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Stratigraphy and structure of the northeast margin of the Bowser Basin, Spatsizi map area, north-central British Columbia

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Abstract

Tight folding and related thrust faulting along the boundary of Bowser and Sustut basins accommodated a great amount of northeasterly shortening of the Jurassic and Cretaceous strata. A thrust fault, which places Lower Jurassic volcanic rocks on middle Cretaceous nonmarine strata, indicates significant tectonic burial of rocks which are a potential source for hydrocarbons. Different structural levels of the contractional deformation are exposed in blocks bounded by steeply dipping, dip-slip faults. Some of the dip-slip faults were active after a post-Kimmeridgian/pre-Albian phase of contractional deformation and prior to Late Cretaceous contractional deformation.

Elements of stratigraphy in the northernmost part of Bowser Basin can be roughly correlated with those near thelappan anthracite coal deposits. An Upper Jurassic(?) shallow marine to nonmarine succession that overlies the Ashman Formation (marine) in the north, may correlate with the lower part of the coal-bearing sequence farther south.

Résumé

Les plis serrés et le chevauchement associé qu'on retrouve le long de la limite des bassins de Bowser et de Sustut sont accompagnés d'un raccourcissement important vers le nord-est des strates jurassiques et crétacées. Une chevauchement qui ramène des roches volcaniques du Jurassique inférieur sur des roches non marines du Crétacé moyen indique un enfouissement tectonique important de roches qui constituent une source possible d'hydrocarbures. Différents niveaux structuraux de la déformation par contraction sont exposés dans des blocs limités par des failles transversales d'effondrement à fort pendage. Certaines failles ont été actives après la phase de déformation par contraction du post-Kimméridgien/pré-Albien et avant la déformation par contraction du Crétacé supérieur.

Il est plus ou moins possible de corréler des éléments de stratigraphie de la partie la plus septentrionnale du bassin de Bowser avec ceux qui sont à proximité des gisements d'anthracite dur de Klappan. Il est possible de corréler une succession marine à non marine peu profonde du Jurassique supérieur (?), qui repose sur la formation d'Ashman (marine) au nord, avec la partie inférieure de la séquence riche en charbon plus au sud.

INTRODUCTION

In summer 1986, mapping at 1:50 000 scale continued in Spatsizi map area (Fig. 75.1). The project was begun in 1985 to gain a better understanding of the structural style and tectonic setting of the northeastern margin of Bowser Basin (Evenchick, 1986).

The Bowser Basin contains Middle to Upper Jurassic marine and nonmarine clastic sediments (Bowser Lake Group) that overlie Lower Jurassic volcanic rocks of the Hazelton Group (Cold Fish volcanics), and fine grained, in part volcanogenic(?) sediments of the Spatsizi Group. It is bounded to the northeast by Cretaceous, mainly nonmarine sediments of Sustut Basin (Sustut Group). Northeast-verging folds and thrust faults that involve strata of the Bowser and Sustut basins, and their basement, have accommodated major northeasterly contraction. Steeply dipping dip-slip faults were active prior to deposition of the Sustut Group and after contractional deformation of the lower part of the Sustut Group.

A synthesis of the stratigraphy and its relationship to regional tectonics was described by Evenchick (1986). This report addresses: stratigraphy of Bowser Lake Group at the northeasternmost part of Bowser Basin, and possible correlation with the stratigraphy in the vicinity of the Klappan coal deposits to the south; and structure in the east-central part of the area and its implications for regional structure, stratigraphy, and timing of deformation.

STRATIGRAPHY OF THE BOWSER LAKE GROUP

The term Bowser Lake Group was first used by Tipper and Richards (1976) for Upper Jurassic marine strata in the southern Bowser Basin. It was applied to Middle and Upper Jurassic strata in the northern part of the basin by Gabrielse and Tipper (1984).

The base of the Bowser Lake Group is largely dark grey to black marine shale and siltstone, but in the extreme northeastern part of the basin coarse conglomerate lenses occur with the siltstone. Ammonites indicate a Bathonian to Callovian age (Gabrielse and Tipper, 1984, and personal communication, 1986). The shale sequence is overlain by a coarsening-up clastic sequence, and the youngest sediments known (Oxfordian-Kimmeridgian-Tipper, personal communication, 1986) are coarse, massive, chert-pebble to cobble conglomerate.

