9237-C145-1E

FIELD TRIP TO THE NORTHERN RICHARDSON MOUNTAINS

JUNE 2002
CONOCO

LEADER: J. DIXON, GEOLOGICAL SURVEY OF CANADA

FIELD TRIP TO THE NORTHERN RICHARDSON MOUNTAINS JUNE 2002

ITINERARY

June 10: Depart Calgary for Inuvik

June 11: Helicopter traverse, route A.
Meet at helicopter hangar, Inuvik airport at 8.30 a.m.
Return by about 5.30 p.m.

June 12: Helicopter traverse, route B.
Meet at helicopter hangar, Inuvik airport, at 8.30 a.m.
Return by about 5.30 p.m.

June 13: Road trip along Dempster Highway
Depart from hotel about 9.00 a.m.
Return in mid to late afternoon

June 14: Depart Inuvik for Calgary.
Morning free to shop and be a tourist.

PARTICIPANTS

Conoco:

Gary Prost
David Bywater
Guy Peasley
Anh Duong

Geological Survey of Canada:

Jim Dixon (guide)

INTRODUCTION

The aim of the field trip is to familiarise geoscientists from Conoco-Philips Canada with the geology of the northern Richardson Mountains and, where possible, point out analogies to the subsurface geology of the adjacent Mackenzie Delta, especially the Lower Cretaceous succession. Two helicopter-supported routes have been planned, and one day of road travel along the Dempster Highway. However, weather conditions may force us to adjust the timetable, with the use of the helicopter taking precedence.

Wherever possible photographs of the stops have been provided, along with some views that will be seen as we fly around the Richardson Mountains.

REGIONAL SETTING

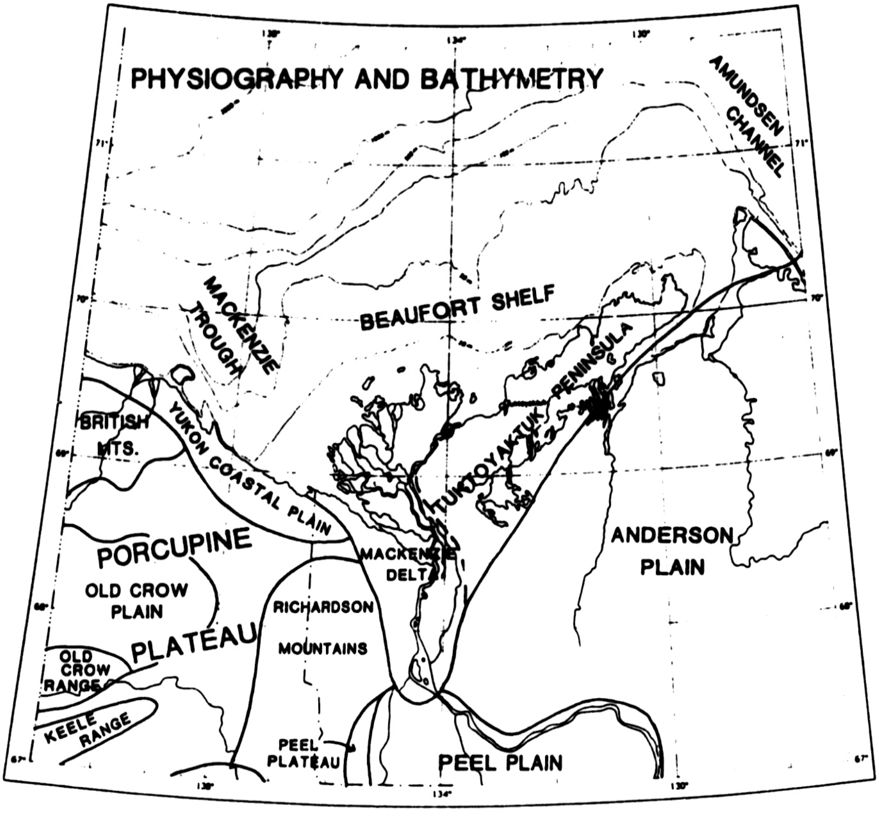
Cambrian to Middle Devonian sedimentation in the area is characterized by a carbonate platform underlying the area southeast and south of the Mackenzie Delta, grading into basinal shale to the west (Richardson Trough). However, an isolated carbonate platform is present within the shale trough, now seen in the White Mountains. In the late Middle Devonian orogenesis created a large foreland basin into which were shed large volumes of sediment gravity-flow deposits (Imperial Formation).

A major unconformity separates the Devonian and Carboniferous successions. Carboniferous to Triassic sedimentation was a mixture of carbonates and siliciclastics, deposited on a continental shelf. Continental shelf sedimentation continued into the Jurassic and Early Cretaceous, but as siliciclastics only. In the Albian, the influence of Cordilleran tectonics began to influence sedimentation and foreland basins began to from. Thick Albian basinal deposits of turbidites and shales are present throughout the northern Yukon and adjacent NWT, with shelf shales present to the south and southeast of the Mackenzie Delta.

The Beaufort-Mackenzie Basin is a late Cretaceous to Recent depositional basin resting on the continental margin and oceanic crust that formed in the mid-Cretaceous. The southeast margin is characterised by large, deep-seated extensional faults (Eskimo Lakes Fault Zone) that were active during the Jurassic and Early Cretaceous (although there has been minor subsequent reactivation). The southwest margin has been over-printed by Late Cretaceous and Tertiary compressional structures. This younger compressional event has resulted in the reactivation of older features, commonly manifested as inverted structures.

A number of small to large uplifts characterize the area. In the northern Richardson Mountains there are four culminations, the Rat, Scho, White and Cache Creek uplifts. Similar scale features are known in the subsurface - the Napoiak and Tununuk highs.

A number of major unconformities are significant in terms of understanding the tectonic history of the area and in how they affect the preservation of strata. A late Devonian unconformity marks the culmination of a period of orogenesis, followed by a long period in which extensional faulting


PHYSIOGRAPHY AND BATHYMETRY
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ANDERSON PLAIN
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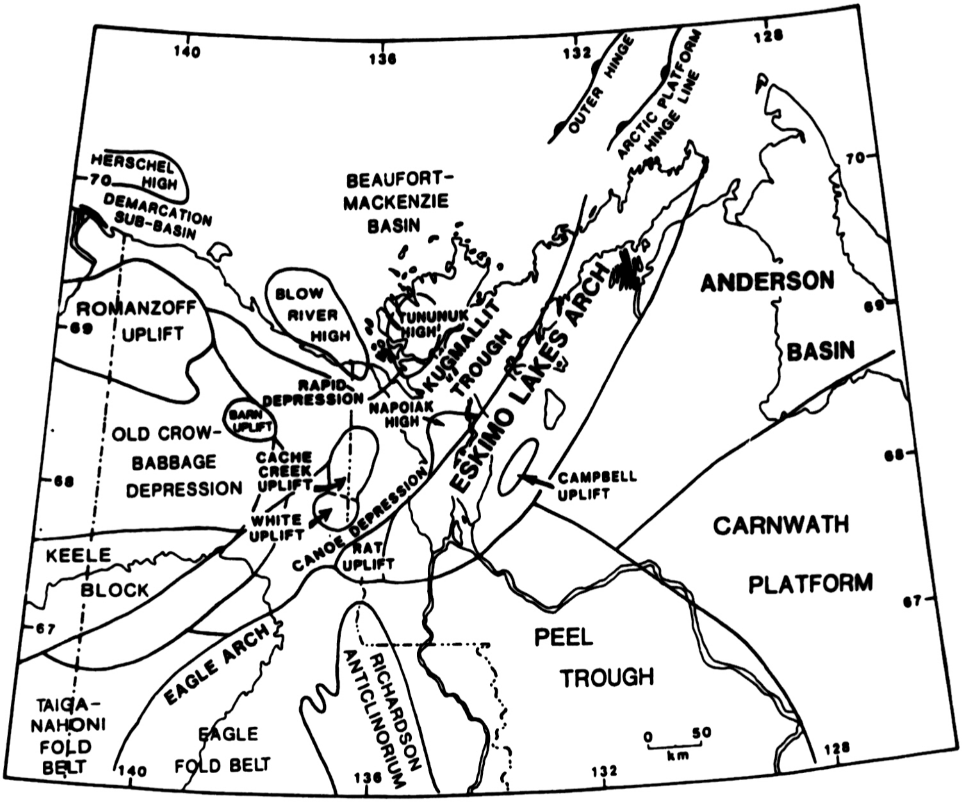


TECTONIC ELEMENTS

was the prevalent tectonic style. Within this period of extensional faulting a number of major erosional events affected the distribution and preservation of strata - these include those at the base of Jurassic, base-McGuire Formation (Valanginian) and base-Mount Goodenough Formation (late Hauterivian to early Barremian). Other unconformities exist in the Carboniferous to Lower Cretaceous succession but they are not as prominent. The next most prominent unconformity is in the mid-Cretaceous; strata above the Albian tend to be less consolidated, consequently the Upper Cretaceous to lowermost Tertiary rocks contain decollements. The Late Cretaceous to Recent succession is characterized by compressional folding in the western and central parts the basin. In the central basin, folds and listric faults are common, with folding dying out to the east.

STRATIGRAPHY

Strata from the Proterozoic to Cenozoic are present in the Beaufort-Mackenzie area, but during the field trip the emphasis will be on Upper Paleozoic to Lower Tertiary rocks. Triassic strata are poorly represented in the Richardson Mountains and are not believed to be present in the subsurface of Mackenzie Delta. Also, Tertiary strata have limited outcrop occurrence at the very northern edge of the Richardson Mountains and in the Caribou Hills east of the delta. In the former area, strata of the Paleocene Moose Channel Formation and lower Reindeer Formation are exposed. Along Caribou Hills, the Reindeer Formation is poorly exposed and is unconformably overlain by a thin veneer of Oligocene strata, equivalent to the Kugmallit Formation. Both are overlain unconformably by isolated occurrences of the Pliocene Iperk sequence (underlying Storm Hills).

In general, the Cambrian to Middle Devonian succession is characterised by platformal carbonates underlying the southern part of Mackenzie Delta, Tuktoyaktuk Peninsula, and Peel Plain. These pass westward into shales of the Road River Group, which occupy much of the core of the Richardson Mountains. However, in the White Mountains a platformal carbonate succession occurs, surrounded by basinal shale.

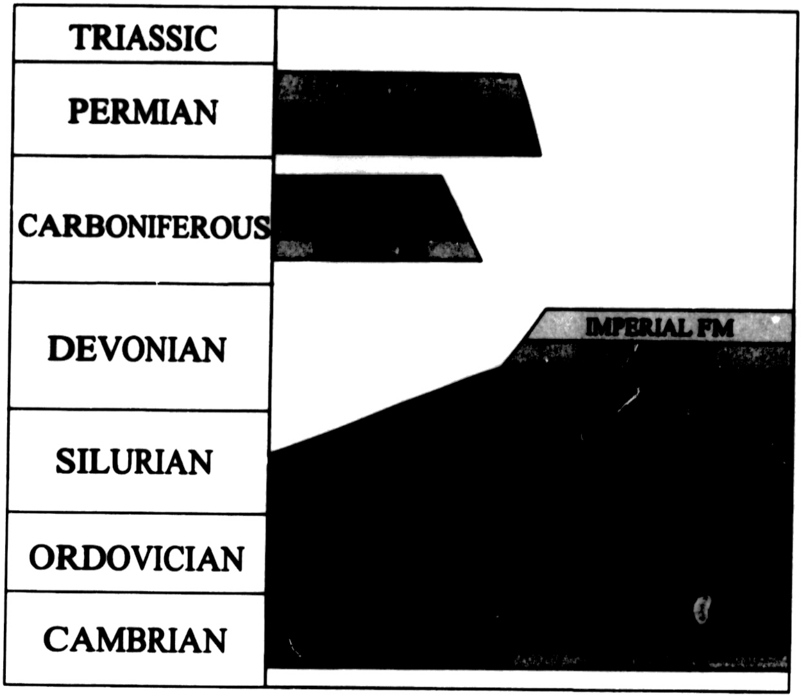
In the late Middle Devonian, depositional conditions changed dramatically and a thick wedge of siliciclastic sediments, the Imperial Formation, were deposited over the carbonates and basinal shales. These predominantly Upper Devonian strata are characterised by the abundance of turbidite beds and other sediment gravity-flow deposits.

At the end of the Devonian a major unconformity developed, marking the end of a significant tectonic phase. After an initial phase of siliciclastic deposition (Kekiktuk and Kayak formations) in the Carboniferous, carbonate deposition returned (Lisburne Group). However, during the Permian, siliciclastics (Jungle Creek and Longstick formations) returned with only minor deposition of carbonates. The basal Permian beds under the southern Mackenzie Delta and adjacent Richardson Mountains are characterized by very distinct red-beds of alluvial fan origin. However, a short distance westward these change to marine sandstones. The end of the Permian marks the termination of a major tectonic phase and the overlying Jurassic beds rest unconformably on the Permian. Triassic beds are known only from one isolated occurrence in the5 northern Richardson Mountains, and from several minor exposures on the east flank of the central Richardson Mountains (at Salter Hill). However, to the west, in the Barn and Romanzof mountains, Triassic beds are better exposed although they only represent a small part of the Triassic (principally the Norian, with some Lower Triassic in the westernmost occurrences).

