COAL GEOLOGY OF THE MOUNT KLAPPAN AREA IN NORTHWESTERN BRITISH COLUMBIA (104H/2, 3, 6, 7)

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INTRODUCTION

The Mount Klappan area is approximately 150 kilometres northeast of Stewart and 500 kilometres northeast of Prince Rupert in northwestern British Columbia. Gulf Canada Resources Inc. has been conducting coal exploration in the Mount Klappan area since 1981.

The present project began with a reconnaissance survey of the Mount Klappan area during the summer of 1983 (Koo, 1984). Fieldwork was continued during the summer of 1984 to investigate the Mount Klappan area in more detail. This report presents preliminary results from work done during the 1984 field season in a 250-square-kilometre area in the Mount Klappan region (Figs. 119 and 120). Objectives of this project are to increase the understanding of the stratigraphy, depositional environment, structural development, and relationships with surrounding rocks of the coal measures in the Mount Klappan area.

REGIONAL GEOLOGICAL FRAMEWORK

The Mount Klappan area is located in the northwestern part of the Groundhog Coalfield within the northeastern portion of the Bowser Basin. Uplift of the Skeena Arch in Middle Jurassic time separated the Early to Middle Jurassic Hazelton eugeosynclinal trough into the Bowser and the Nechako Basins (Tipper and Richards, 1976). The Stikine Terrane, the Atlin Terrane, and the Omineca Crystalline Belt merge in the vicinity of the Bowser Basin. Tectonic interactions of the three crustal blocks controlled sedimentation in the Bowser Basin (Eisbacher, 1981). The Groundhog Coalfield contains about 3 500 metres of Late Jurassic to Cretaceous marine and non-marine strata. Eisbacher (1974b) subdivided the sedimentary strata at the eastern margin of the Bowser Basin into three facies that were referred to as the Duti River-Slamgeesh, Groundhog-Gunanoot, and Jenkins Creek. Richards and Gilchrist (1979) divided the stratigraphic succession in the Groundhog Coalfield into four map units that were referred to as channel, channel-overbank, overbank-channel, and overbank facies. More recently Bustin and Moffat (1983) revised this succession into four stratigraphic units; in ascending order these are the Jackson, the Currier or Prudential, the McEvoy, and the Devil's Claw units. The Groundhog succession unconformably overlies the Triassic to Middle Jurassic Takla-Hazelton assemblage and is unconformably overlain by the Late Cretaceous Tango Creek Formation of the Sustut Group (Eisbacher, 1974a, 1974b).