The Bowser Lake Group is most complete in a plunging anticline-syncline pair between the culmination of Cold Fish

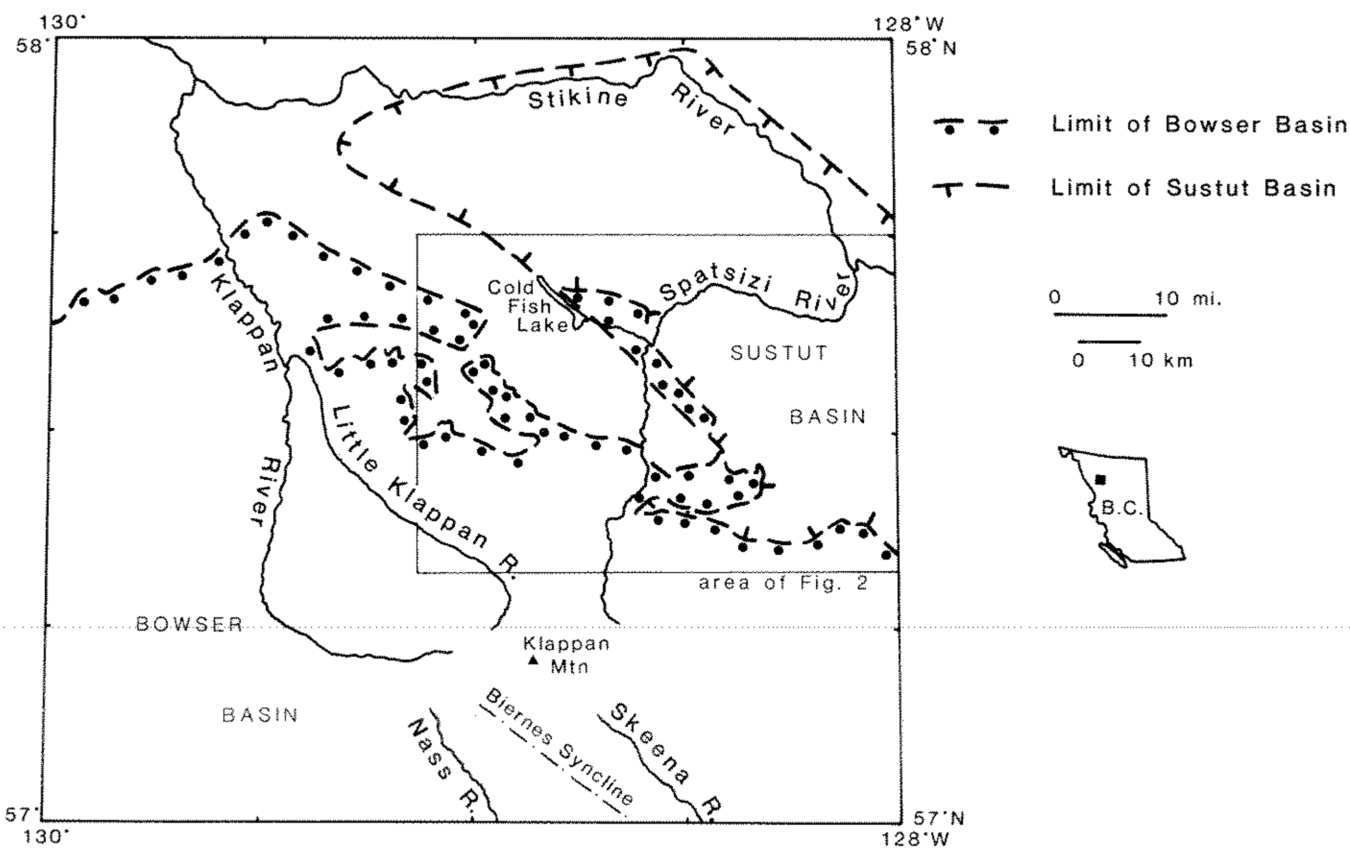

Figure 75.1 Map showing regional geological and geographic features of Spatsizi map area and the location of the study area.

volcanics at the Joan Lake Anticline and the core of a syncline west of the Spatsizi River valley (Fig. 75.2, 75.6 between sections DE and FG). The volcanics in the Joan Lake Anticline are overlain by sediments of the Spatsizi Group which thin to the northeast, and are overlain by the Bowser Lake Group. The base of the Bowser Lake Group is black siltstone. About 30 m above the base is a massive conglomerate member about 20 m thick that is locally made up of coalescing lenses. The conglomerate is overlain by thick, black and grey siltstone (Fig. 75.3), and then by siltstone with coalescing lenses of conglomerate on the north limb of the syncline, less common lenses on the south limb, and rare lenses to the southeast. The sequence of dominantly siltstone with varying amounts of chert-pebble conglomerate is about 1500 m thick. It is overlain gradationally by a unit of siltstone interbedded with intervals about 10 to 15 m thick of massive, medium grained, very well sorted, chert sandstone (Fig. 51.4). Chert-pebble conglomerate is rare and the unit has marine and nonmarine fossils. The sandstone/siltstone interval is 50 to 100 m thick. It is overlain by a rusty weathering sequence characterized by thick, massive, chert-pebble to cobble conglomerate (Fig. 75.5). Interbeds of siltstone and sandstone occur from 20 m above the base to the highest exposed beds. They comprise about 15% of the unit, and are generally less than 1 m thick. The thickest is near the top of the unit and is 15 m thick. The sandstone interbeds have abundant, coalified plant remains up to 15 cm long; one calcareous sandstone interval near the highest exposed strata