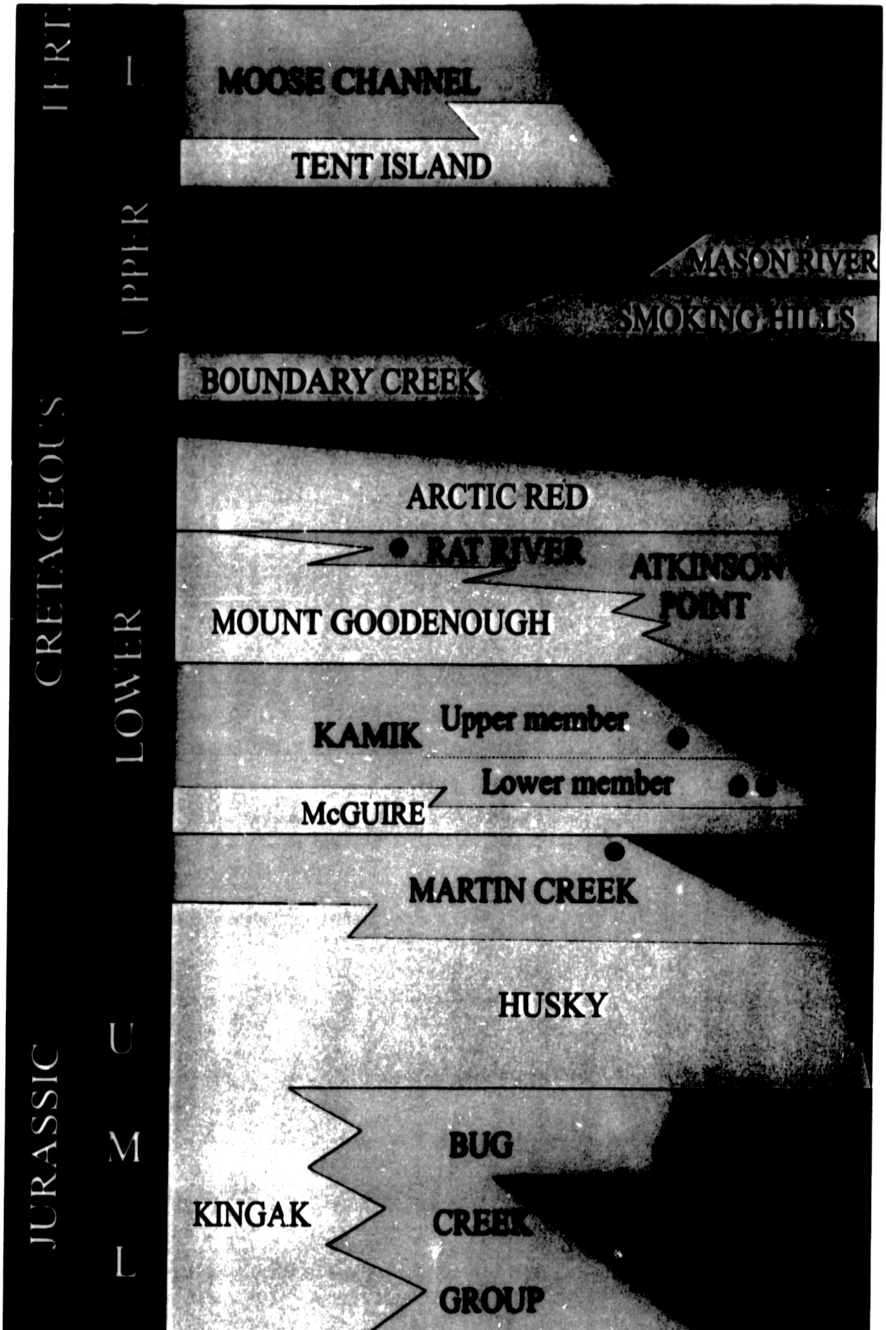
The Jurassic to Lower Cretaceous succession consists of alternating shale- and sandstone-dominant formations, the sediment source of which was from the east and southeast. In general the sandy formations tend to become shalier westward. The east/southeast origin of the clastic material is reflected in their composition, being predominantly quartz arenites. Strata of the Parsons Group are the most important interval in this succession, having significant reserves of gas, and lesser amounts of oil.

Albian time saw the beginning of a major shift in source terrain and depositional style. The influence of Cordilleran tectonics is first seen in Albian sedimentation and in the Richardson Mountains Albian rocks are represented by slope to basinal iron-rich shale (Rapid Creek Formation). On the west flank of the Richardson Mountains and extending westward is a thick succession of shale, sandstone and conglomerate deposited as sediment gravity-flow beds in deep-water troughs. To the east, shales of the Arctic Red Formation were deposited on a broad shelf, part of which underlies the Tuktoyaktuk Peninsula. From the Late Cretaceous to the Pliocene the stratigraphic record is seen as a series of northward migrating deltaic sediment wedges. The Cenomainian to middle Maastrichtian record in the Richardson Mountains and Mackenzie Delta consists of mostly organic-rich shale successions of the Boundary Creek and Smoking Hills formations, and east of Mackenzie Delta the younger Mason River Formation, although the latter is not organic rich.

In the late Maastrichtian a major northward shift in the facies belts occurred and thick accumulations of deltaic and related sediments began to accumulate on the continental margin of the Beaufort Sea (Tent Island and Moose Channel formations). Since the late Maastrichtian most sediment accumulation has been in the Beaufort-Mackenzie Basin, with only minor deposition on the continental areas to the south. In general, the Tertiary deltas have tended to migrate basinward and to the northeast through time.



Cambrian to Permian stratigaphic units in the Mackenzie Delta - Tuktoyaktuk area.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ARCTIC RED
RAT RIVER
ATKINSON POINT
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KAMIK
Upper member
Lower member
McGUIRE
MARTIN CREEK
HUSKY
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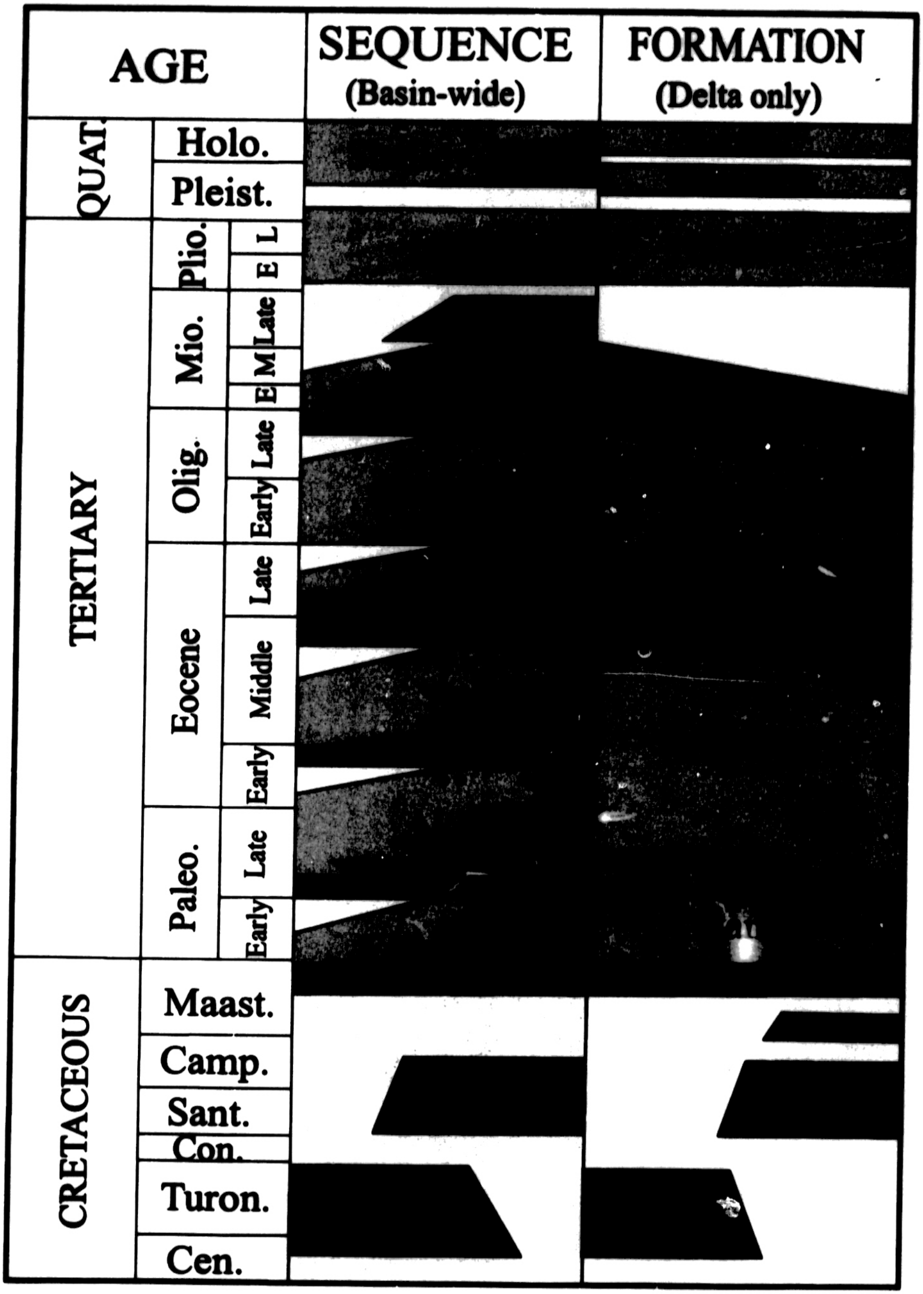
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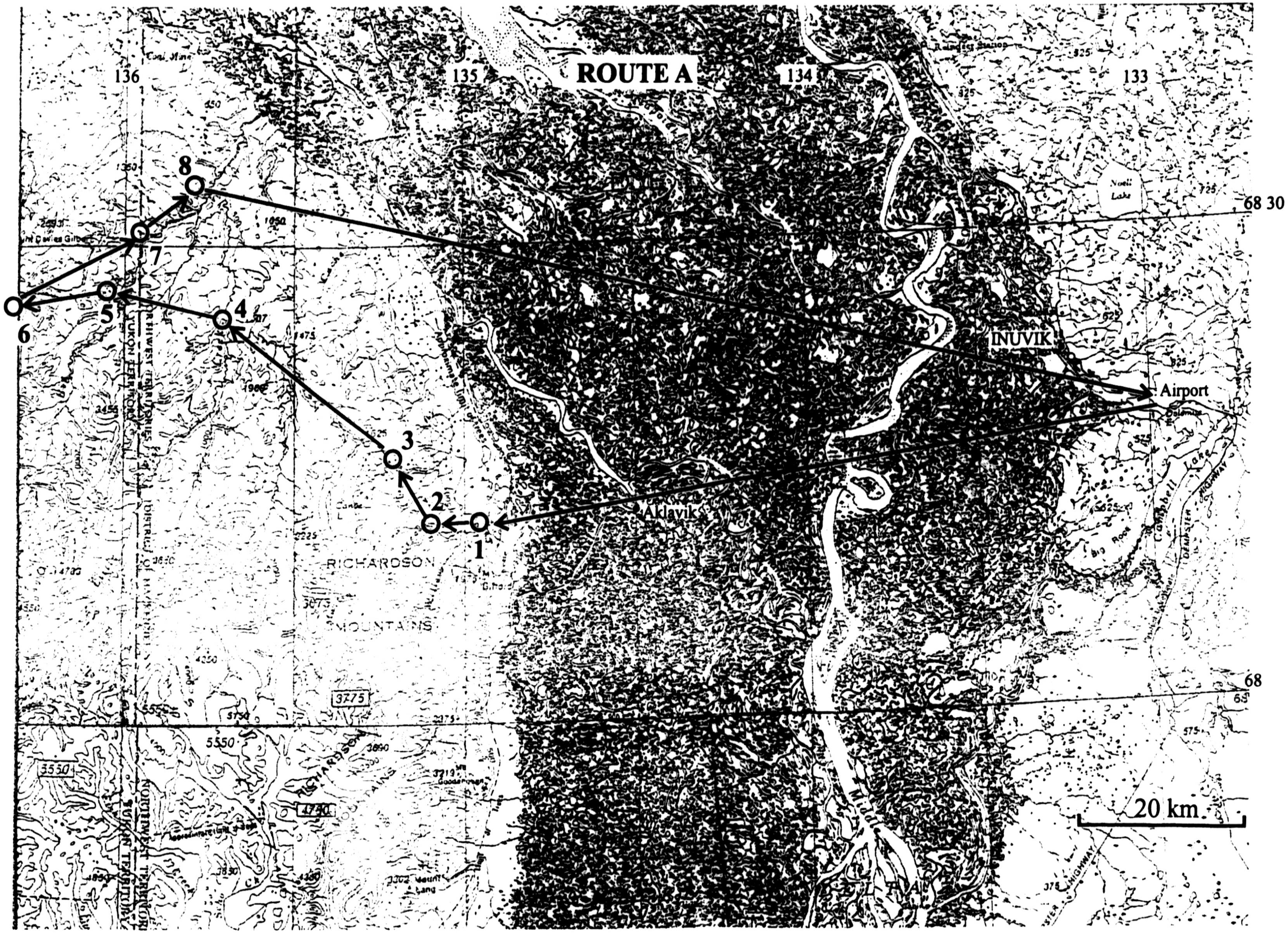
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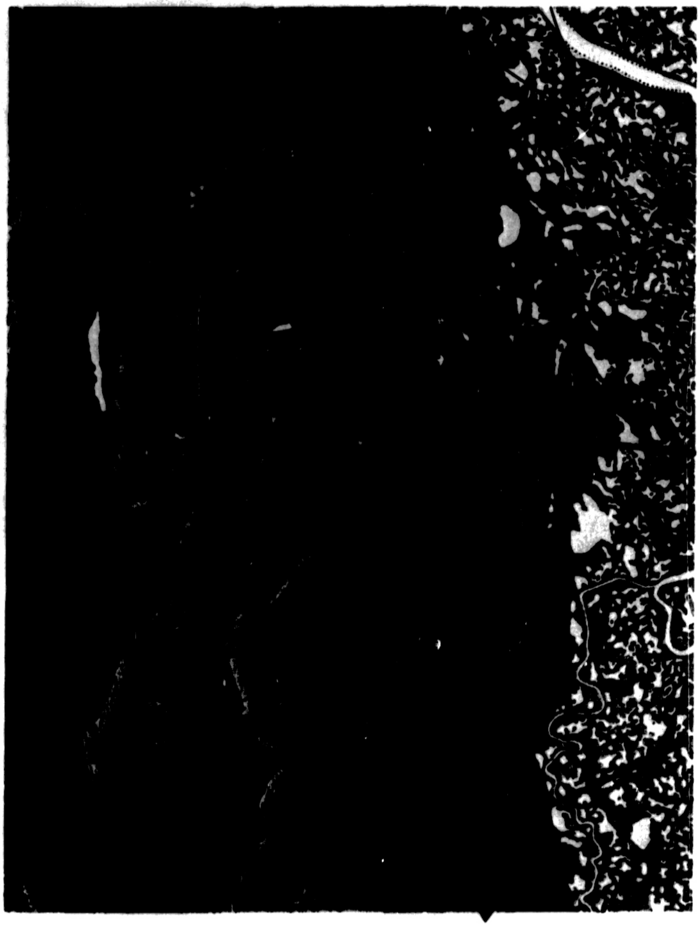


Map reproduced from:
Norris, D.K. 1981. Geology Aklavik, District of Mackenzie. Geological Survey of Canada, Map 1517A, 1:250 000

ROUTE A
Stop 1: Lower Canyon, Willow River
Location 7564900N 482200E

At this site, strata of the Lower member, Kamik Formation are exposed. Immediately to the west of this exposure a fault (Donna Fault) juxtaposes the Kamik with the Mount Goodenough Formation. Within this fault zone can be found patches of gypsum and anhydrite, the origin of which is unknown. Downstream the lower Kamik is overlain by the Upper member, Kamik Formation.