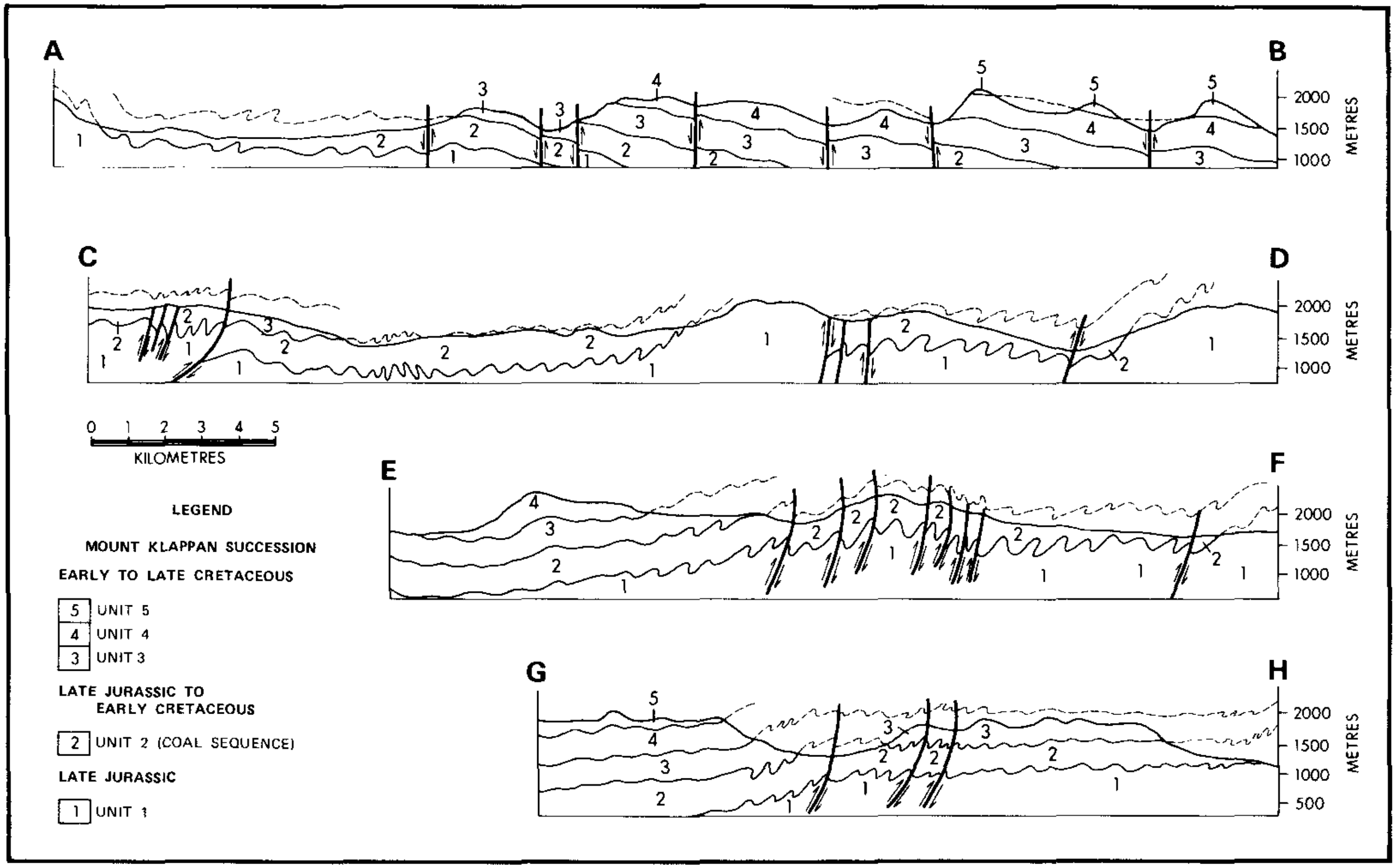

Figure 120. Geological cross-sections of the Mount Klappan area.

The Mount Klappan area is underlain by a 1 300 to 1 500-metre succession of conformable marine and non-marine strata, referred to here as the Mount Klappan succession. It consists of coal seams, claystones, siltstones, sandstones, and conglomerates. Johnson and Pituley (1984) divided the succession into the lowest marine, Klappan, Malloch, and Rhonda sequence in ascending order. The present study divided the Mount Klappan succession into five mappable stratigraphic units that are numbered 1 to 5 in ascending order (Figs. 119 and 120). These units correlate closely with those of Bustin and Moffat (1983) and Johnson and Pituley (1984), except the McEvoy unit or the Malloch sequence which the present study subdivided into units 3 and 4.

STRATIGRAPHY

UNIT 1

Unit 1 is the lowest 200-metre stratigraphic interval of the Mount Klappan succession. It is exposed widely in the northwestern part of the Mount Klappan area (Fig. 119). Gabrielse and Tipper (1984) mapped the Middle to Late Jurassic Bowser Lake Group in the Spatsizi area immediately to the north. Unit 1 correlates with part of the upper sequence of the Bowser Lake Group. Up to 11 coarsening upward cycles are included in this unit; individual cycle thicknesses vary from 2 to 50 metres. The cycles consist mainly of interbeds of grey to black claystones and siltstones, and grey to brown fine to medium-grained sandstones; claystones and siltstones are three to five times as abundant as sandstones. Claystone and siltstone layers are up to 40 metres thick; beds within them are 1 to 5 centimetres thick. About 10 per cent of the layers are impure carbonate interlayers that range in thickness from 0.5 to 2 metres. The sandstones range in thickness from 1 to 5 metres and are planar-bedded. Marine bivalves and intense bioturbation are common in the layers of intercalated siltstones and sandstones. Conglomerate occurs in a few lenticular layers up to 5 metres thick near the top of this unit; clasts in the conglomerate consist of subrounded chert and volcanic pebbles up to 3 centimetres in diameter. In places, it grades into thin discontinuous coarse-grained sandstone lenses. Unit 1 typifies a marine deltaic sequence. The coarsening upward cycles result from successive progradation of delta channels over fine-grained prodelta sediments.