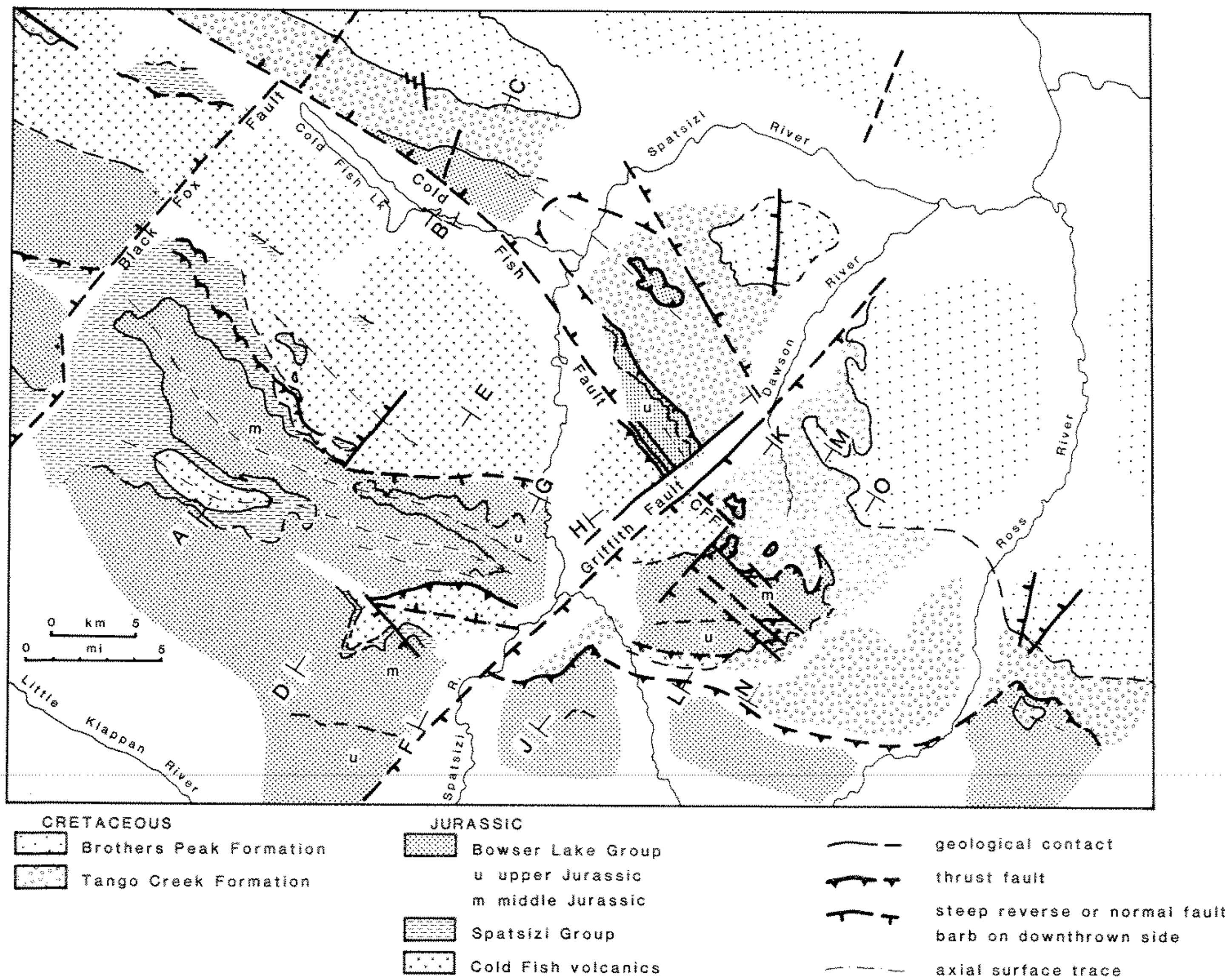

Figure 75.2 Geological map of the study area.