The base of the formation is not exposed, hence the exact stratigraphic position within the Lower member is not known.

Two facies assemblages are represented in this outcrop. The lower assemblage consists of thick beds of trough and planar cross bedded, medium to coarse grained sandstone. These are interpreted to be channel-fill strata. Above the lower beds the facies is characterized by thinly intercalated shale and sandstone with a few occurrences of thin coal seams. Small channel-fill units are also preserved. The upper facies assemblages is interpreted to be floodplain deposits. When placed in a regional context these beds are part of a large deltaic complex.

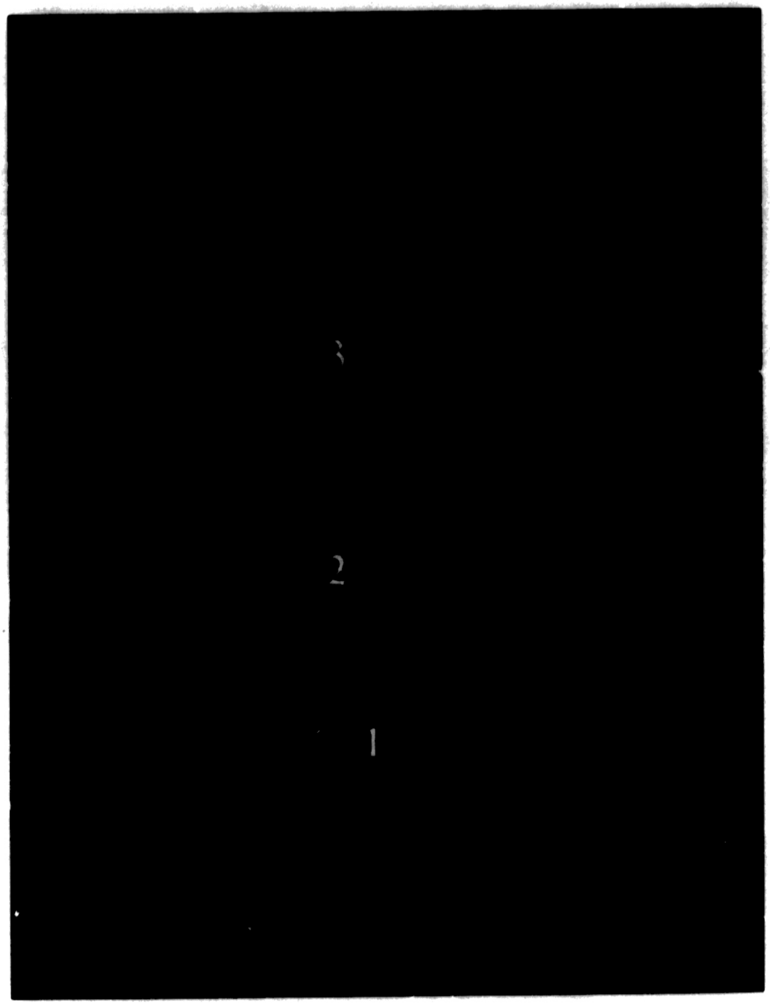
Flight between stops 1 and 2
We will fly along Martin Creek (westward) and observe the stratigraphic succession in the canyon walls. Immediately to the west of stop 1 is the Donna Fault in which are exposed gypsum and anhydrite (of unknown stratigraphic affinity).

As we fly towards the Martin Creek canyon the valley sides contain shale of the Mount Goodenough Formation. Entering the canyon there is a distinct, white-weathering, cliff-forming sandstone - this is the Lower member, Kamik Formation. Note that much of the Kamik Formation has been removed - the result of erosion at a major unconformity at the base of the Mount Goodenough Formation. Immediately below the white sandstone is a covered interval, although locally a black shale may be visible - this is the McGuire Formation. The bulk of the canyon is occupied by the banded sandstones of the Martin Creek Formation. As we near the western entrance to the canyon the Martin Creek Formation is underlain by shales of the Husky Formation.

Stop 2: Martin Creek
Location: 7565100N 475900E

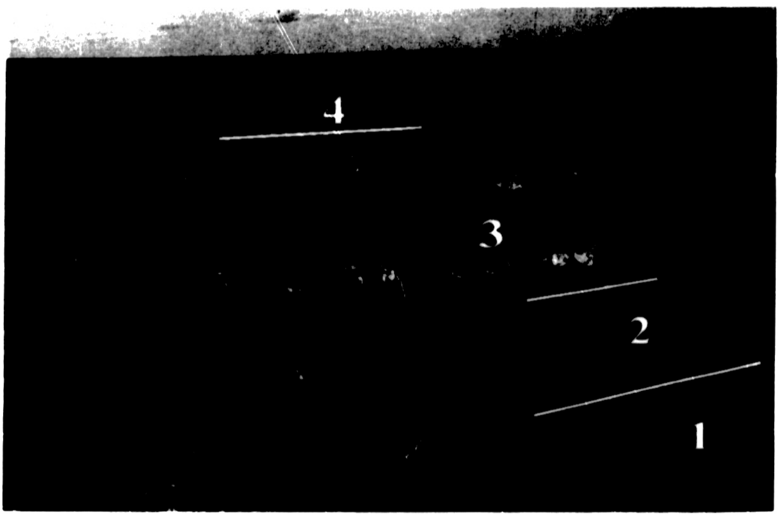
This site involves a scramble down, and return, via a gully in order to examine the lowermost beds of the Lower member, Kamik Formation..

The thin, dark grey to black, very friable McGuire shale is rapidly overlain by fine grained



Stop 1, route A: Lower Canyon, Willow River. Beds of the Lower member, Kamik Formation. Thick beds of cross-stratified channel sandstone (1) overlain by thin-bedded floodplain deposits (2) that includes a crevasse channel (3).

Stop 2, route A. Martin Creek. Lower member of the Kamik Formation. Long, very low-angle cross laminae. Possibly beach lamination



Stop 3, route A: Grizzly Gorge. Martin Creek Formation (1) abruptly overlain by shales of the McGuire Formation (2), in turn succeeded by a truncated Kamik Formation (3). The Mount Goodenough Formation (4) unconformably overlies Kamik strata. The bulk of the Kamik Formation has been eroded.

sandstone of the Lower member, Kamik Formation. However, talus tends to cover the actual contact. The first 4 m of the Kamik is distinctly coloured banded in reddish yellow and orange hues and contains poorly defined subhorizontal bedding and is burrowed in places. Overlying this is about 18.5 m of fine to medium grained, friable, light grey to white sandstone with very long, very low-angle cross laminae. This well bedded interval contains scattered lenses of burrowed sandstone and a few molds of small bivalves. Abruptly overlying the well bedded white sandstone is about 6 m of medium to coarse grained, locally pebbly, cross bedded sandstone.

This succession is interpreted to represent a vertical change from offshore deposits (McGuire shale) through a rapid transition into shoreface deposits (colour banded sandstone), overlain by beach deposits (white sandstone) in turn overlain possibly by tidal channel/inlet beds (coarser grained sandstones).

Stop 3: Grizzly Gorge
Location: 7573400N 475000E

Strata of the Martin Creek Formation are well exposed in the valley and are abruptly overlain by a thin McGuire shale, in turn overlain by a thin, rusty to white-weathering sandstone of the Kamik Formation. At the top of the slope the sandy beds may be the basal part of the Mount Goodenough Formation. Looking eastwards, down the valley, a wedge of white-weathering sandstone is seen to thin to the west. This is interpreted to be due to westward erosion of Kamik strata under the base-Mount Goodenough unconformity.

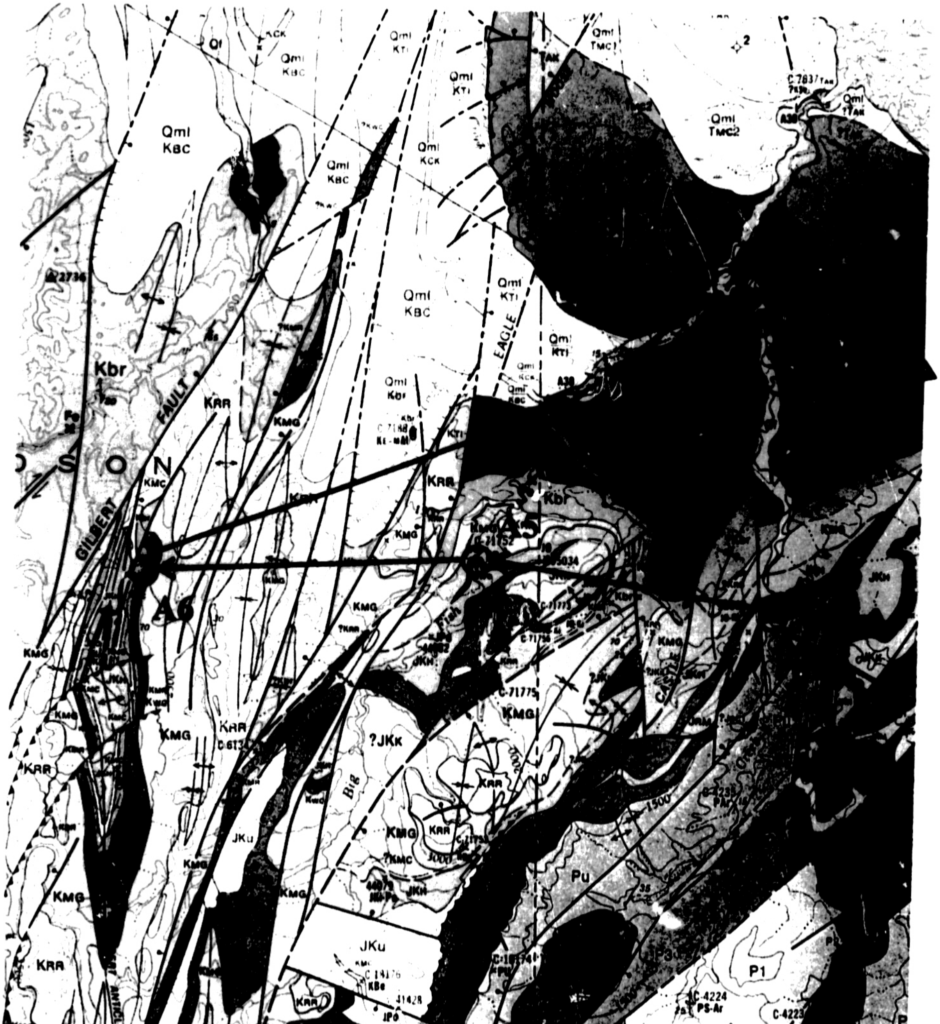
Martin Creek strata are very fine to fine grained sandstones with an abundance of hummocky cross stratification, swaley cross stratification, wave and current ripple laminae, and bivalve debris. Vertical and horizontal burrows are very common.

The McGuire shale rests abruptly on Martin Creek strata and regionally this is an unconformity surface. It is a highly friable, soft shale in which belemnites can be found.

The Kamik Formation consists of fine to medium grained sandstone, some coarse grained, with fine subhorizontal lamination and some cross bedding. This interval is equivalent to the white sandstone seen to the east in the Martin Creek canyon. A marine origin is interpreted for this interval.

Beds in the upper slope are poorly exposed, but elsewhere along the valley equivalent beds contain mostly bioturbated, fine grained sandstone with scattered occurrences of thin pebble beds.

Flight between stops 2 and 3
We fly into the core of the Cache Creek Uplift, the eastern flank of which has gently eastward dipping Jurassic strata (Bug Creek Group and Husky Formation). The bulk of the uplift is cored



Map reproduced from:
Norris, D.K. 1981. Geology Blow River and Davidson Mountains, Yukon Territory - District of Mackenzie. Geological Survey of Canada, Map 1516A, 1:250 000

by Permian strata of the Jungle Creek Formation, with scattered outliers of the Bug Creek Group resting on hill tops.

Stop 4: Junction of Cache and Almstrom creeks
Location: 758910N 451300E

Beds of the Jurassic Bug Creek strata are well exposed in a cut-bank and lie in close proximity to the contact with underlying Permian beds. The basal unit of the Bug Creek Group, the Murray Ridge Formation, consists of very fine to fine grained sandstone with abundant planar laminae, hummocky and swaley cross beds. These beds are interpreted to have been deposited in a lower shoreface setting, as storm generated beds.

Stop 5: Fish River
Location: 7592800N 437700

A much truncated Martin Creek Formation unconformably overlain by Mount Goodenough Formation.

