

Stratigraphy, Structure, and Tectonic History of the Pink Mountain Anticline, Trutch (94G) and Halfway River (94B) Map Areas, Northeastern British Columbia

Steven J. Hinds* and Deborah A. Spratt
University of Calgary, 2500 University Dr. NW, Calgary AB, T2N 1N4
hinds@shaw.ca

ABSTRACT

Pink Mountain Anticline stands out in front of the Foothills of northeastern British Columbia (57°N, 123°W). Geologic mapping and prestack depth-migrated seismic sections show that it is localized above and west of a northwest-trending subsurface normal fault. Along with isopach maps they demonstrate episodic normal movement during deposition of the Carboniferous Stoddart Group, Triassic Montney Formation and possibly the Jurassic-Cretaceous Monteith-Gething formations. West of this step, during Laramide compression, a pair of backthrusts nucleated on either side of a minor east-west trending Carboniferous fault and propagated across it in an en échelon pattern. One backthrust ramped laterally across the area and separated the Pink Mountain and Spruce Mountain structures, which both are contained within a 30+ km long pop-up structure above the Besa River Formation detachment.

Glomospirella fossils confirm the existence of the Upper Jurassic Upper Fernie Formation and Upper Jurassic to Lower Cretaceous Monteith Formation at Pink Mountain.

Economic Significance of the Pink Mountain Area

Since the building of the Alaska Highway during the early 1940's, various companies have carried out petroleum, coal, and mineral surveys of the study area. To the east of Pink Mountain, several shallow gas fields such as the Julienne Creek and Julienne Creek North gas fields (Figure 1) were successfully drilled and produced gas from Triassic sandstone and carbonate rocks that were gently folded during the formation of the northern Rocky Mountains.

During 1962, the first exploration well, C-090-C/94G2 was drilled near the summit of Pink Mountain (Lepard et al. 1999). This well successfully produced gas, which led to the eventual drilling of fourteen wells on Pink Mountain from 1962 to 1994 in the Elbow Creek Gas field. This gas field plus the Grassy and