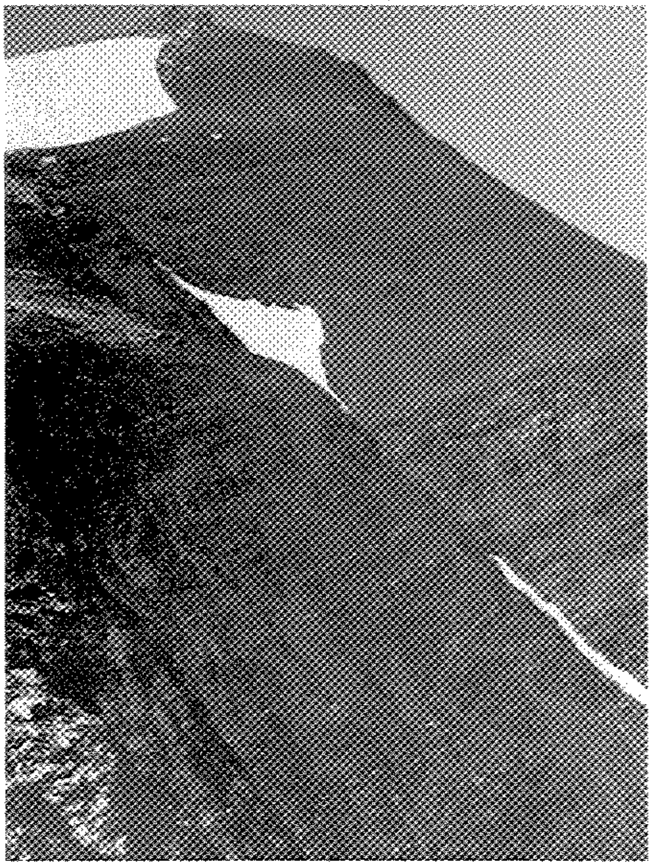

Figure 75.3 View south to siltstone of the Ashman Formation.

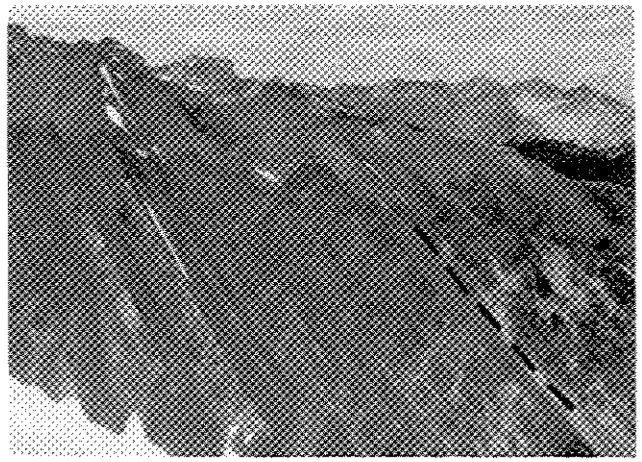

Figure 75.4 View northwest to the interbedded siltstone and sandstone unit above the Ashman Formation. The dashed black line marks the base of the conglomeratic unit that overlies the siltstone/sandstone unit.

has pelecypods, ammonites, and belemnites. The age of these beds based on the ammonite fauna is Oxfordian/Kimmeridgian (Tipper, personal communication, 1986).

Four kilometres to the south, Pliensbachian Cold Fish volcanics are in fault contact with the Bowser Lake Group (Fig. 75.2, 75.6), and are overlain by 100 m of Spatsizi Group. At the base of the Bowser Lake Group, black siltstone with one member of resistant conglomerate about 30 m thick occurs 10 to 20 m above the base. The conglomerate is overlain by a thick (at least 1000 m), folded black siltstone sequence with less than 5% sandstone and no conglomerate. Six kilometres southwest of the base of the Bowser Lake Group contact, the sequence is overlain by siltstone interbedded with white weathering massive sandstone (Fig. 2). Two kilometres farther southwest, and across anticlinal and synclinal closures, the sequence is overlain by very rusty weathering, massive, well sorted, sandstone interbedded with black siltstone, rare conglomerate, and coal. Marine and nonmarine fossils are present. Similar lithologies have been described by Koo (1986) and Moffat (1985) in this area and south of Klappan Mtn., in the Biernes Syncline (Fig. 75.2).

From the transect described above, and two days spent in the Biernes Syncline, the following conclusions can be made.

A dark grey to black siltstone and shale unit (Fig. 75.3) with middle Jurassic marine fossils and varying amounts of chert-pebble conglomerate lenses can be mapped regionally. The term Ashman Formation (defined by Tipper and Richards, 1976) has been applied to this sequence by Gabrielse and Tipper (1984). Overlying the Ashman Formation is a unit of siltstone interbedded with sandstone (Fig. 75.4) that is distinct from overlying massive pebble conglomerate in the north, and sandstone interbedded with siltstone, conglomerate, and coal in the south. Along trend to the northwest, a similar sequence of Ashman Formation overlain by sandstone and siltstone, then by pebble conglomerate with Oxfordian/Kimmeridgian fossils occurs in the northwest corner of the Bowser Basin (Tipper, personal communication, 1986).