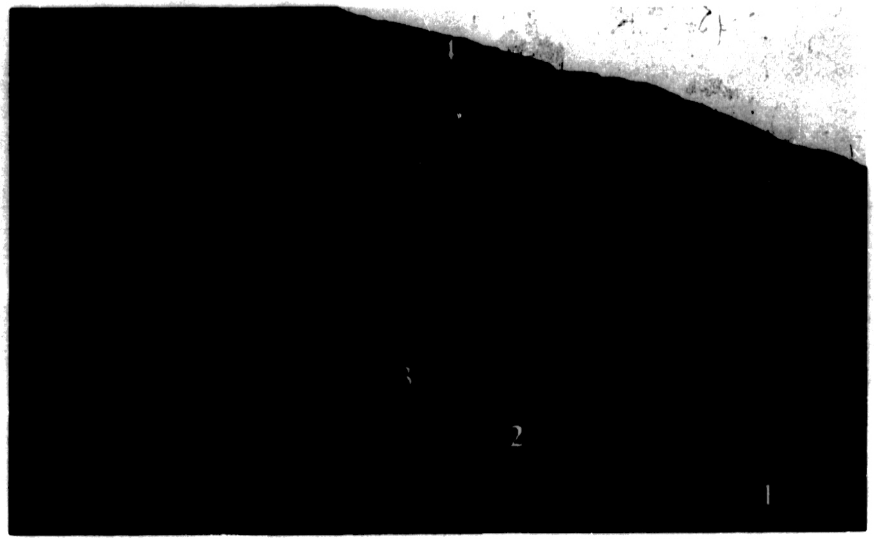
The base of the cliff reveals the transition between Husky shales and Martin Creek sandstone. Martin Creek strata consist of finely laminated, very fine to fine grained sandstone. Bivalve debris is common in these sandstones.

Although there is a profound unconformity, the basal Mount Goodenough beds are silty shales - there is no basal sandstone. Although rare, some highly polished, black-coated, very small pebbles have been seen in the basal beds. The slight whitish weathering colour of these basal beds differentiates them from the overlying shales. However, the reason for the weathering difference has not been determined.

Beyond (to the west) this cut-bank can be seen the remainder of the Mount Goodenough Formation in the cliffs of the valley slope, consisting of a thick, shale-dominant succession. Capping the high cliff is the first sandstone of the Rat River Formation.

Stop 6: Gilbert Anticline
Location: 7593600N 429100E

This site is located on the eastern limb the Gilbert Anticline where the Kamik Formation forms very prominent ridges. Although only 8 km from stop 5, where there is only a thin remnant of the Martin Creek Formation, here there is a full succession of the Parsons Group, several hundred metres thick. Also, the degree of cementation has increased and the sandstone units have low porosity values. This rapid change in stratigraphy is believed to reflect an active Cache Creek



Stop 5, route A: Fish River. A thick, shale-dominant succession of the Mount Goodenough Formation (3) unconformably overlying the lowermost Martin Creek Formation (2), transitionally overlying Husky shale (1). Rat River beds (4) cap the cliff.

Uplift during the Early Cretaceous. Although it is apparent from the stratigraphic relationships that the uplift was a positive element immediately prior to Mount Goodenough deposition, no evidence is available to indicate if it was active during Parsons deposition.

The silica cementation and uniform fine grained character of the Martin Creek and Kamik sandstones makes it difficult to detect sedimentary structures and hence interpret in detail the sedimentology. However, based on the regional setting and data from nearby outcrops, where there are some visible sedimentary structures, the Martin Creek and Kamik formations are entirely marine at this location.

Stop 7: Boundary Creek-Fish River junction
Location: 7599000N 440500E

Cuesta Creek Member, Tent Island Formation: we will examine the conglomerate-sandstone facies that fill a large channel-like feature within the Cuesta Creek Member. Beds vary from a few centimetres to 2 m thick - although some thicker beds are present but they are probably amalgamated beds. Ungraded and normal graded beds are common, with only a few known examples of reverse grading. Pebbles are mostly chert and predominantly 5 cm or less in diameter, although locally, larger clasts are present.

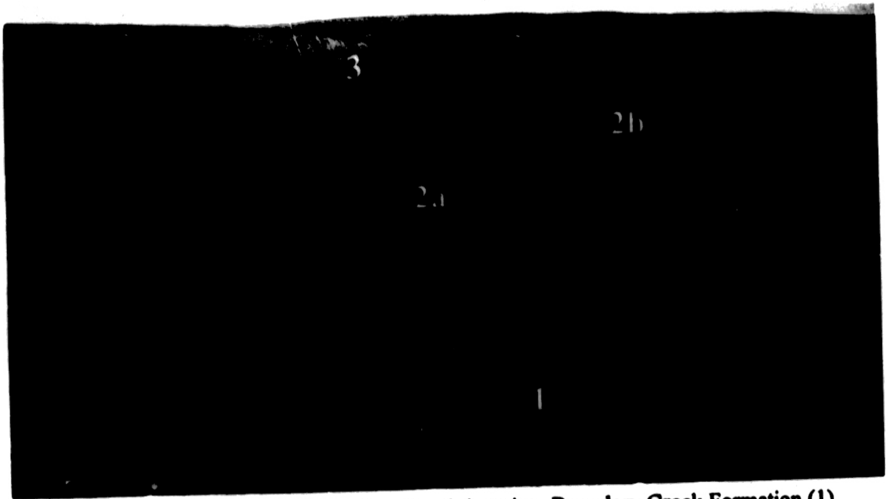
Sedimentary structures tend to be lacking in the conglomerate and sandstone beds, although some planar laminae may be present. All beds have erosional bases, and in some instances load deformation features are present.

Originally these sandstone-conglomerate beds were interpreted as braided river deposits (Holmes and Oliver, 1973; Young, 1975) but the characteristics of these and associated beds clearly point to deposition as sediment gravity-flow beds in a submarine canyon or on a submarine fan (Dixon, 1988). This latter conclusion was reiterated by Myers (1994) who did a more comprehensive study of these beds..

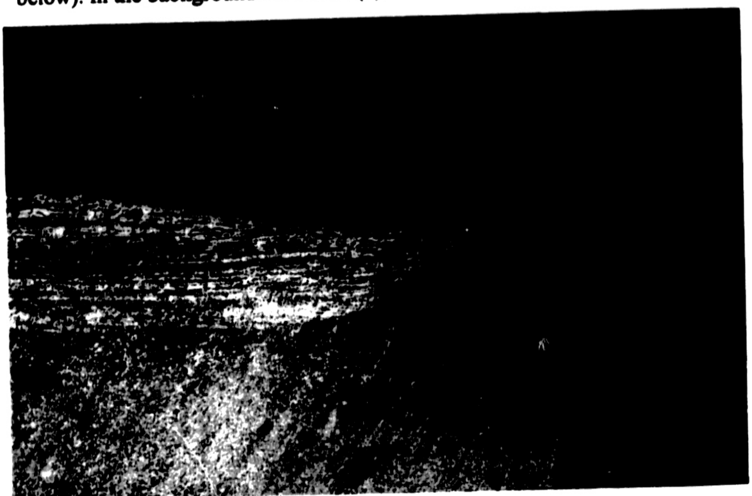
Stop 8: Cache Creek-Fish River junction
Location: 76048000N 449200E

Lower beds of the Paleocene Moose Channel Formation: the short segment of strata we will examine contains fine to coarse grained, locally granular to pebbly, sandstone. A variety of cross bedding types can be seen.

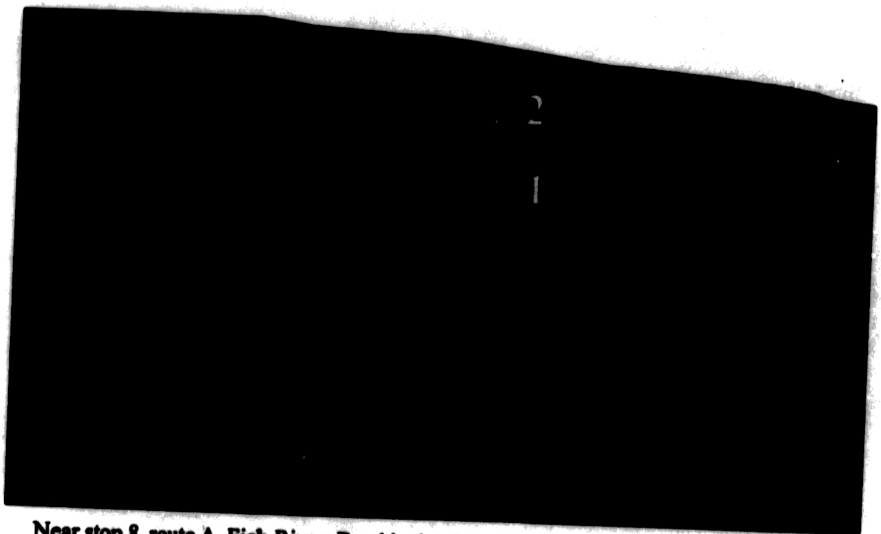
These strata probably represent marginal marine deposits associated with the Moose Channel delta complex.



Stop 7, route A: Fish River/Boundary Creek junction. Boundary Creek Formation (1) covered by talus. Overlying beds of the Cuesta Creek Member (2), Tent Island Formation contain thin to thick bedded turbidites (2a) erosionally overlain by conglomerates (2a) of sediment gravity-flow origin. The conglomerates occupy a large channel, the other margin of which is present to the south (see photograph below). In the background are shales (3) of the Tent Island Formation.

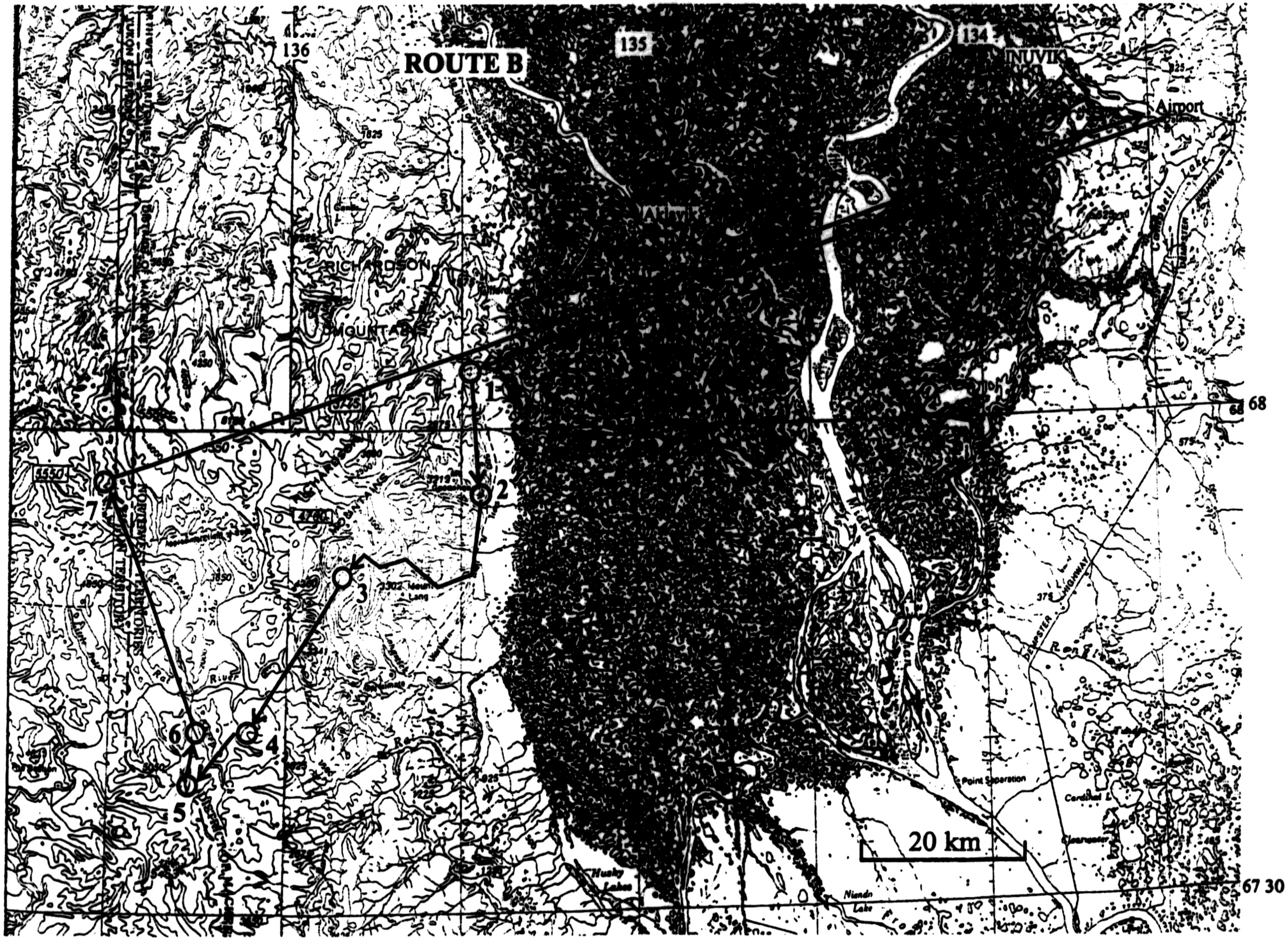


South of stop 7, route A. Fish River. South margin (arrow) of the submarine channel examined at stop 7.



Near stop 8, route A, Fish River: Basal beds of the Moose Channel Formation. The well bedded strata (1) are interpreted to be delta-front beds and the thick bedded unit (2) is believed to be a distributary channel-fill.

Stop 8, route A. Junction of Cache Creek and Big Fish River. Moose Channel Formation.


ROUTE B
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Map reproduced from:
Norris, D.K. 1981. Geology Aklavik, District of Mackenzie. Geological Survey of Canada, Map 1517A, 1:250 000

ROUTE B

Stop 1: Jurassic Butte
Location: 7546000N 481200E

Jurassic Butte is unique in the Richardson Mountains in that within a small area Ordovician-Silurian, Permian and Lower to Middle Jurassic strata are well exposed in a faulted anticline. The west limb of the anticline forms the Butte with a fault on its eastern slope. The east limb is highly faulted and some of the beds are near-vertical.

