oligocene Endako Group volcanic rocks. However, the raw residual 3-D model shows the peak as flanked by Chilcotin Group. The probable reason for this error is that Mount Alex Graham was a paleotopographic feature that rose abruptly up from the plateau atop which the Chilcotin basalts were deposited. Basalt flows would have lapped up against the ancient flanks of Mount Alex Graham, but the model contours are biased by the kriging of the predominantly gently undulating Chilcotin Group base away from the peak.

A profile section was chosen (Fig 5, located on Fig 4) to demonstrate this problem and to highlight other features of the model. Additional estimates of lava thickness in the middle of the large expanses of Chilcotin basalt, and the mapping of small Chilcotin Group outliers atop expanses of older rocks, would greatly improve the accuracy of the model.

A second-order problem is those artifacts generated by DEM downsampling. These are seen in Figure 4 as a 'tiger stripe' pattern caused by the intersection of the relatively smoothly contoured basal Chilcotin contact surface with the step-like DEM (Fig 3).

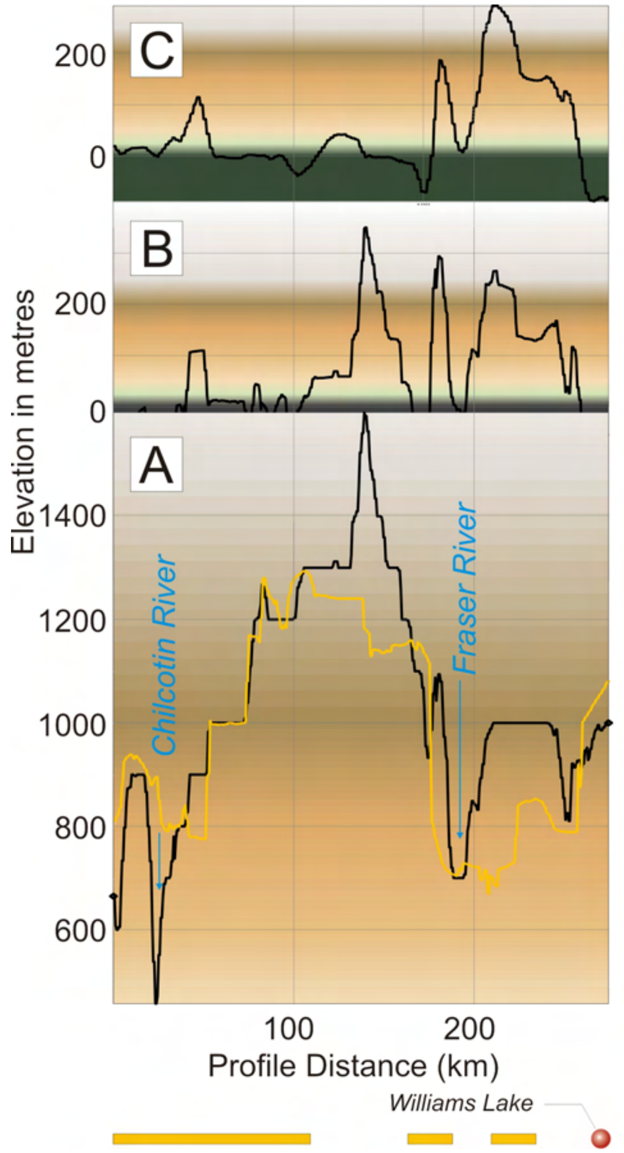

Figure 5. Profiles generated for the section line located in Figure 4: A) Base Chilcotin Group profile (yellow) is subtracted from the topography profile (black) to obtain the resultant thickness profile in (B). Height of land is Mount Alex Graham. Rekriging with a zero thickness buffer set 0.1° outside Chilcotin Group polygons yields the profile (C). See text for discussion. Distribution of Chilcotin Group along the section line as shown by Massey *et al*. (2005) is represented by the yellow bars at the base of the figure.