The Ashman Formation is lithologically similar to the part of the Jackson unit below the top 100 m as described by Bustin and Moffat (1983). Fossils from 100 m below the top of the Jackson unit are pre-Oxfordian (C. Stelck, *in* Bustin and Moffat, 1983) and are consistent with the Bathonian/Callovian age assigned to the Ashman Formation by Gabrielse and Tipper (1984). The overlying sandstone/siltstone unit in the north may be equivalent to the upper Jackson unit, which has similar lithologies and Oxfordian ammonites (P. Smith, *in* Bustin and Moffat, 1983). The upper conglomerate (with abundantlant debris) in the north may represent channels feeding a thick prograding deltaic sequence farther south, which is represented by part of the coal-bearing Currier and younger units in the Biernes Syncline (Fig. 1 and see Moffat, 1985). An Upper Jurassic age for plant fossils in the Currier unit (Rouse, in Bustin and Moffat, 1983) supports the correlation. The age of the youngest coal-bearing strata in the Biernes Syncline is unknown; they may have no time-equivalent in the north, due to either erosion, or to burial by thrust sheets.

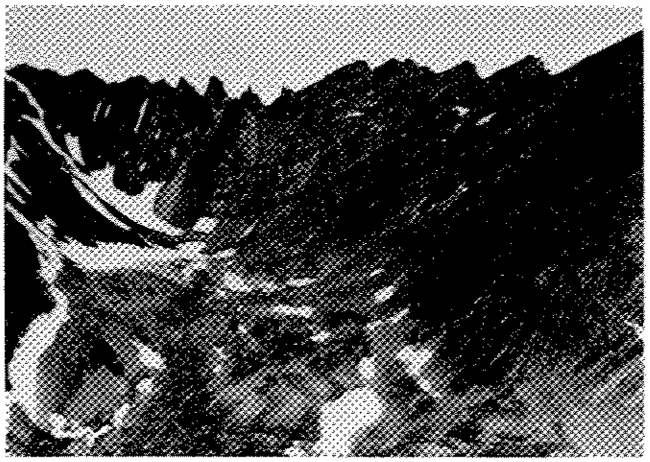

Figure 75.5 View northwest to a syncline of massive chert-pebble conglomerate at the top of the Bowser Lake Group. The dashed black line marks the base of the unit.

According to Bustin and Moffat (1983) and Koo (1986), in the Biernes Syncline the thick sequence of siltstone with sandstone, abundant plant fossils, minor conglomerate and coal is overlain by a massive conglomeratic sequence with minor sandstone and siltstone, informally named the Devils Claw unit by Bustin and Moffat (1983). Palynology on samples from the sequence yielded an Albian age (Moffat, 1985). However, rocks of the same age in the Sustut Basin (the basal Tango Creek Formation) are sandstone and siltstone with abundant, coarse detrital muscovite that is expected to be easilyransported throughout the depositional system. An Albian age for the Devils Claw unit presents an enigma because the rocks in the Biernes Syncline bear no resemblance to Albian rocks of the Sustut Basin 35 km to the northeast. Possibly a northwest-trending arch was present in Albian time between the Sustut Basin and the area that eventually became the Biernes Sycnline. This explanation is consistent with latest Jurassic to early Cretaceous deformation inferred from a structural analysis of the region.