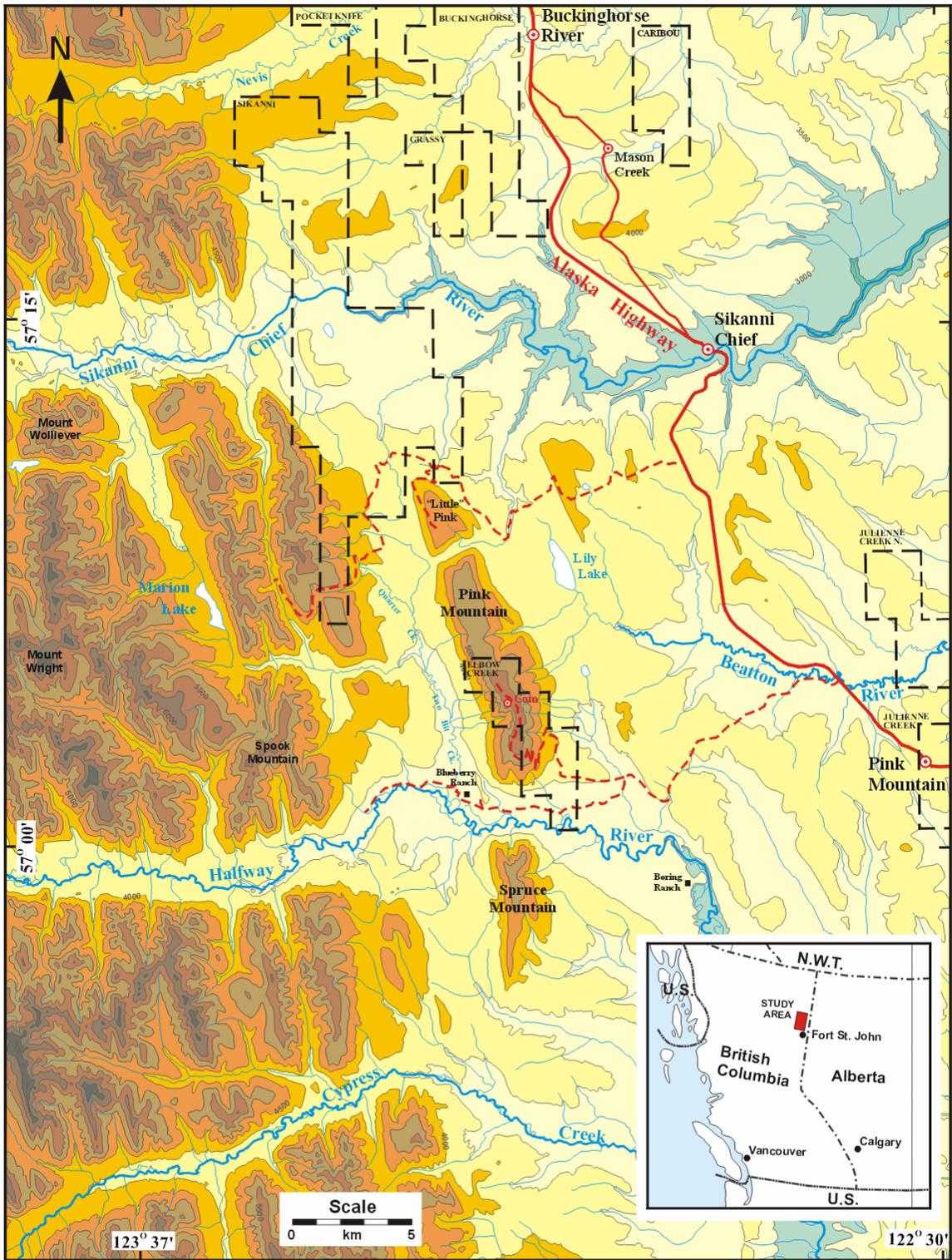


Fig. 1. Location and surrounding physiography of the Pink Mountain Anticline. Oilfield boundaries are heavy dashed lines.

Sikanni fields (Figure 1) produce gas from deeper Carboniferous rock units such as the Debolt Formation carbonates (top of Prophet Formation equivalent in Figure 2).

Generalized Stratigraphic Summary

Figure 2 portrays the entire surface and subsurface stratigraphy of the study area. The exposed surface stratigraphy consists of the Triassic Montney Formation to the lower Cretaceous Sikanni Formation. At present, the oldest identifiable unit in the well logs is the Silurian-Devonian Muncho-McConnell Formation. Stratigraphy older than the Muncho-McConnell Formation is identified in the study area through extrapolation from measured sections, geology maps, and seismic sections farther west (Cecile 1999, Taylor 1979, Thompson 1989).

In 1999, the existence of the Monteith and upper Fernie Formations at Pink Mountain were confirmed as a result of the discovery of *Glomospirella*, *Saturnella brookeae*, and *Labrespir goodenoughensis* microfossils. These microfossils have an Oxfordian – Kimmeridgian (and possibly Berriasian) age range in the upper Jurassic (MacNeil, 2000). On the western flank of the Pink Mountain Anticline, the Monteith Formation exhibits some bitumen staining but at one site the conglomeratic portion of the Monteith (?) Formation has a major concentration of bitumen and coal fragments that appear to have a high thermal maturity (MacNeil, 2000). This suggests the possibility of the generation, migration and accumulation of hydrocarbons during some stage of the development of the Pink Mountain Anticline.

Structural Geology of the Trutch (94G) and Halfway River (94B) Areas

From surface mapping observations, folding is the dominant structural process that occurs, within the Triassic and younger strata of the Trutch (94G) and Halfway River (94B) areas, in response to the Laramide Orogeny (Stott 1963; Figure 3). Within the 94G/2 and 94G/3 areas, the folds of Triassic and younger strata in this area are mostly asymmetrical box folds with the steeper limb commonly dipping to the west (Cecile 1999). In areas where the Triassic strata are capped by the thicker, more resistant clastic sequences of the lower Cretaceous, the box folds at this stratigraphic level are broader with more shallowly dipping asymmetrical limbs. In the Triassic cores of these folds, the less resistant shales and carbonates of the Triassic have steeper limbs that are more symmetrical in appearance (Lane et al. 1999), one such example is the Pink Mountain Anticline (Figure 3).