We will examine one of the southeast spurs where the beds are vertical. The base of the section consists of blue-black shale and cherty shale of the Lower Paleozoic Road River Group. Near the contact with the overlying Permian there is a band of white-weathering nodules which are interpreted to have formed by pedogenic processes when the unconformity developed. The Road River Group is part of the deep-water fill of the Early Paleozoic Richardson Trough.

Overlying the dark coloured shales are brick-red strata of the Permian Jungle Creek Formation. These red-beds are the basal member of the formation and consist of alternating units of red mudstone and breccia. The mudstones are silty and locally contain thin lenses and pods of breccia. Within the breccia units individual beds are commonly difficult to identify. The breccia clasts are predominantly chert and can be matched to the bedded chert seen in the subjacent Road River Group. Usually the fabric is totally disorganized, but some beds do have normal grading. The red-beds are interpreted to have formed as subaerial sediment gravity-flows on an alluvial fan. The bulk of the Jungle Creek Formation has been eroded at this site. In the subsurface to the east, similar beds are present in the Aklavik wells.

Abruptly and unconformably overlying the red-beds is conglomeratic, coarse grained sandstone of the Jurassic Bug Creek Group (Murray Ridge Formation). There is a sharp contrast in colour between the Permian and Bug Creek Group. Chert pebbles are the dominant clast type. Some fossil debris has been collected from the Jurassic beds at this site (ammonites and bivalves). The presence of Lower Jurassic fossils indicates a marine origin for these beds.

At the Butte, a thick succession of the Bug Creek Group forms the cap of the peak. Below are Permian beds, but not red-beds - they are grey in colour and consist of sandstone and some shale and appear to be marine. Separating the Jurassic from the Permian is an angular unconformity. The eastern slope of the Butte is traversed by a fault and this juxtaposes Permian, non-marine red-beds against the Jurassic and the underlying marine Permian beds. Just a few kilometres west of the Butte there is an area of exposed Permian rocks which consist of mixed marine and non-marine strata. This intimate mixing of the Permian facies types suggests that the alluvial fans were formed along a coastal area, such as is seen in the modern Red Sea.

Stop 1, route B: Jurassic Butte. Lower Paleozoic shale and bedded chert (1) of the Road River Group overlain unconformably by red beds of the Permian Jungle Creek Formation (2a). On the Butte itself a high-angle thrust fault separates a Permian (2b) and Jurassic (Bug Creek Group) succession (3) from the red beds. The Bug Creek Group unconformably overlies marine beds of the Permian (2b) Jungle Creek Formation

Map reproduced from:
Norris, D.K. 1981. Geology Fort McPherson, District of Mackenzie. Geological Survey of Canada, Map 1520A, 1:250 000

Stop 2: Southeast Mount Goodenough
Location: 7535500N 481000E

The bulk of the slope and cliffs is formed from shale and siltstone of the Mount Goodenough Formation, capped by sandstones of the Rat River Formation. A transitional contact separates the two formations but within the lower part of the Rat River Formation there is a significant truncation surface which, when traced northwards, can be seen to be a large channel-like feature. Rat River strata consist of very fine to fine grained sandstone in beds 30-50 cm thick with fine, subplanar laminae, hummocky cross stratification, ripple laminae and burrows. The Rat River strata have characteristics associated with storm-deposited beds in a nearshore marine environment. The significance of the truncation and channel-like setting in the marine strata of the lower Rat River Formation remains elusive. It would appear to be a local feature.

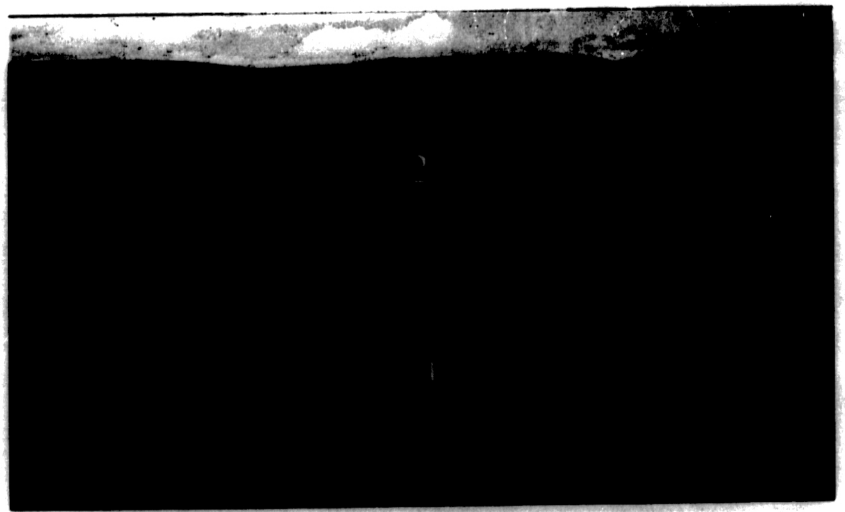
Flight Between Stops 3 and 4
Between stops 3 and 4 we will fly above Treeless Creek and see some stratigraphic-structural relationships. Near the beginning of the entrenched part of Treeless Creek there is light grey shale of the Upper Cretaceous Boundary Creek Formation in fault contact with Jurassic to lowermost Cretaceous, dark grey shale of the Husky Formation. Further up the valley is a resistant ledge of sandstone within the Husky Formation - the Arenaceous member - overlain by the Red-weathering member. The Husky Formation is unconformably overlain by shales of the Mount Goodenough Formation. A ledge-forming sandstone above the Red weathering member is considered to be the basal bed of the Mount Goodenough Formation. The Parsons Group has been eroded at this locality.

Stop 3: East Bear Creek
Location: 7527500N 466300E

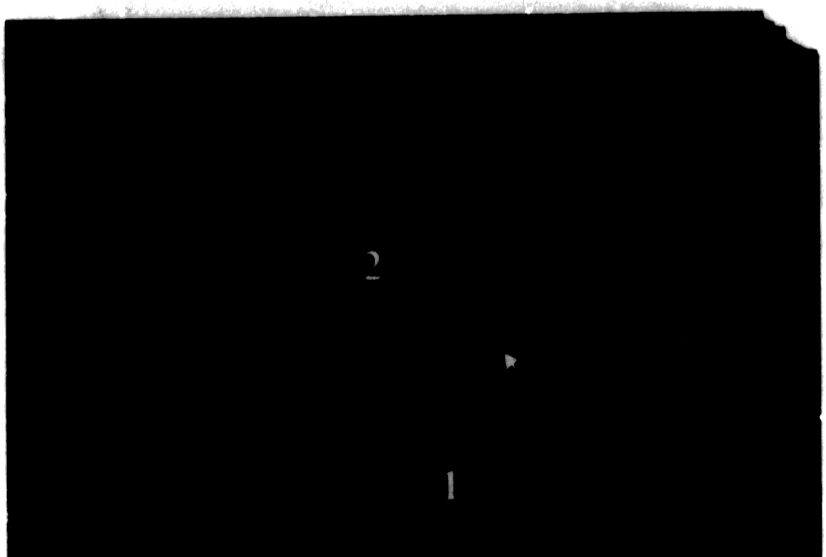
Cambrian carbonates and Cambrian-Silurian shales (Road River Group) in the core of the Scho Uplift are unconformably overlain by Permian strata, in turn unconformably overlain by the Jurassic Bug Creek Group. Compared to Jurassic Butte there is a more complete Permian section, consisting of a basal red-bed succession overlain by shale - these constitute the Jungle Creek Formation, in turn overlain transitionally by sandstones of the Longstick Formation. Capping the top of the slopes are sandstones of the Bug Creek Formation.

Within this valley the Permian red-beds show more variation in sedimentary style than that seen at Jurassic Butte. Here, mudstones are less common and the breccia units are thinner. Also, at the top of the red-beds cross bedded sandstones and conglomeratic sandstones commonly are present. The latter bed types indicate the action of stream flow, as opposed to debris flows.

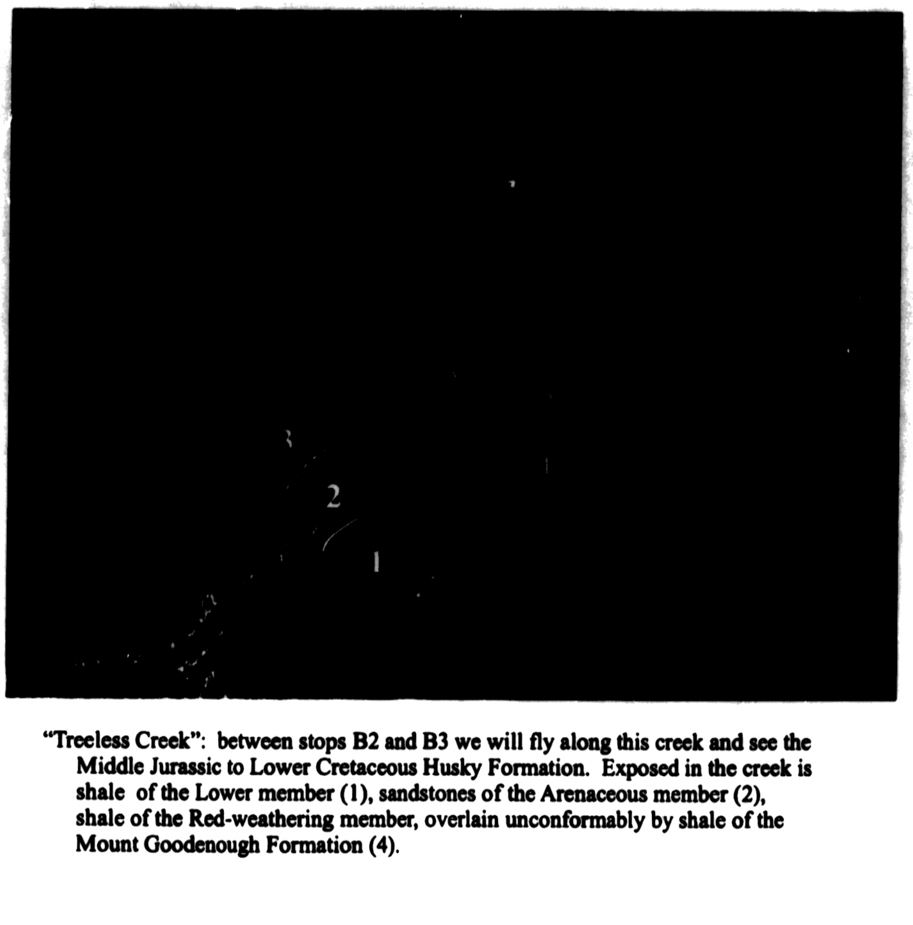
The Longstick Formation contains very fine to fine grained sandstone. Much of the Longstick strata is bioturbated and *Zoophycus* and *Skolithus*-like trace fossils are abundant. Some cross bedding is present but not particularly common. The valley contains the type section of the



Mount Goodenough, route B: Shale of the Mount Goodenough Formation (1) gradationally overlain by Rat River sandstone (2)



Stop 2, route B: east face of Mount Goodenough. Detail of the transition between Mount Goodenough (1) and Rat River (2) formations. The base of the thick-bedded sandstone interval within the Rat River Formation is an internal truncation surface (arrow).



"Treeless Creek": between stops B2 and B3 we will fly along this creek and see the Middle Jurassic to Lower Cretaceous Husky Formation. Exposed in the creek is shale of the Lower member (1), sandstones of the Arenaceous member (2), shale of the Red-weathering member, overlain unconformably by shale of the Mount Goodenough Formation (4).

Stop 3, route B: East Bear Creek. Core of the Scho Uplift occupied by Cambrian carbonates (1) and shale of the Ordovician-Silurian Road River Group (2). Unconformably overlying Lower Paleozoic rocks is the Permian Jungle Creek Formation (3), which consists of a basal reb-bed member (3a) overlain by a shale succession (3b), in turn gradationally overlain by sandstones of the Permian Longstick Formation (4) - the type section occupies the prominent gully where the number 4 is printed. Unconformably overlying the Permian are sandstones of the Bug Creek Group (5).

Map reproduced from:
Norris, D.K. 1981. Geology Bell River, Yukon Territory - Northwest Territories. Geological Survey of Canada, Map 1519A

Longstick Formation, in a prominent gully on the southern slope.

Stop 4: South of Rat River
Location: 7508500N 453200E

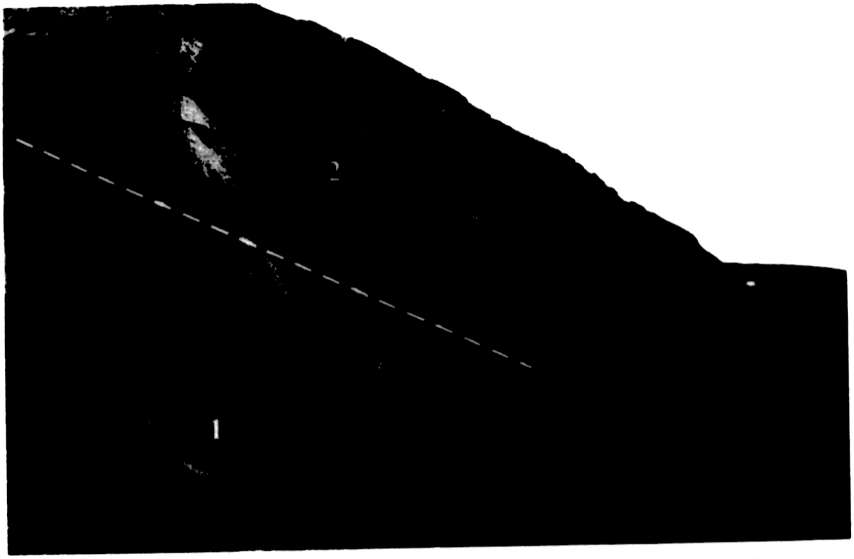
This stop is to show a general overview of the of the Husky to Kamik succession, although the Martin Creek Formation is absent due to pre-McGuire erosion. The prominent cliff is the Lower member of the Kamik Formation. In contrast to the equivalent, non-marine beds seen at Stop 1 Route A, these beds are marine - consisting of very fine to fine grained, massive-appearing to finely laminated, sandstone.