UNIT 2

Unit 2 is the principal coal-bearing sequence of the Mount Klappan area. Its thickness ranges from 350 to 420 metres and it occurs mainly at lower elevations in the central part of the area (Figs. 119 and 120). This unit can be subdivided into lower, middle, and upper members. The lower member, which ranges in thickness from 150 to 200 metres, contains seven to eleven coarsening upward cycles, each between 6 and 30 metres in thickness. The cycles begin with grey to black interbedded claystones and siltstones and grade upward to grey to brown fine to coarse-grained sandstones. In the lower member, the total amount of claystone and siltstone is about twice as much as that of sandstone. Claystone and siltstone layers are as thick as 20 metres; commonly they are associated with coal seams. The sandstone layers, which are up to 10 metres thick, have widespread ripple crossbedding. Grains in the sandstones consist mainly of chert, feldspar, and volcanic rocks. A few lenticular layers of conglomerate occur in the upper zone of the lower member; they are up to 5 metres thick and 200 metres in lateral extent. Bivalves and bioturbation occur in some siltstone layers that appear to be of marine origin. The lower member is the type of sequence found in a constructive deltaic system with wide, subaerial delta plains and intermittent coal swamps.

The middle member of unit 2 consists mainly of dark grey to brown claystones, siltstones, and fine to medium-grained sandstones; it ranges in thickness from 100 to 150 metres. Only a minor amount of coarse-grained sandstone occurs as thin lenses at the base of this member. The total amount of claystone and siltstone is almost equal to that of sandstones in the member; all three are closely intercalated. Individual beds vary from a few centimetres to 3 metres in thickness; scours, mud cracks, and rip-ups are widespread. Despite the intercalations, six to ten fining upward and two coarsening upward cycles with individual thickness from 10 to 30 metres can be recognized. Dwarfed, brackish water bivalves and bioturbation occur in a few black mudstone zones within the coarsening upward cycles. This member comprises mainly fluvial cycles that are intertongued by several marine cycles. The environment of deposition varied between marine deltaic and non-marine fluvial conditions.

The upper member of unit 2 consists of 100 meters of claystones, siltstones, sandstones, and conglomerates. Up to 12 fining upward cycles occur; they range from 6 to 35 metres in thickness. The claystones and siltstones, which are approximately twice as abundant as the sandstones, are black to grey, show widespread mud cracks and rip-up clasts, and form layers that range in thickness from 2 to 15 metres. They are closely associated with the potentially economic coal seams. The sandstones are fine to coarse grained, dark grey to brown, and form lenticular layers up to 10 metres thick. They are composed of chert, feldspar, and volcanic rock grains. The conglomerates comprise lenticular layers with erosional bases that represent channel-fill deposits. These layers are as thick as 6 metres and gradually wedge out laterally over distances of about 100 metres. The lowest conglomerate layer, which marks the base of the member, consists mainly of chert and volcanic pebbles that are up to 6 centimetres across. The upper member of unit 2 was deposited in a fluvial channel and backswamp environment.

UNIT 3

Unit 3 is comprised of 220 metres of mudstones, sandstones, and conglomerates in up to 20 fining upward cycles. It is exposed mainly at intermediate elevations in the central part of the Mount Klappan area (Figs. 119 and 120). Cycles vary in individual thickness from 5 to 30 metres. The mudstone layers are dark grey to brown, 30 centimetres to 8 metres in thickness, and locally calcareous or carbonaceous; they are associated with coal seams up to 30 centimetres thick. Petrified tree trunks are widespread in unit 3. The sandstones consist mainly of chert and volcanic rock grains with a minor amount of feldspar. They are fine to coarse grained and dark grey to brown. The sandstone layers range from 30 centimetres to 8 metres in thickness and from 10 to 300 metres in lateral extent. The conglomerate consists mainly of subrounded chert and volcanic pebbles 1 to 6 centimetres across. It forms lenticular layers that have erosional bases, are 2 to 7 metres thick, and extend laterally for about 200 metres. The lowest conglomerate layer forms the base of unit 3. The sequence of rocks in unit 3 were deposited in an environment which was changing from fluvial plains to distal alluvial fans.