Surface Structural Geology of the Pink Mountain Anticline

Both Pink and Spruce Mountains comprise a box anticline structure with a major axis that appears to be both offset and re-oriented across the Halfway

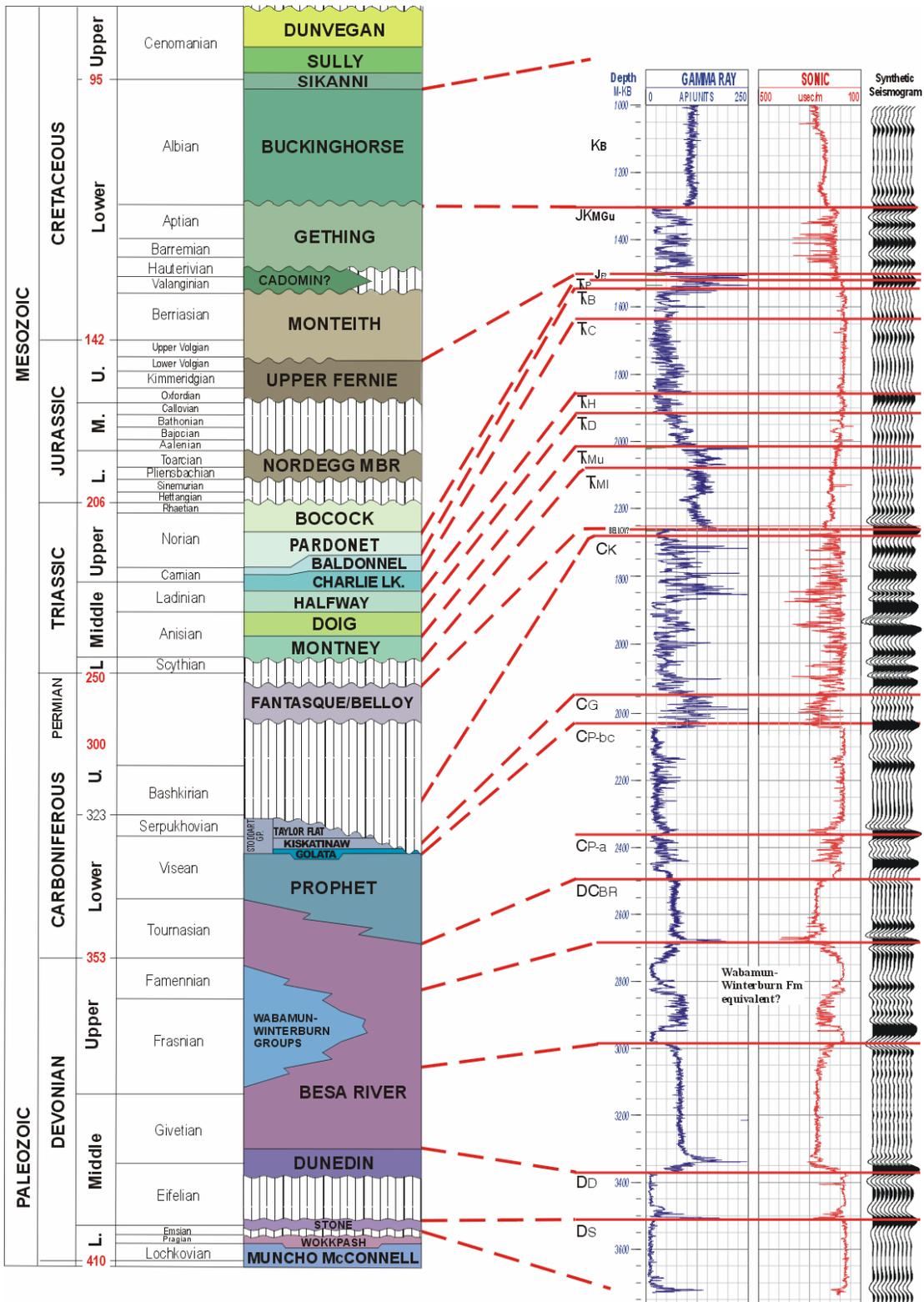


Fig. 2. Stratigraphy of the study area (modified from Stockmal 1999, Glass 1997, Pyle and Barnes 2000, and Stott 1991) with subsurface well log interpretation and synthetic seismogram.

River (Figure 3). Older interpretations of Pink Mountain show one anticline with an axial trace that changes from approximately 344° to 355° at Halfway River (Hage 1944, Taylor 1979). However, new map data and stereonet of the Halfway River area show that all fold axes trend between 335-340° and the plunge direction changes along the Pink Mountain Anticline (Figure 3). The changes in fold plunge are similar to those documented in the Sikanni River area by Cecile (1999). From both surface and stereonet analysis, the major box anticline that extends northward from Spruce Mountain across Halfway River is separate from and dies out west of the major Pink Mountain box anticline.