Stop 5: YT-NWT boundary
Location: 7498500N 447700E

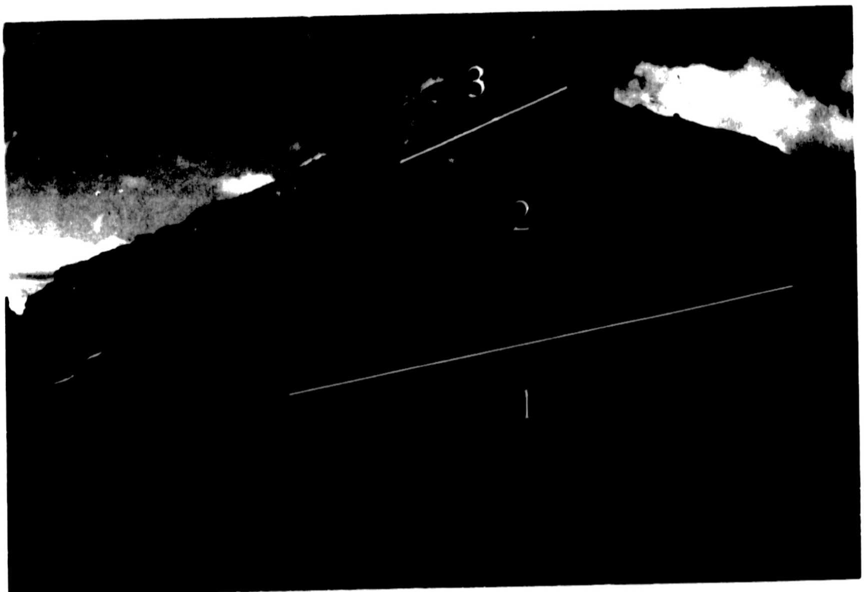
At this site we can better see the absence of Martin Creek strata. Here the McGuire shale rests directly on Husky shale, indicating a sub-McGuire unconformity. Also, we will examine the McGuire to Kamik transition which occurs over a very short vertical interval of interbedded sandstone and shale. The lower Kamik beds range from very fine to coarse grained, contain ripple cross beds, small-scale trough cross beds, and commonly occurring vertical burrows.

Stop 6: Sheep Creek
Location: 7509600N 446800E

At this site is one of the best examples of the angular unconformity between Devonian and Carbo-Permian beds. The Devonian beds are the ubiquitous Imperial Formation - consisting of turbidite sandstones interbedded with shale. Unconformably overlying the Devonian is a succession of silty and muddy sandstones with a few thin limestone beds, these in turn are overlain by pebbly, coarse-grained sandstone beds. Initially the muddy beds were believed to be part of the Permian succession but some doubt has recently been cast on this conclusion. Mattner (1990) was the first to note the disparity between the muddy sandstone beds (which he informally called the Coral Unit) and the overlying coarser grained strata and also found some corals in the carbonates associated with the muddy sandstones. He tentatively interpreted the muddy sandstone succession to be possibly Carboniferous (the coral was not age specific), overlain by Permian strata that are more typical of Permian beds in the immediate area. When I re-examined this section, I concurred with Mattner's (op. cit.) conclusion and further noted that the coarse-grained beds rest erosionally on the muddy sandstone interval (Dixon, 1998)



Stop 4, route B: South of McDougall pass; 1) Husky/McGuire formations, 2) Lower member, Kamik Formation



Stop 5, route B: On the YT-NWT boundary. 1) Husky Formation, 2) McGuire Formation, 3) Lower member, Kamik Formation.

Stop 6, route B, Sheep Creek. The Devonian Imperial Formation (1) unconformably overlain by Carbo-Permian beds (2). Unit 2 may be a thin erosional remnant of Carboniferous strata, overlain erosionally by Permian beds.

Stop 7: White Uplift
Location: 7537000N 433400E

Occupying the core of the White Uplift are the spectacular limestone peaks of the White Mountains. These carbonates are Silurian to Devonian beds that formed on an isolated platform outward of the main continental carbonate platform to the east, and surrounded by basinal shale of the Road River Group. Because of the carbonate rocks in this terrain few streams survive above-ground after the initial spring melt.

Flanking the Lower Paleozoic carbonates is a thick succession of Carboniferous limestones (Lisburne Group). The landing site will be close to the top of these beds and large horn corals and large colonial corals weather from the limestone. A thin veneer of sandstone rests on the limestone which is thought to be a remnant of Permian strata, which in turn is overlain by Jurassic to Cretaceous beds.

Looking to the east a prominent ridge dominates the near-horizon. This is Murray Ridge where the Lower to Middle Jurassic Bug Creek Group is well exposed.

Lower Paleozoic carbonates in the White Mountains (route B)

Stop 7, route B: Carboniferous limestones on the east flank of the White Mountains

Map reproduced from:
Norris, D.K. 1981. Geology Aklavik, District of Mackenzie. Geological Survey of Canada, Map 1517A, 1:250 000.

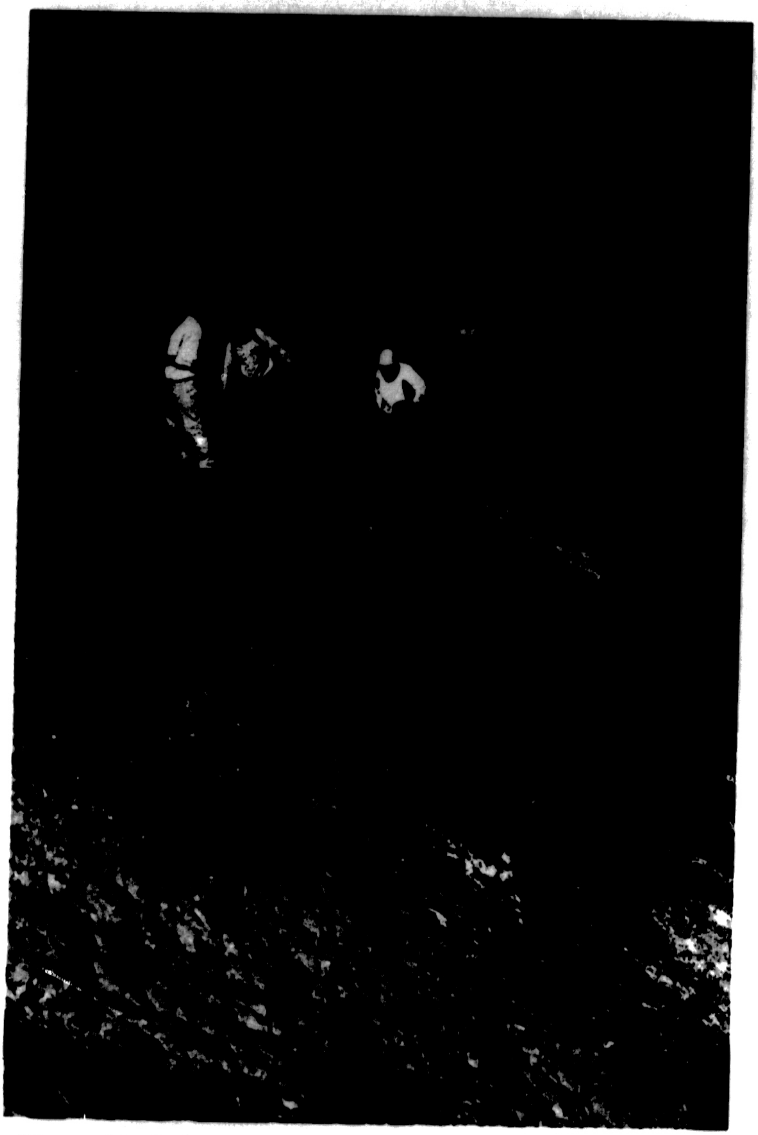
ROAD TRIP

The first stop on the road trip is about a 1 hour drive out of Inuvik at an abandoned quarry where a bitumen dyke intrudes the Devonian Imperial Formation. The jet-black, lustrous, solid bitumen was first thought to be coal when the quarry was initially opened but studies by the Norris and Cameron (1986) properly identified it as pyrobitumen. Where the solid hydrocarbon originated is still perplexing but it has been speculated that the underlying Canol Formation, a known organic-rich Devonian shale, may have been the source.

On the return drive to Inuvik we will examine a number of quarries, most of which are still active. The second quarry we will visit is on the south side of the highway at the beginning of a slight rise in the topography. This quarry contains thin-bedded turbidites and shale of the Upper Devonian Imperial Formation. Fine examples of sole marks can be found in may beds.

About mid-way along the south shore of Campbell Lake is another operational quarry from which Middle Devonian limestone is crushed and used as road metal. Within this quarry can be seen preserved paleokarst, wherein large cavities and pipes are filled with yellow-weathering rubble. At a similar quarry near the airport, Cretaceous ages from some of the karst-fill indicates the karst surface is Cretaceous in age.

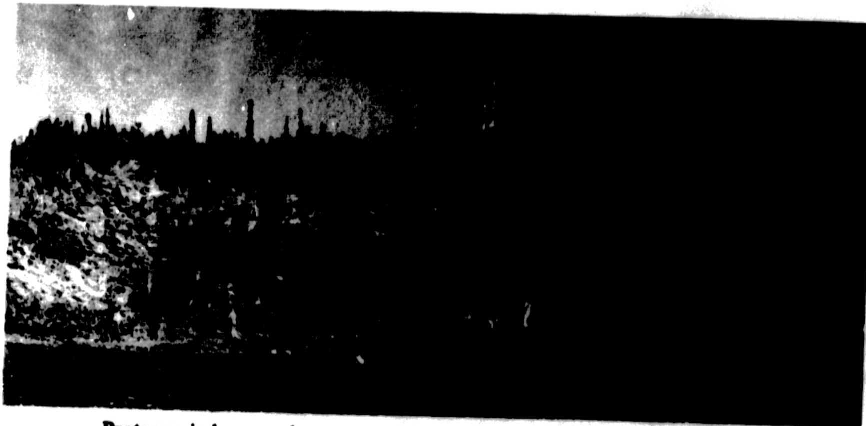
On the north side of the airport Proterozoic rocks are quarried. These consist of low-grade metamorphic rocks - phyllites and altered carbonates. The exact age of these Proterozoic beds is still in question, although paleomagnetic data suggests its paleopole position is consistent with a Helikian age (Norris and Black, 1964) .



Bitumen dyke in the Upper Devonian Imperial Formation, north side of the Dempster Highway, approximately 45 to 60 minute drive from Inuvik

Thin bedded turbidites in the Upper Devonian Imperial Formation. Quarry on south side of Dempster Highway. 20-30 minutes from Inuvik.

Sole marks on thin bedded turbidites from the Imperial Formation



Proterozoic low-grade metamorphic rocks at the airport quarry, Inuvik

Paleokarst (arrow) in Middle Devonian limestones, south side of Dempster Highway, approximately 15 minute drive from Inuvik

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NEB Operation Identifier No.: 9237-C145-1E
NEB File: 9180-C845-2

Conoco Richardson Mountains Field Excursion
Kamik Sandstone Outcrops

Approx. 68° 00' N 135° 30' W
June 11-13, 2002

Off Interest Re: Significant Discovery Licence No. 032
Interest Owners: Conoco Canada (North) Limited (a wholly owned subsidiary of Conoco Canada Resources Limited) and ExxonMobil Canada Properties

FINAL REPORT for NATIONAL ENERGY BOARD

Prepared by:
Dr. Gary Prost
for
Conoco Canada Resources Limited
August 26, 2002

Field Team (left to right): Jim Dixon (GSC); David Bywater, Guy Peasley, Anh Duong, Gary Prost (Conoco Canada); Daniel Edwards (Gwich'in Environmental Monitor)

TABLE OF CONTENTS

Abstract and Statistical Summary

The purpose of this research is to observe the distribution of sandstone within the Kamik Formation along outcrops in the Richardson Mountains in order to understand and model the distribution of sandstone in the Parsons Lake gas field 2600 meters below the surface of the Mackenzie delta and SDL-032. The six member party was led by Jim Dixon (Canadian) of the Geological Survey of Canada (see Guidebook for original routes and location descriptions) and was attended by Gary Prost (Canada landed immigrant – US citizen), Dave Bywater (Canadian), Guy Peasley (Canadian/British), and Anh Duong (Canadian) of Conoco. In addition there was an environmental monitor, Daniel Edwards, of the Gwich'in community. The party contracted Trans North (Arctic) Helicopters for transport.

Of the three days allotted to this excursion, the first two were rained out. On the final day, June 13, 2002, we visited four of the six top priority areas: we were unable to land at two sites due to a thunderstorm in the area. The four sites visited were (see Route A and B maps – attached):

1) Grizzly Gorge [UTM zone 8: 7572857N 470997W]
2) Willow River [7564900N 482200W]
3) Jurassic Butte [7545357N 480508W]
4) East Bear Creek [7525632N 466215W]

Most of our time was spent at Grizzly Gorge and Willow River. At these two sites, the party collected a total of six hand samples from the lower sand (Kamik C) for petrographic analysis.

Summary of Conclusions

The Martin Creek Formation contains some fine-grained thick and laterally-continuous sands and is highly jointed. This could be a fair to good gas reservoir, relying on matrix porosity for volume and on fractures for permeability.

The lower Kamik C (C3_50 and C3_100) are laterally-continuous for several kilometers, and are massive sandstone interbedded with thin shales and coals. Porosity ranges from very low to 25%, depending on cement, making this either a poor or a good reservoir, respectively.

Sands in the upper Kamik C (C2) are thinner and less continuous laterally and vertically than sands in the lower Kamik C. Large amounts of silica cement (and corresponding low porosity) make this a poor to fair reservoir.

Kamik B sands appear laterally continuous in outcrop exposures, but tend to be thinner than C sands.

Reservoir Units – Outcrop Observations

Martin Creek Formation

The Martin Creek Formation is a minor reservoir at Parsons Lake field because it is structurally low and is a fine-grained sandstone and siltstone with relatively low porosity. As seen in Grizzly Canyon, it is a laterally continuous unit with some sand layers up to several meters thick, and with a strongly jointed upper unit (figs. 1, 2).