UNIT 4

Unit 4 consists mainly of coarse to medium-grained sandstones and conglomerate with minor amounts of fine-grained sandstone and mudstone. It contains as many as eight fining upward cycles and ranges in thickness from 280 to 300 metres. Unit 4 rocks are exposed widely at higher elevations in the southern part of the Mount Klappan area (Figs. 119 and 120). The coarse to medium-grained sandstones consist largely of grey chert and volcanic rock grains; volumetrically these sandstones are almost three times as abundant as the other components - conglomerate, fine-grained sandstone, and mudstone. Layers in the coarse to medium-grained sandstone are 2 to 30 metres thick and have widespread crossbedding. Conglomerates consist of subrounded chert and volcanic pebbles in a matrix of coarse-grained sandstone. They occur in about 10 layers that vary from 30 centimetres to 5 metres in thickness. Layers of conglomerate and coarse to medium-grained sandstone have a lateral extent of up to 300 metres; conglomerate commonly grades laterally into coarse to medium-grained sandstone. The lowest conglomerate or sandstone layer marks the base of unit 4. The fine-grained sandstones and mudstones commonly are carbonaceous and 2 to 4 metres thick. Unit 4 rocks represent an environment in which a series of distal alluvial fans were crossed by a system of braided streams.

UNIT 5

Unit 5 is up to 170 metres in thickness and consists mainly of conglomerate and coarse to medium-grained sandstone; fine-grained sandstone and mudstone comprise only 10 per cent of the total sequence. A maximum of eight fining upward cycles constitute the unit. This unit is exposed at higher elevations in the southeastern part of the Mount Klappan area. The conglomerate consists of moderately sorted, subrounded chert and volcanic pebbles up to 5 centimetres in diameter; it occurs in five to eight layers with thicknesses from 2 to 30 metres. The coarse to medium-grained sandstone layers are 3 to 30 metres thick, grey to brown, and commonly crossbedded. Conglomerate and sandstone layers have a lateral extent of about 500 metres. The fine-grained sandstones and mudstones commonly are carbonaceous; layers are 2 to 4 metres thick. The sequence of rocks in unit 5 represent an environment in which proximal to intermediate alluvial fans were dissected by streams with braided channels.

COAL DEPOSITION

POTENTIALLY ECONOMIC COAL SEAMS

Potentially economic coal seams occur in the lower, middle, and upper members of unit 2 in the Mount Klappan area. As many as six coal seams occur that are 17 to 50 metres apart in the lower member; individual seams can be 5 metres thick. The coal seams are associated closely with marine mudstones that commonly contain significant amounts of iron sulphide. Up to six coal seams that are 5 to 35 metres apart occur in the middle member; their individual thicknesses can be 5 metres thick. Four more coal seams occur in the upper member; they are 6 to 35 metres apart and their individual thicknesses range up to 8 metres.

Coal seams in unit 2 consist of semi-anthracite, anthracite, and meta-anthracite. Their mean maximum reflectance values of vitrinite in oil range from 2.5 to 5.0 per cent.

DEPOSITIONAL ENVIRONMENTS

The Mount Klappan succession is an accretional megacycle that resulted from a major marine regression in the Mount Klappan basin. The rocks in the succession reflect a gradual transition from marine deltaic through fluvial to alluvial environments. The Mount Klappan succession is an overall coarsening upward megacycle; chert fragments are significant components. The provenance of the succession could be from the north where the chert-bearing Cache Creek Group crops out in the Atlin Terrane (Eisbacher, 1981). The channel loads of streams entering the Mount Klappan basin steadily increased in volume and coarseness, and regression continued. This sediment load, which is marked by sands and gravels in units 1 and 2, built paleodeltas seaward and extended the subaerial part of the deltaic system until the whole Mount Klappan basin was gradually infilled; this time is represented by fluvial sedimentary rocks of units 2 and 3. Peat swamps flourished on the subaerial delta and fluvial plains during deposition of unit 2. Overbank deposits inundated some swamps, and others disappeared due to shifts in drainage patterns; consequently, several coal seams occur in the unit 2 sequence. Conditions gradually changed and the peat swamps slowly disappeared as they were overridden by progressively coarsening fluvial and alluvial sediments transported into the basin by streams flowing in from the north.