The major box anticline of Pink Mountain is clearly seen at Halfway River and its axis extends northwest with a northwest plunge until its surface expression disappears to the north. South of Halfway River at Spruce Mountain, the major box anticline axis is accompanied by five minor fold axes that appear to die out 1.5 kilometres to the southeast, whereas the major axis continues southward and plunges southeast beneath the surface at 56°57' north latitude (Figure 3). The folding style of the Pink Mountain Anticline varies northward from an asymmetric box anticline at Halfway River to a broader anticline with shallower limb dips at the north end of the mountain. The fold structure of Spruce Mountain is mostly an asymmetric box anticline with a steeper west limb and a mostly planar, shallowly dipping eastern limb (Figure 3).

Balanced Cross-section of the Pink Mountain Anticline

The 13.5 kilometre long seismic section exhibits 1.3 kilometres of shortening of strata above the Besa River Formation (Figure 4). This is equivalent to a shortening percent ($\frac{l_o - l_f}{l_o} \times 100$) of 8.8%. However, the strata below the Besa River detachment experienced less than 200 metres of net shortening (<1.5%). This agrees with previous proposals that, in the eastern part of the Rocky Mountain Foothills, the Besa River Formation shales absorb most of the tectonic stresses and the older strata are relatively undeformed (Thompson 1989).

Conclusions

One of the most important discoveries of this study is that Pink Mountain, previously interpreted by Taylor (1979), McLearn (1950), and Hage (1944) to be a single continuous anticline, is actually two separate box anticlines separated by en échelon backthrusts in the Halfway River area (Figure 3). The Pink Mountain area has a complex two-staged tectonic evolution that involves Carboniferous extensional tectonics followed by Cretaceous compressional tectonics during the Laramide Orogeny.