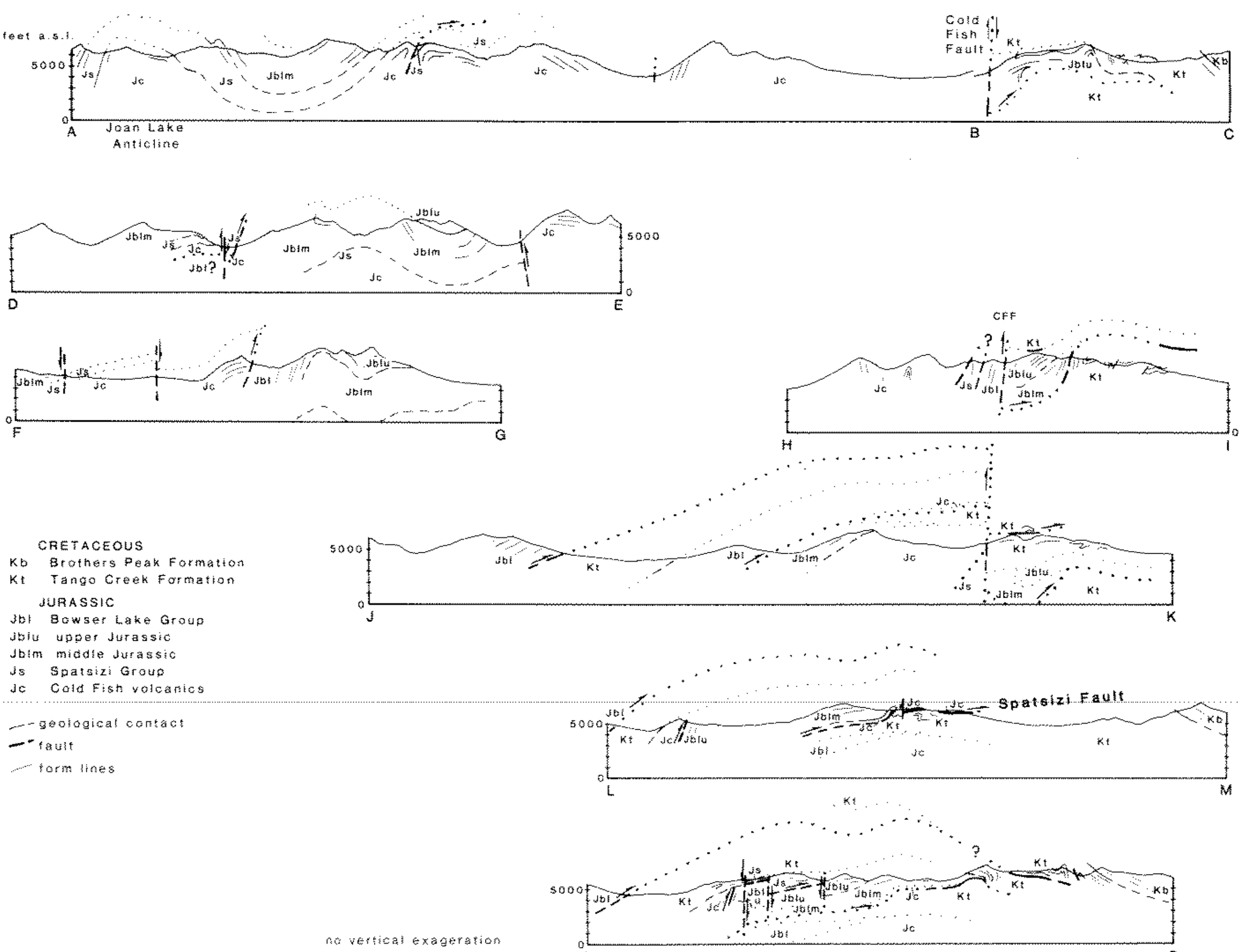

Figure 75.6 Schematic cross-sections of the study area. The locations of the sections are shown in Figure 75.2.

STRUCTURE

The focus of this contribution is on interpretation of the distribution of map units and map-scale structures. Strata involved in major northeasterly-verging contractional deformation at the northern boundary of the Bowser and Sustut basins are: Pliensbachian Cold Fish volcanics, Toarcian to Bajocian Spatsizi Group, Bathonian to Kimmeridgian Bowser Lake Group, and Albian to Santonian(?) Tango Creek Formation of the Sustut Group. High angle dip-slip faults divide the region into blocks in which the contractional structures can be traced coherently along trend and plunge. The structural geometry in the area between two dip-slip faults, the Black Fox and Griffith faults (Evenchick, 1986, Fig. 75.6, sections ABC, DE, FG) is relatively straightforward. Locating those structures on the southeast side of Griffith Fault is not straightforward, in part because of the complexity of the contractional structures. The structure of the two areas is tentativly linked by attempting to match structures in a block-faulted area immediately southeast of the Griffith Fault (Fig. 75.6, section JK) with those in section HI, which can in turn be related along plunge to those in section BC.

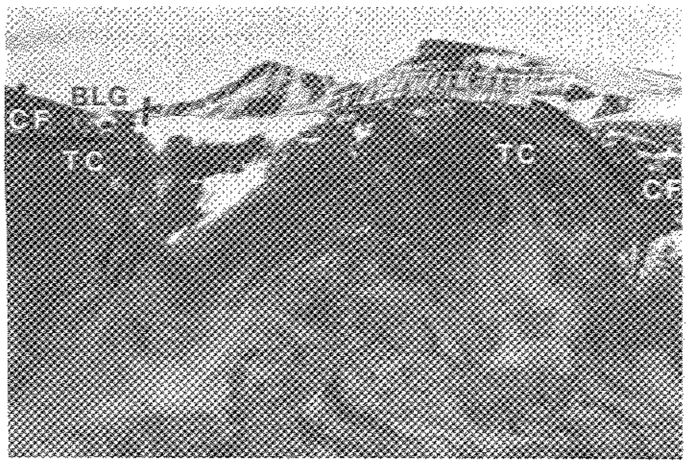

Figure 75.7 View southeast to the Spatsizi fault where it outcrops in section LM. The fault is marked by a solid black line, the dashed line is a dip-slip fault that cuts the Spatsizi fault. Cold Fish volcanics CF; Bowser Lake Group BLG; Tango Creek Formation TC.