Potentially economic coal seams, which occur in unit 2, formed during the transitional period between the deposition of marine-dominated and non-marine-dominated sequences of the Mount Klappan succession. Marine conditions ended during deposition of the middle member of unit 2, at the top of the Bowser Lake Group. This boundary also appears to separate Jurassic and Cretaceous sequences; therefore, the economic coal seams may range in age from Late Jurassic to Early Cretaceous. Seams in the unit 2 lower member can be correlated with the upper part of the Middle to Late Jurassic Bowser Lake Group, and seams of the unit 2 upper member can be correlated with the lower part of the Early to Late Cretaceous Skeena Group (Koo, 1984).

DEFORMATION

Two phases of post-sedimentary deformation affected the Mount Klappan succession. Folds trend northwesterly and northeasterly, respectively. The northwesterly trending deformation occurred first; it created a major synclinorium with associated minor folds and faults. The synclinorium comprises the northwestern part of the Beirnes syncline of the Groundhog Coalfield (Richards and Gilchrist, 1979); the Mount Klappan area lies within the synclinorium, which embraces the whole Mount Klappan succession. Its core zone is best outlined by exposures of units 4 and 5 in the southern part of the Mount Klappan area. The synclinorium is apparently asymmetrical with gently folded limbs and a vertical axial plane. Its axial surface strikes north 35 to 45 degrees west and its axis plunges 10 to 35 degrees to the southeast. The east and west limbs of the synclinorium dip approximately 35 degrees to the southwest and to the northeast, respectively.

The minor folds of the synclinorium vary in style depending on the lithology. Minor fold amplitudes range from 200 to 400 metres, and wavelengths from 100 to 400 metres. Their hinges plunge 10 to 35 degrees to the southeast parallel to the axis of the synclinorium. Minor folds in the competent rocks of units 4 and 5 are mainly open symmetrical in style; less commonly, box folds occur in relatively thick zones of fine to medium-grained sandstones and mudstones.

Phase 1 deformation is more intense in the less competent units -- 1, 2, and 3. The minor folds in these units are mainly asymmetric chevrons or nearly isoclinal in style. Their limbs and axial traces are commonly inclined to the southwest on the northeast limb of the synclinorium, and to the northeast on the southwest limb. The dips of the limbs range from 25 to 85 degrees. The steeply dipping limbs of the asymmetric chevron folds are associated closely with thick layers of incompetent claystone, siltstone, and fine-grained sandstone, and are commonly overturned. The gently dipping limbs of these folds occur in the competent stratigraphic intervals that are dominated by conglomerate and coarse to medium-grained sandstone. Box-shaped or open symmetric folds commonly are associated with the competent stratigraphic intervals. Disharmonic folds occur locally in adjacent layers of sandstones and mudstones. The potentially mineable coal seams are generally in the gently dipping limbs where they are amenable to extraction by surface mining methods.

Phase 1 faults and shear zones strike 25 degrees north to 50 degrees west and dip 40 to 80 degrees to the southwest. Nearly isoclinal, overturned folds commonly occur within competent stratigraphic intervals in proximity to major phase 1 faults. Movements on the faults are generally reverse and range from a few metres to 300 metres. The phase 1 faults and shear zones frequently disrupt the steeply dipping axial planes and limbs of the chevron or isoclinal folds. The shear zones range up to 300 metres in width, and commonly grade into sets of faults. The faults and shear zones represent loci of intense deformation that was initiated during phase 1 deformation but continued beyond the period of folding. Coal seams in these structures are stretched or dismembered into lenticular bodies.

Phase 1 structures are deformed and cut by northeasterly trending folds and faults. Phase 2 faults strike north 30 to 60 degrees east and dip almost vertically; displacements on them are mainly vertical and range up to 500 metres. Most of the faults are associated with a series of southeasterly dipping monoclines in units 4 and 5.

Phase 2 folds are mainly open symmetric or tightly angular chevron folds that are overturned in places. Fold axial planes strike north 30 to 60 degrees east with dips from vertical to 40 degrees to the northwest. Amplitudes range from 50 to 400 metres, and wavelengths from 300 to 2 000 metres; amplitudes are larger and wavelengths smaller in the northwest part of the Mount Klappan area than in the southeast. Phase 2 folds refold phase 1 folds; consequently, phase 1 axial traces became curved, and axes become doubly plunging; phase 1 axes now plunge 10 to 35 degrees either southeast or northwest.