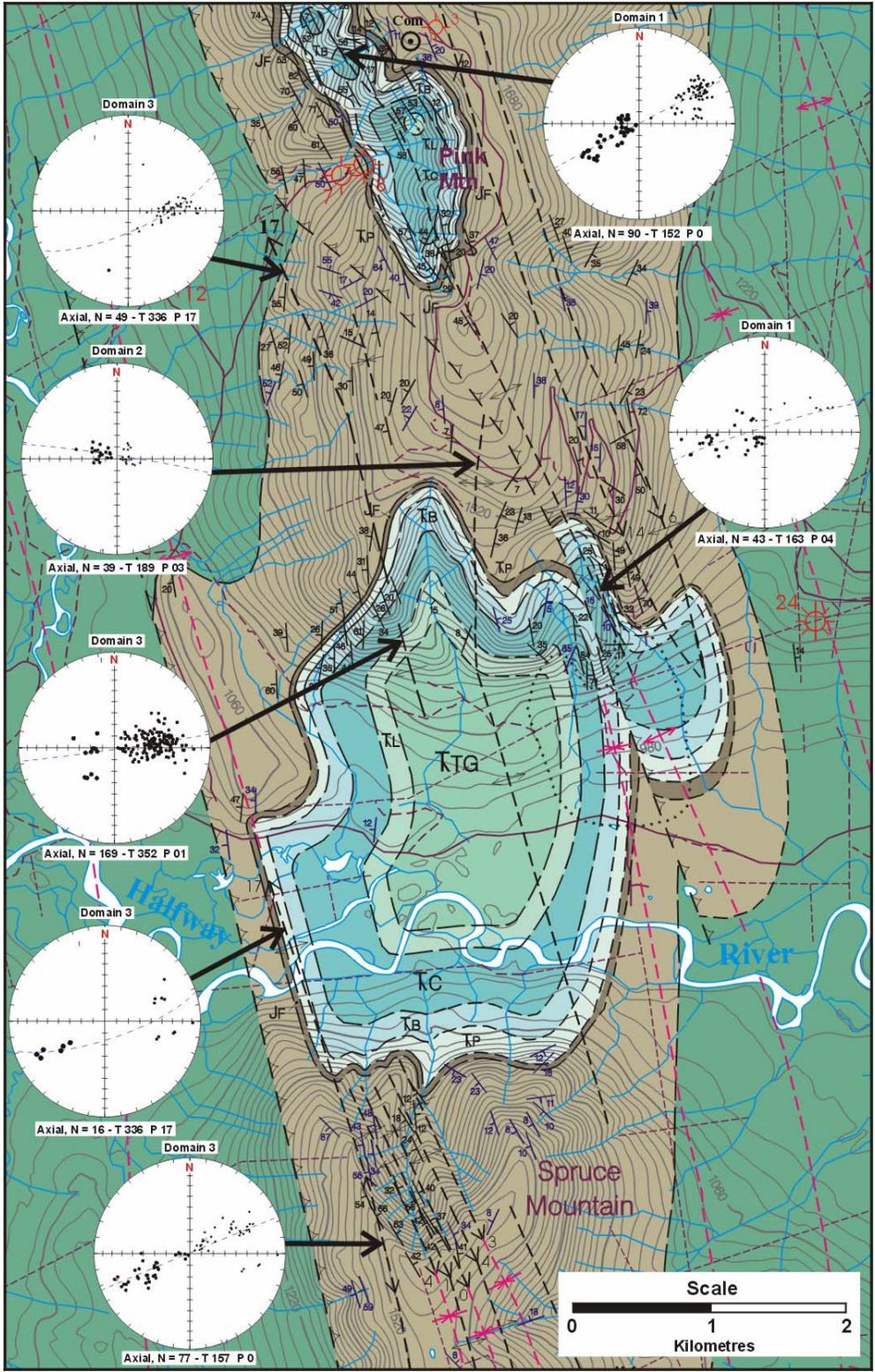


Fig. 3. Map of Pink and Spruce Mountains at Halfway River with stereoplots showing the three main fold domains (see Figure 2 for legend).

Isopach maps of the Carboniferous Stoddart Group indicate the presence of normal faults within the Carboniferous and older strata that have been formed by extensional tectonics related to the formation of the Dawson Creek Graben Complex in the Peace River area (Barclay et al. 1990, Figure 5). In this study area, the Halfway River, Elbow Creek, Cameron River, and Sikanni Chief River all follow the trends of the major normal faults and insights into the extents of these faults can be made by studying these rivers. This conclusion was reached only after the isopach maps and seismic sections were constructed independently of the topographic information.

In the beginning of the Permian, the paleosurface of the Trutch-Halfway River area consisted of a lateral disconformity, with the Prophet Formation occupying the Beaton High area to the east and the Stoddart Group occupying the down-dropped normal fault blocks to the west. From seismic interpretations, the extensional tectonic activity appears to have periodically occurred interspersed with the compressional tectonics of the Columbian and Laramide Orogenies. This extensional tectonic phase has no formal name, but has affected the deposition of the Carboniferous Stoddart Group, the Triassic Upper Montney Formation, and possibly the Lower Cretaceous Monteith-Gething formations.

During the Laramide Orogeny, the Triassic and younger strata were deformed into detachment folds and faults above the Devonian-Carboniferous Besa River Formation; the locations of folds and thrusts were controlled by the positions of the deeper subsurface normal faults within the Carboniferous and older strata. In the Pink Mountain area, a major northwest-trending normal fault appears to have served as a stress concentrator, causing the Lily Lake thrust to ramp at and to the east of the Pink Mountain detachment fold and localizing the reverse fault beneath Pink Mountain (Figure 4). A minor east-west trending branch fault off the major Carboniferous normal fault appears to have caused the backthrust beneath Pink Mountain to develop into an en échelon structure that bisected the anticline into the separate Pink and Spruce Mountain structures.

From seismic interpretations, both Pink and Spruce Mountains are contained within a thrust-backthrust pop-up structure that extends from Robertson Creek to the Sikanni Chief River. The faults of this pop-up structure extend down to the Devonian-Carboniferous Besa River Formation décollement horizon and the section shown in Figure 4 confirms Thompson's (1989) observations that the Besa River Formation acts as a thin-skinned detachment horizon. The location of this pop-up appears to be related to a deeper normal fault, hence the thick-skinned tectonic influence mentioned by Cooper (2000) is also confirmed by this section. The pop-up structure itself is a thin-skinned detachment structure (Thompson 1989) with a thick-skinned influence and the processes of normal fault re-activation are not as strong as Cooper (2000) suggests in the Halfway River area. The Pink and Spruce Mountain structures owe their existence to a combination of Thompson's (1989) and Cooper's (2000) tectonic models.