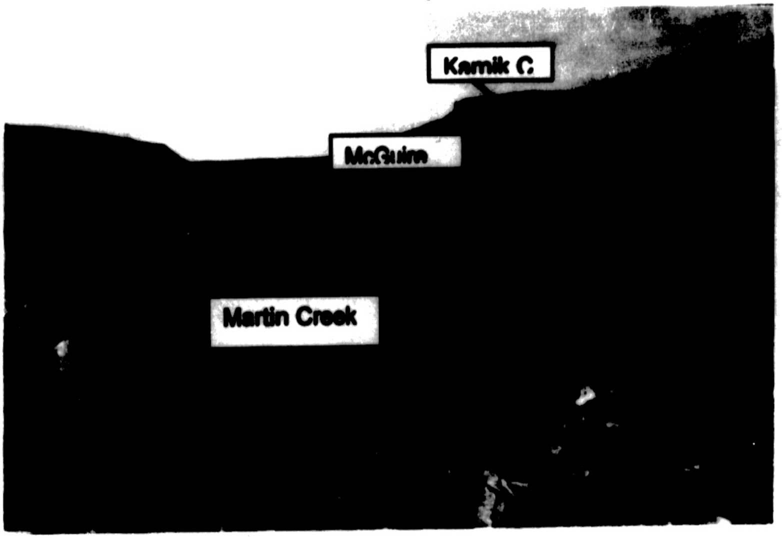

Figure 1. Martin Creek Formation, view W up Grizzly Gorge.

Figure 2. Jointed pavement at top Martin Creek Formation, Grizzly Gorge.

Kamik Formation

Observations of Kamik outcrops suggest that the lower (or "C") sands are laterally continuous over several kilometers and vertically discontinuous over tens of meters (fig. 3). Lateral continuity is broken primarily by widely spaced faults with offsets of a few meters to a few tens of meters (figs. 4, 5). Vertical continuity is broken by shale beds and occasional coals of less than a meter to several meters thick. Jointing was observed in sand in the lower Kamik C at Grizzly Gorge: this massive (10+ meters thick) fine-grained sandstone contains joint sets 20-40 cm wide separated by unjointed rock 1.3-2 m wide (figs. 6, 7). Joints appear to be extension fractures and are either open or have iron oxide coatings. No calcite or silica vein filling was observed at the outcrop. At Willow River the lowermost Kamik C sandstone was massive (10+ meters thick) and unjointed. The contact with the MaGuire is sharp, with an iron-rich and silica-rich sandstone extending upward several meters, and in turn overlain by a massive white sandstone (figs. 8, 9, 10).

The middle and upper sands in the Kamik C interval are less continuous laterally and vertically (figs. 11, 12).

Kamik B sands appear laterally continuous over the space of the outcrop exposure, but tend to be thinner than C sands, i.e., on the order of several meters thick (fig. 13).

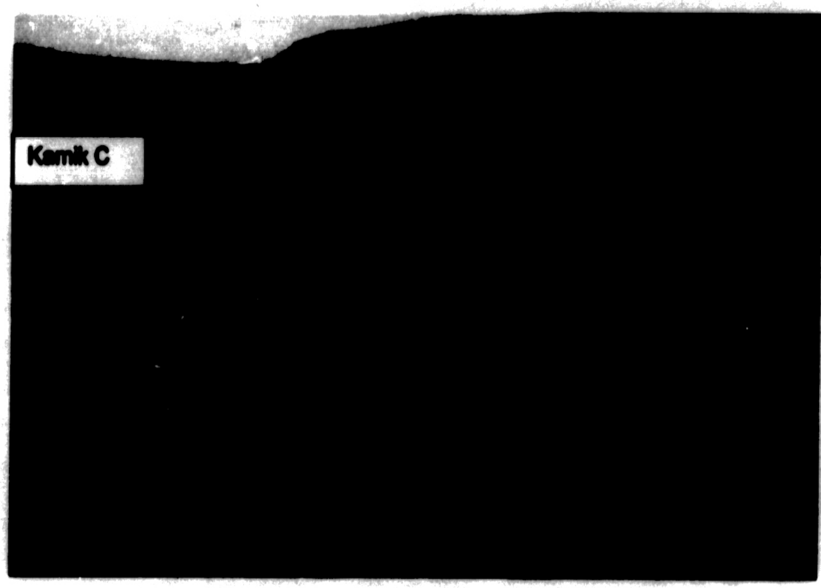

Figure 3. Laterally continuous Kamik C sandstone, Grizzly Gorge.

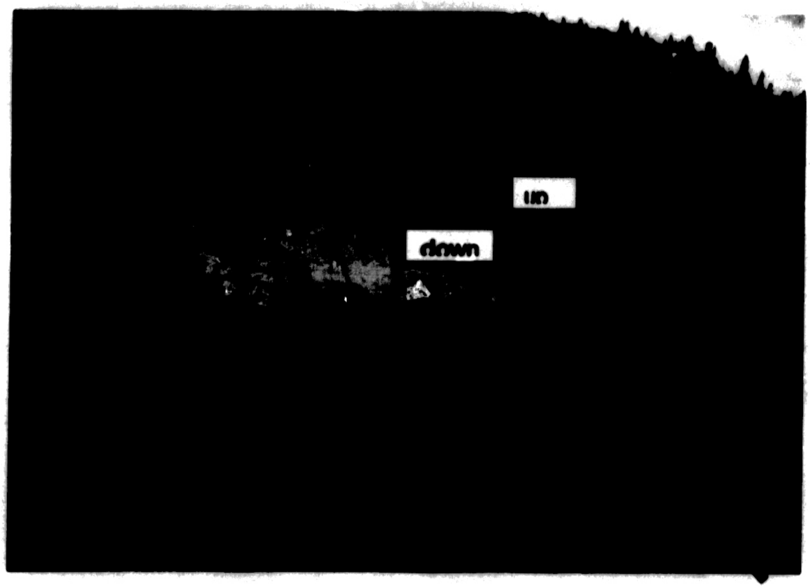

Figure 4. Normal fault in Kamik C, Grizzly Gorge.

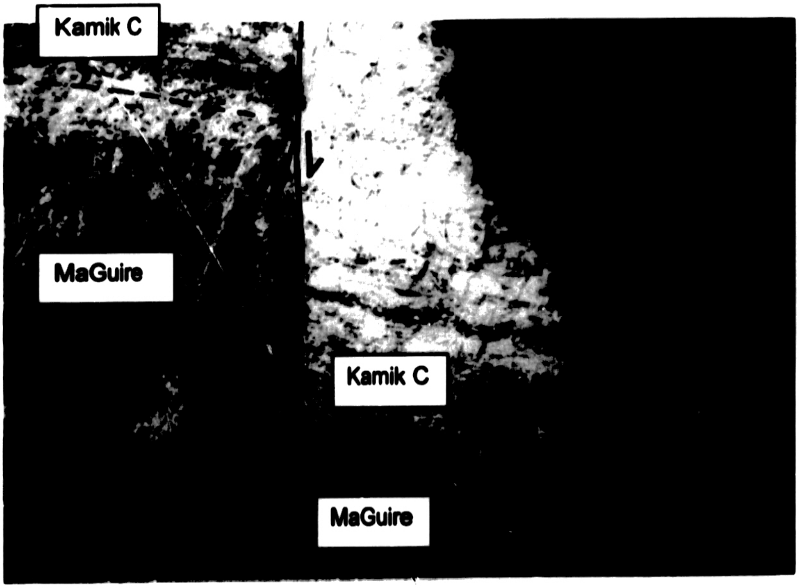

Figure 5. Normal fault at base of Kamik C with ~ 5 m offset, Grizzly Gorge.

Figure 6. Jointed Kamik C sandstone, Martin Creek valley.

Figure 7. Jointing in base of Kamik C sandstone, Grizzly Gorge. Note iron oxide weathering on surface.

Figure 8. Iron oxide-rich zone at base of Kamik C, Grizzly Gorge.

Figure 9. Iron oxide-rich zone in Kamik C, Grizzly Gorge.

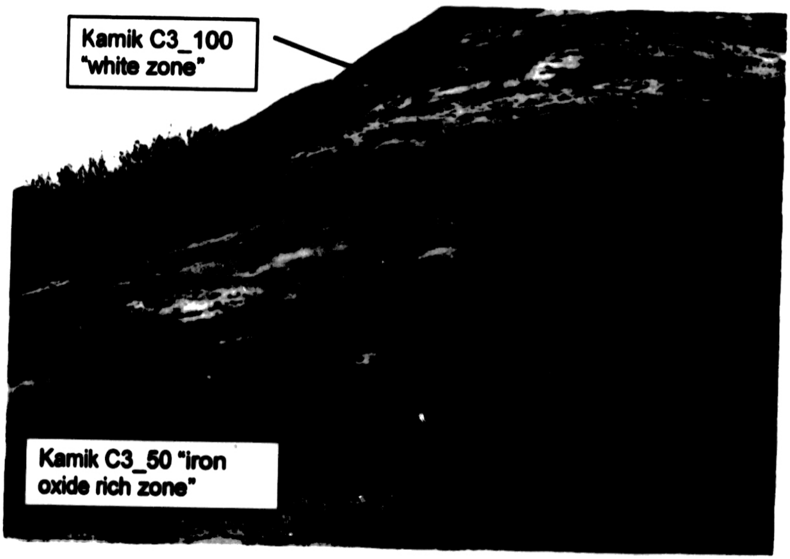

Figure 10. Massive unjointed "white" sandstone above basal rusty zone in Kamik C, Grizzly Gorge.

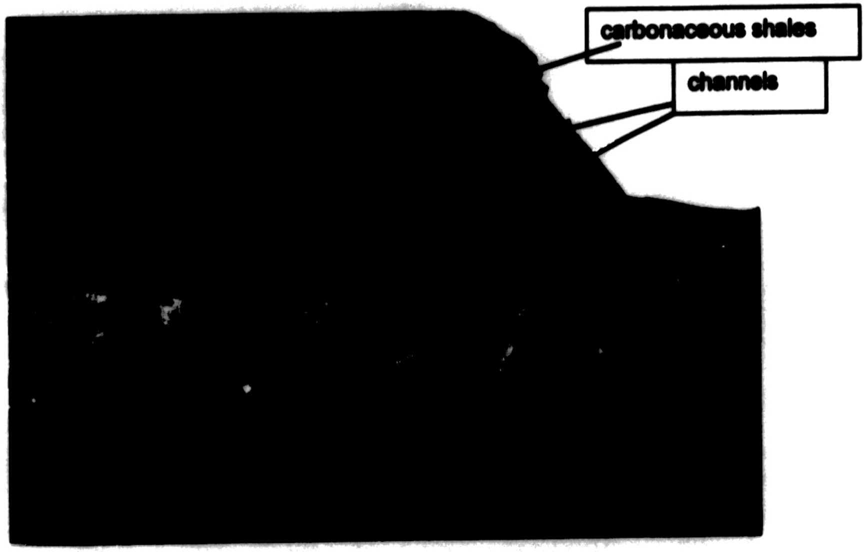

Figure 11. Thinner and laterally less continuous sands in the upper Kamik C, Willow River canyon. Note channel sand and carbonaceous layers.

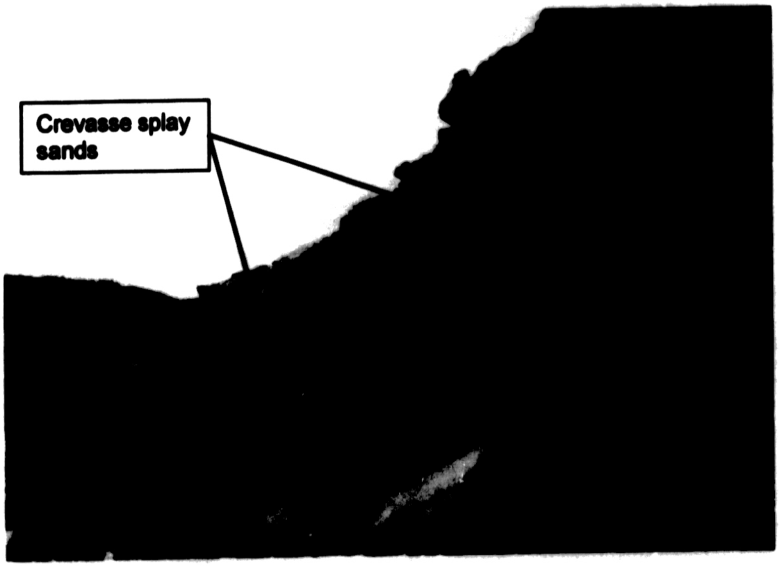

Figure 12. Crevasse splays in a delta plain setting, middle-upper Kamik C, Willow River canyon.

Figure 13. Kamik B sand, lower Martin Creek canyon.

Good examples of Kamik A sandstones were not observed.

Mt. Goodenough Formation

The Mt. Goodenough Formation shales are thick and continuous, and appear to be an excellent top seal for any gas accumulation (fig. 14).

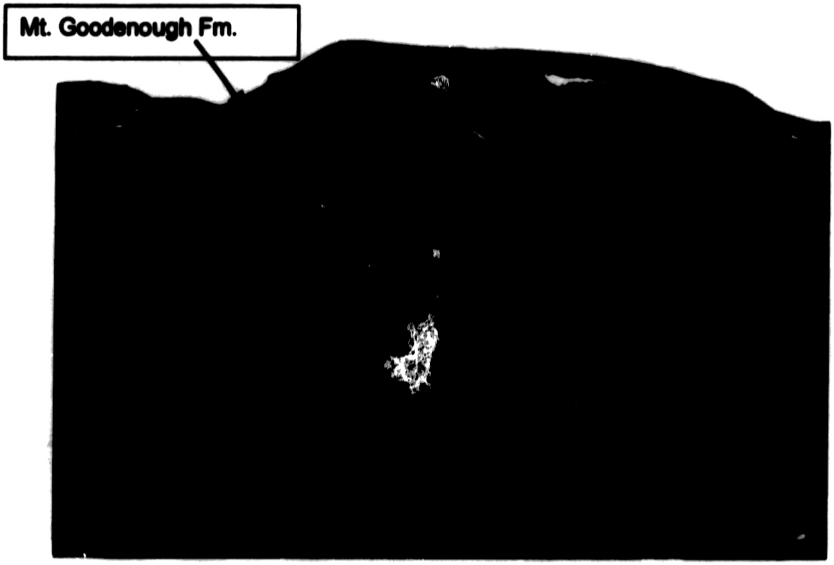

Figure 14. Mount Goodenough Formation south of Aklavik; view to the west.