CONCLUSIONS

The Mount Klappan succession is an accretional megacycle deposited during a time of marine regression. The potentially economic coal seams occur in a transitional unit between the marine and non-marine sequences. The coal seams are of marine deltaic and non-marine fluvial origin. Two phases of post-sedimentary deformation resulted in folding, cross-folding, and faulting of the Mount Klappan succession. Deformation was most intense in the less competent, coal-bearing sequence than in other sequences; nevertheless, low angle, near-surface fold limbs provide favourable structural sites for potential future surface mining of the coal seams in the sequence of unit 2.

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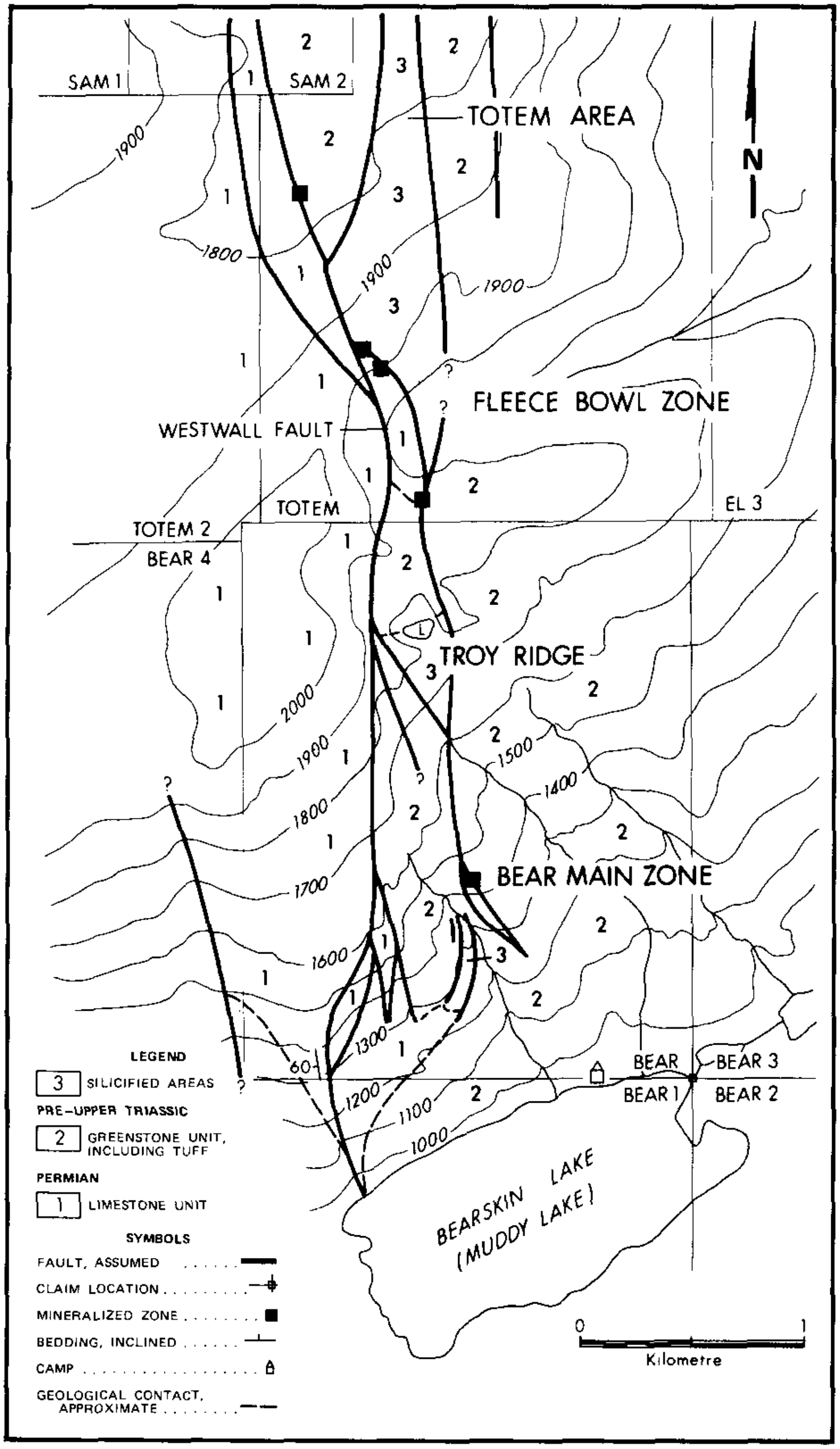

Figure 121. Geological plan of the Muddy Lake prospect (after company plans).