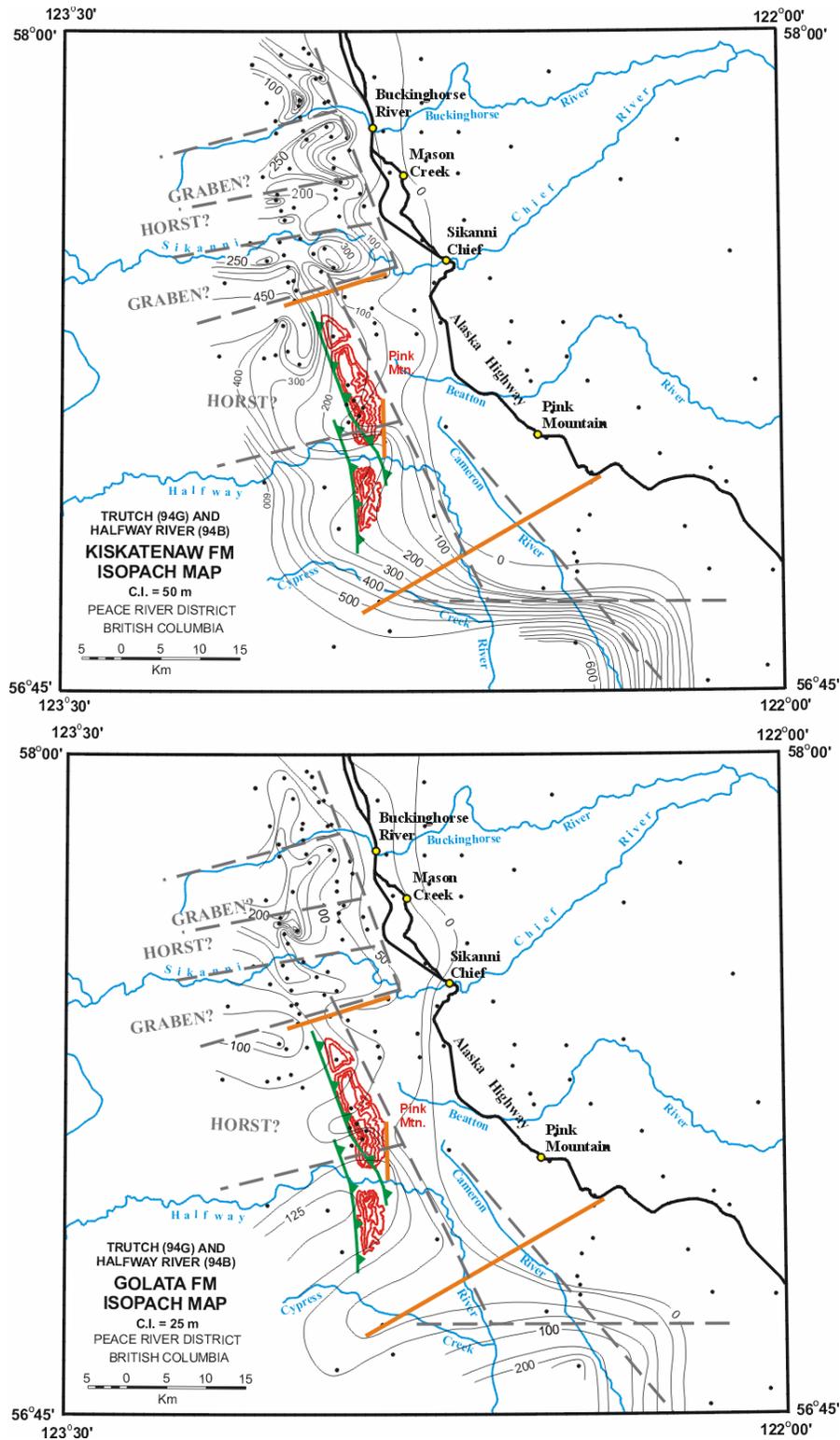


Fig. 5. Isopach maps (contours in metres) of the Carboniferous a) Kiskatinaw and b) Golata formations in the Trutch and Halfway map areas. Seismic lines shown in orange; dashed grey lines are possible subsurface faults.

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