NORTHWEST OF GRIFFITH FAULT

The Cold Fish volcanics, Spatsizi Group, and Bowser Lake Group are folded into a gently southeasterly plunging upright anticline-syncline pair that tightens to the southeast and has a curved axial surface trace. Although the core of the Joan Lake Anticline appears to be doubly plunging, the disappearance of volcanics to the northwest is probably an expression of thicker Spatsizi Group preserved beneath the Bowser/Spatsizi unconformity. The adjacent syncline outlined by the contact between the Spatsizi and Bowser Lake groups does not plunge to the northwest. The north contact of the Spatsizi Group with the volcanics is a folded and faulted unconformity (Fig. 75.6, section AB). In section DE the contact is a reverse fault that forms the south boundary of a block of uplifted volcanics. In section FG the volcanics are in steep fault contact with the Bowser Lake Group. The fault is either the ramp of a thrust fault, or is a reverse fault. High angle faults south of the thrust(?) fault offset contacts several hundred metres.

SOUTHEAST OF GRIFFITH FAULT

The most significant newly identified thrust fault puts Cold Fish volcanics on Tango Creek Formation (Fig. 75.6, section LM), and is herein informally named the Spatsizi fault. The Spatsizi fault is gently dipping where the volcanic rocks occur as two klippen on the top of a ridge of folded Tango Creek Formation. The volcanics are in steep fault (ramp) contact with the Tango Creek Formation 200 m south of the southmost klippe, and are overlain by the Bowser Lake Group (Fig. 75.7). In places the volcanics in the hanging wall of the fault are absent or are only 1-2 m thick and interleaved with the Bowser Lake Group. The Spatsizi fault can be followed downplunge southeast to section NO, where the Bowser Lake Group, low on the hillside, lies structurally on the Tango Creek Formation (Fig. 75.8). Near the top of the same ridge, the Bowser Lake Group is unconformably overlain by the Tango Creek Formation (Fig. 75.8). To the northeast, the unconformity is interpreted to be folded and cut by a hanging wall ramp as the Spatsizi fault cuts up-section (Fig. 75.6, section NO). The fault dips northeast because it is on the northeast limb of an anticlinal warp that postdates all contractional structures. The Tango/Bowser unconformity that outcrops in section NO can be traced to the southwest several kilometres. Where the unconformity crosses a small gully

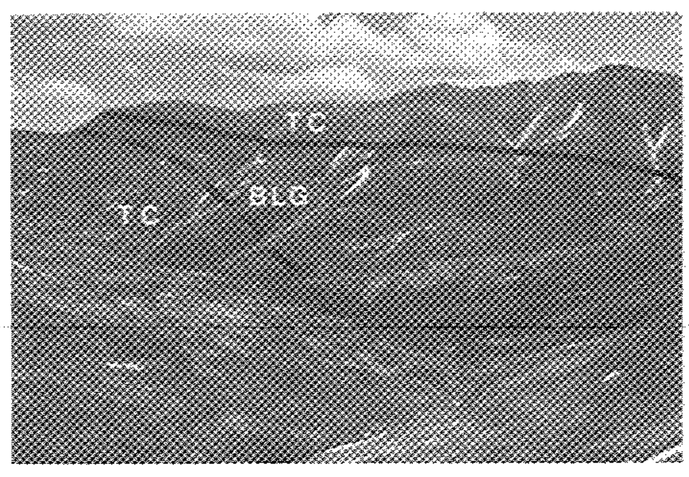

Figure 75.8 View southeast to the relationships illustrated in section NO. The Tango Creek Formation lies unconformably on Bowser Lake Group, which is thrust over the Tango Creek Formation. The solid line is the unconformity, and the dashed line is the Spatsizi fault.

3 km southwest of the right side of Figure 75.8, the underlying rock is siltstone of the Spatsizi Group. The Spatsizi Group has a structural thickness of 500 m from ridge top to valley bottom, and is inferred to be thrust on the Bowser Lake Group on slopes to the north. Another 1.5 km southwest, the Spatsizi Group beneath the unconformity abruptly has a structural thickness of 100 m, and is structurally above the Bowser Lake Group. Less than 1 km to the southwest, the Tango Creek Formation is dropped against the Spatsizi Group by a northwest-trending high angle fault, and below the unconformity is conglomerate of the upper Bowser Lake Group in steep fault contact with volcanics (Fig. 75.6, section NO). The presence of different units, and abrupt changes in thickness of units unconformably below the Tango Creek Formation is interpreted to be a result of pre-Albian deformation. The thrust fault that places Spatsizi Group on the Bowser Lake Group is offset by high angle faults that are overlapped by the Tango Creek Formation, and therefore the high angle faults, and the thrust fault are pre-Albian. The distribution of various map units in the valley north of the unconformity suggests that the steep faults are northwest-trending. The geometry of units could be accounted for if the Cold Fish volcanics and Spatsizi Group were thrust onto the upper Bowser Lake Group. The thrust fault was folded, and as a result the hanging wall ramp of volcanics on the Bowser Lake Group is steeply dipping as in section NO, and the fault is gently dipping where the Spatsizi Group overlies the Bowser Lake Group. The thrust fault was cut by two northwest-trending high angle faults that dropped it down to the northeast. Following erosion, basal Tango Creek Formation (Albian) was deposited on a block-faulted terrane. Tango Creek rocks were then overridden by a thrust fault that carried the Cold Fish volcanics, and a block-faulted terrane of pre-Albian strata that is unconformably overlain by Tango Creek Formation. The presence of pre-Albian block faults poses a major problem for structural analysis because the same post-Albian thrust fault need not have a predictable footwall or hanging wall pre-Albian stratigraphy along trend. The problem is compounded where pre- and post-Albian thrust faults must be identified across post-Albian high angle faults. Downplunge to the southeast of section NO (southeast of Ross River), a thrust fault with Bowser Lake Group in the hanging wall and Tango Creek Formation in the footwall, is shown schematically as the structure above the Spatsizi fault in section NO.