FUTURE THICKNESS MODELS

Next steps in revision of the model should include:

1) Addition of other sources of data that bear on the thickness of the Chilcotin Group, such as:
   a) water-well bore information,
   b) exploration oil-well cuttings,
   c) seismic sections that image the base of the Chilcotin Group,
   d) addition of future map data, and

e) use of Forest Renewal BC surficial deposits maps to fine-tune the bedrock – glacial deposits thicknesses.

2) Extending the model to include Quaternary glacial deposits. This has already been done in some parts of the modelled region because the age range of the Chilcotin Group as defined by Mathews (1989) extends well into the Quaternary (*e.g.,* 16–1 Ma).

3) Selective weeding of existing point elevation data and/or statistical weighting of high-quality data or outlier data of high importance.

4) Generation of a thickness model with a finer DEM in order to eliminate the 'tiger stripe' artifacts.

5) Field testing of the model by looking for basal Chilcotin Group contacts where predicted by the model.

Future Use of the Model in Mineral Exploration

Future iterations of the Chilcotin Group thickness model may attain levels of sophistication and accuracy that make it a useful tool for predictive mineral exploration. Integration of future thickness models with regional magnetic susceptibility data could enable removal of the Chilcotin Group magnetic response from the regional aeromagnetic survey, enhancing the magnetic fabric of basement rocks. In this way, future thickness models may permit the delineation of exploration targets beneath the Chilcotin Group — beneath a basalt blanket that is probably thinner than once believed.

REFERENCES

Andrews, G.D.M. and Russell, J.K. (2007): Mineral exploration potential beneath the Chilcotin Group (NTS 92O, P; 93A, B, C, F, G, J, K), south-central British Columbia: preliminary insights from volcanic facies analysis; *in* Geological Fieldwork 2006, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2007-1 and *Geoscience BC*, Report 2007-1, pages 229–238.

Bevier, M.L. (1983): Regional stratigraphy and age of Chilcotin Group basalts, British Columbia; *Canadian Journal of Earth Sciences*, volume 20, pages 515–524.

Breitsprecher, K. and Mortensen, J.K. (2004): BCAge 2004A – a database of isotopic age determinations for rock units from British Columbia (Release 2.0); *BC Ministry of Energy, Mines and Petroleum Resources*, URL <http://www.em.gov.bc.ca/Mining/Geolsurv/Publications/OpenFiles/OF2004-03/toc.htm> [December 2006].

Clague, J.J. (2006): Open letter by INQUA Executive Committee; *Quaternary Perspectives*, volume 16, pages 1–2.

Gradstein, F., Ogg, J., Smith, A., Bleeker, W. and Lourens, L. (2004): A new geological time scale, with special reference to Precambrian and Neogene; *Episodes*, volume 27, pages 83–100.

Massey, N.W.D., MacIntyre, D.G., Desjardins, P.J. and Cooney, R.T. (2005): Digital geology map of British Columbia: whole province; *BC Ministry of Energy, Mines and Petroleum Resources*, GeoFile 2005-1.

Mathews, W.H. (1989): Neogene Chilcotin basalts in south-central British Columbia: geology, ages and geomorphic history; *Canadian Journal of Earth Sciences*, volume 26, pages 969–982.

Mihalynuk, M.G. (2007): Evaluation of mineral inventories and mineral exploration deficit of the Interior Plateau beetle infested zone (BIZ), south-central British Columbia; *in* Geological Fieldwork 2006, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2007-1 and *Geoscience BC*, Report 2007-1, pages 137–142.

Parrish, R.R. (1983): Cenozoic thermal evolution and tectonics of the Coast Mountains of British Columbia. 1. Fission track dating, apparent uplift rates, and patterns of uplift; *Tectonics*, volume 2, pages 601–631.

Read, P.B. (2000): Geology and industrial minerals of the Tertiary basins, south-central British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Geofile 2000-3, 110 pages, URL <www.em.gov.bc.ca/mining/Geolsurv/Publications/Geofiles/Gf2000-3/toc.htm> [October 2006].

Souther, J.G. (1986): The western Anahim Belt: root zone of a peralkaline magma system; *Canadian Journal of Earth Sciences*, volume 23, pages 895–908.