In section JK a thick (valley bottom to peak top) section of volcanics occurs only 1 km northwest of the part of section LM where the Spatsizi fault occurs near the valley bottom and has only 1 m of volcanics in the hanging wall. The volcanics in section JK are also bounded to the northwest by a thick section of Tango Creek Formation. The absence of the Spatsizi fault along trend in section JK requires that between sections LM and JK a northeast-trending high angle fault has a minimum of 1000 m of southeast-side-down displacement. The minimum displacement is inferred by assuming pre-Albian uplift which resulted in erosion of much of the Bowser Lake Group. Support for erosion of the Bowser Lake Group is the presence of Tango Creek Formation on volcanics in the northwest corner of Figure 75.2, indicating significant pre-

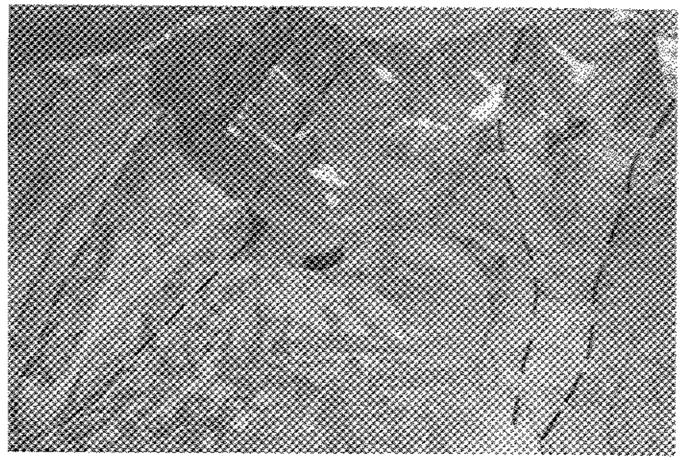

Figure 75.9 View northwest to folded coal-bearing upper Jurassic rocks between Little Klappan and Spatsizi rivers as shown on Figure 75.2. The dashed black line marks the base of the same resistant member.

Albian uplift of a northwest-trending belt bounded to the northeast by a major northeast-side-down fault (Cold Fish Fault). Erosion ofhe Bowser Lake Group below the Tango unconformity is shown schematically in sections LM and NO. The Cold Fish Fault puts thick volcanics against thick Tango Creek in section JK. It is inferred to have had at least 2000 m of post-Albian northeast-side-down displacement. The structure below the Tango Creek Formation northeast of the Cold Fish Fault in section JK is entirely inferred from southeast-side-down displacement of the structure in HI, along the Griffith Fault. The Tango Creek Formation is interpreted to unconformably overlie folded Bowser Lake Group in sections HI and BC (Evenchick, 1986). Below the unconformity in section BC, a thrust fault that places Bowser Lake Group on Tango Creek Formation is the downplunge projection of a folded thrust fault in section HI (*see* Evenchick, 1986).

CONCLUSIONS

Mapping of structures at the boundary of the Bowser and Sustut basins has provided the first direct evidence for involvement of the Lower Jurassic Cold Fish volcanics in major contractional deformation, and as a result indicates that thrust faults sole into a decollement in or below the basement to the Bowser Basin. The amount of shortening represented by both structures between faults, and the overlap of faults, is at least 50% (Fig. 75.6, 75.9, and Fig. 78.7 in Evenchick, 1986). The interpretation of pre-Albian block faults that offset a thrust fault is the most direct evidence for more than one pulse of contractional deformation.

Analysis of the structure involves restoration of northeast-verging folds and faults, and stratigraphy, across: 1) pre-Albian dip-slip faults which resulted in erosion and preservation of different pre-Albian stratigrpahy at the same structural level; 2) post-Albian dip-slip faults.

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