Depositional Environments and Unit Continuity

The environment of deposition of the Kamik C sands in this area appears to be dominantly upper to lower shoreface, with occasional channels (fluvial or tidal) and occasional crevasse splays and coal horizons suggesting a delta plain or lagoon environment. Assuming that the environments in the Richardson Mountains are representative of environments in the subsurface 110 km to the east beneath Parsons Lake, then the sandstone should be continuous along depositional strike (roughly northeast-southwest) and should shale out downdip to the northwest as conditions become more marine. Under these conditions one might expect channels to be oriented roughly northwest-southeast.

Kamik B sandstone was likely deposited in a marine setting, as there are thinner sands separated by thick marine shales. Although they appear laterally continuous on a scale of kilometers, they are more likely to be isolated reservoir units, i.e., separate from the main gas sands in the Kamik C.

Petrographic Analysis

Field samples were examined under a petrographic microscope to determine the main constituents, porosity, type of cement, and other distinguishing characteristics.

The basal Kamik is divided into several sub-units, including the lowermost C3_50 and overlying C3_100. Higher in the section is the C2 subunit.

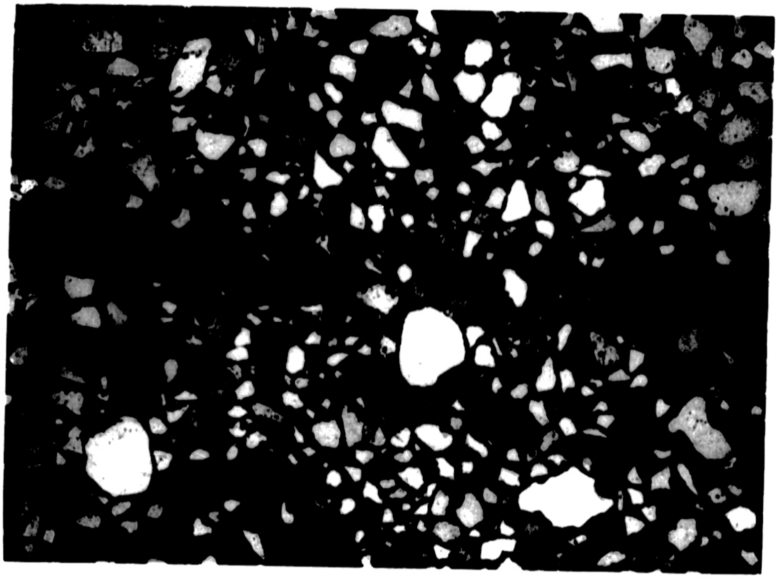

Figure 15. Kamik C3_50 ("iron-silica zone"), Grizzly Gorge, crossed polarization, 4X magnification. Porosity is shown as blue.

The Kamik C3_50 (fig. 15) is 30-40% medium to fine-grained quartz and 60-70% very fine grained to fine-grained carbonate. The grains are subround to angular, poorly-sorted, with little to no visible porosity, strong carbonate cement, and minor hematite cement. Trace amounts of hematite/magnetite/pyrite and glauconite grains can be seen.

This is a tight sandstone due to carbonate and iron oxide cements and would not be a good gas reservoir.

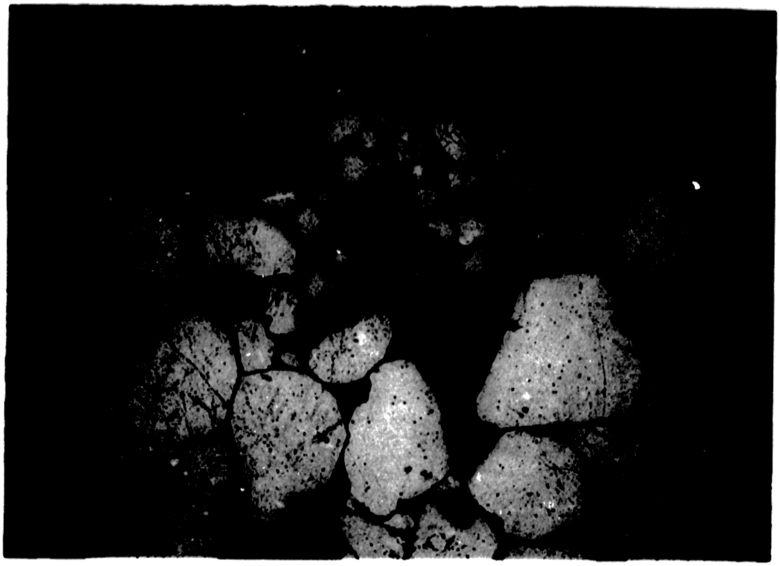

Figure 16. Kamik C3_100 ("iron-silica zone"), Grizzly Gorge, plain light, 4X magnification. Porosity is shown as blue.

This sample from the Kamik C3_100 (fig. 16) consists of approximately 60% fine to coarse-grained, subround to angular (some euhedral), poorly-sorted quartz grains. There is about 20% fine-grained carbonate, and 10% corroded feldspar and chert grains, with a trace of hematite/magnetite/pyrite and glauconite. There is 10-15% intergrannular and moldic porosity and cement is silica (including quartz overgrowths) and carbonate.

Despite the poor sorting, this unit would make a decent gas reservoir.

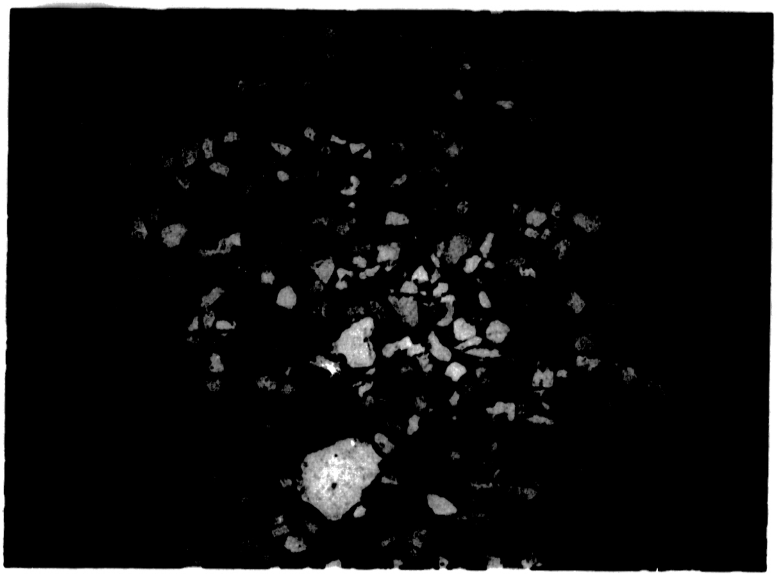

Figure 17. Kamik C3_100 ("white zone"), Grizzly Gorge, cross-polarized light, 4X magnification. Porosity is shown as blue.

The Kamik C3_100 (fig. 17) consists of 80% fine-grained, moderately-sorted, subround to subangular quartz grains; 10% carbonate as grains, 5% corroded feldspars and chert, 2% hematite/magnetite/pyrite, and 2% glauconite, with a trace of sericite. There is 20-25% intergrannular to moldic porosity, and minimal silica (as overgrowths) and hematite cement.

The high porosity in this unit would make it an excellent gas reservoir.

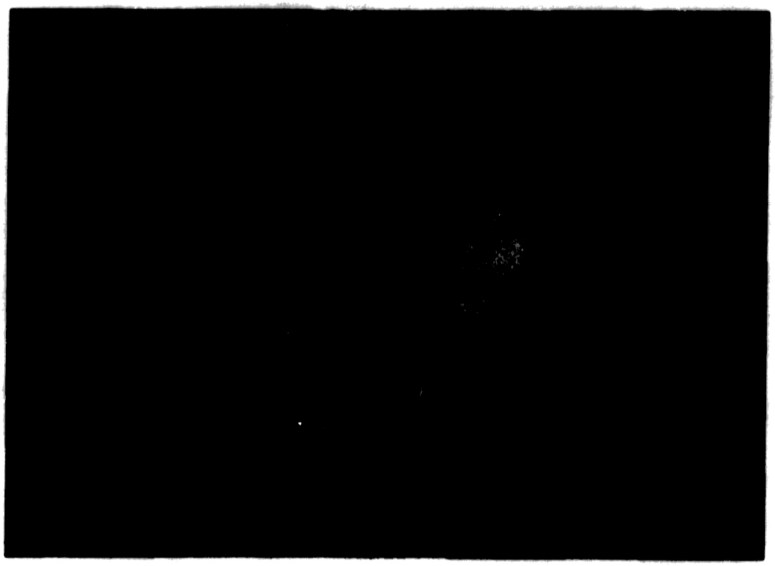

Figure 18. Kamik C2, Willow River, crossed nicols, 4X magnification. Porosity is shown as blue.

The sample from the Kamik C2 (fig. 18; specific subunit not known) is about 60% quartz, 20% carbonate as pore fillings and grains, and 20% corroded and honeycombed feldspars and chert. Quartz grains are medium to coarse-grained, subround to subangular and euhedral (silica overgrowths), with fair sorting. Porosity is 2-5% intergrannular and moldic, and with mainly silica and minor carbonate cement. There are traces of siltstone grains, pyrite grains, fibrous clays, and hematite/magnetite/pyrite cement.

The low porosity (large amount of silica cement) makes this a poor to possibly fair gas reservoir.

This report prepared under the supervision of Abhi Manerikar, Exploration Manager, Canadian Frontiers for Conoco Canada Resources Limited.

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The Association of Professional Engineers, Geologists and Geophysicists of the NWT / NU

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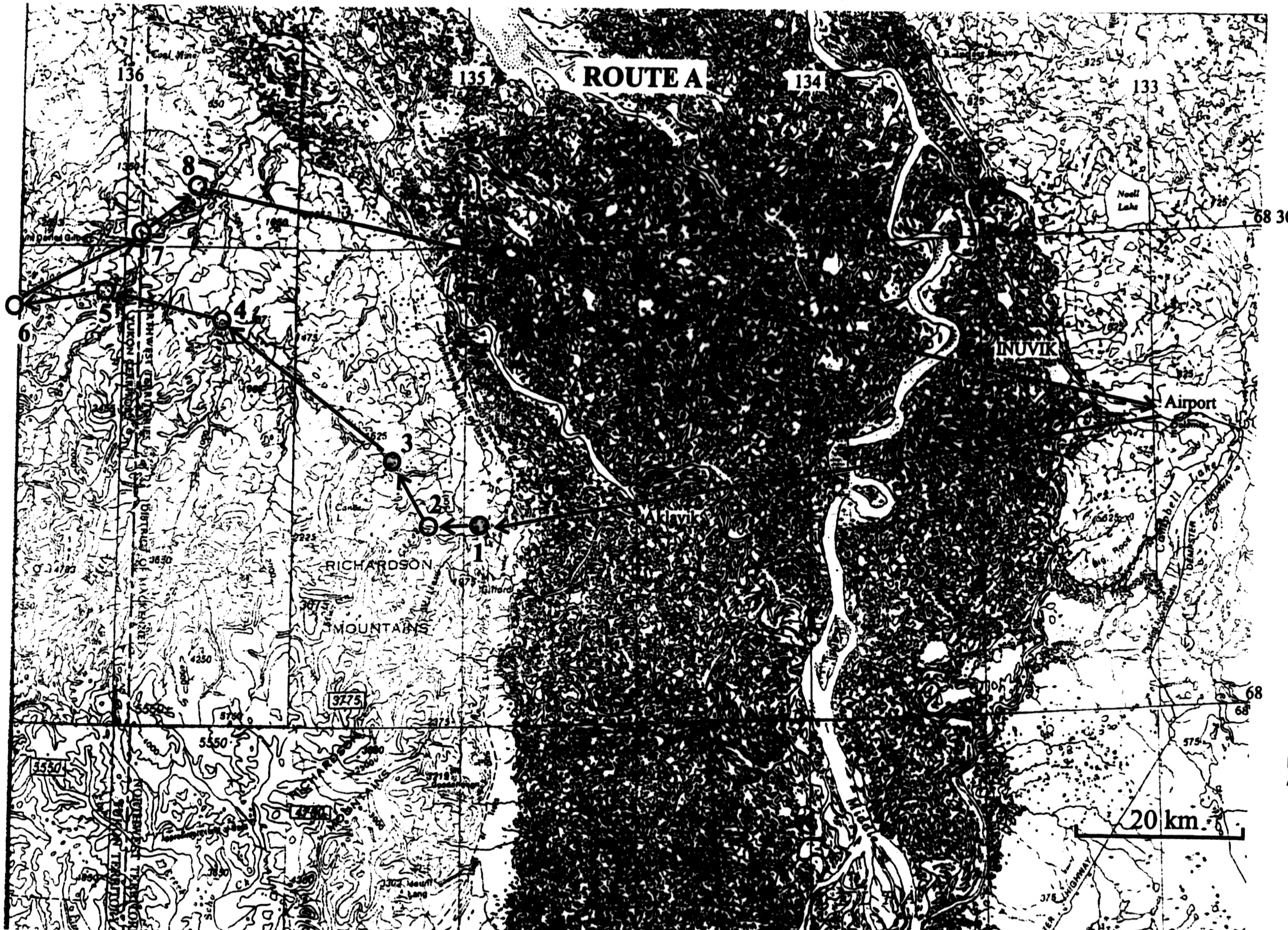
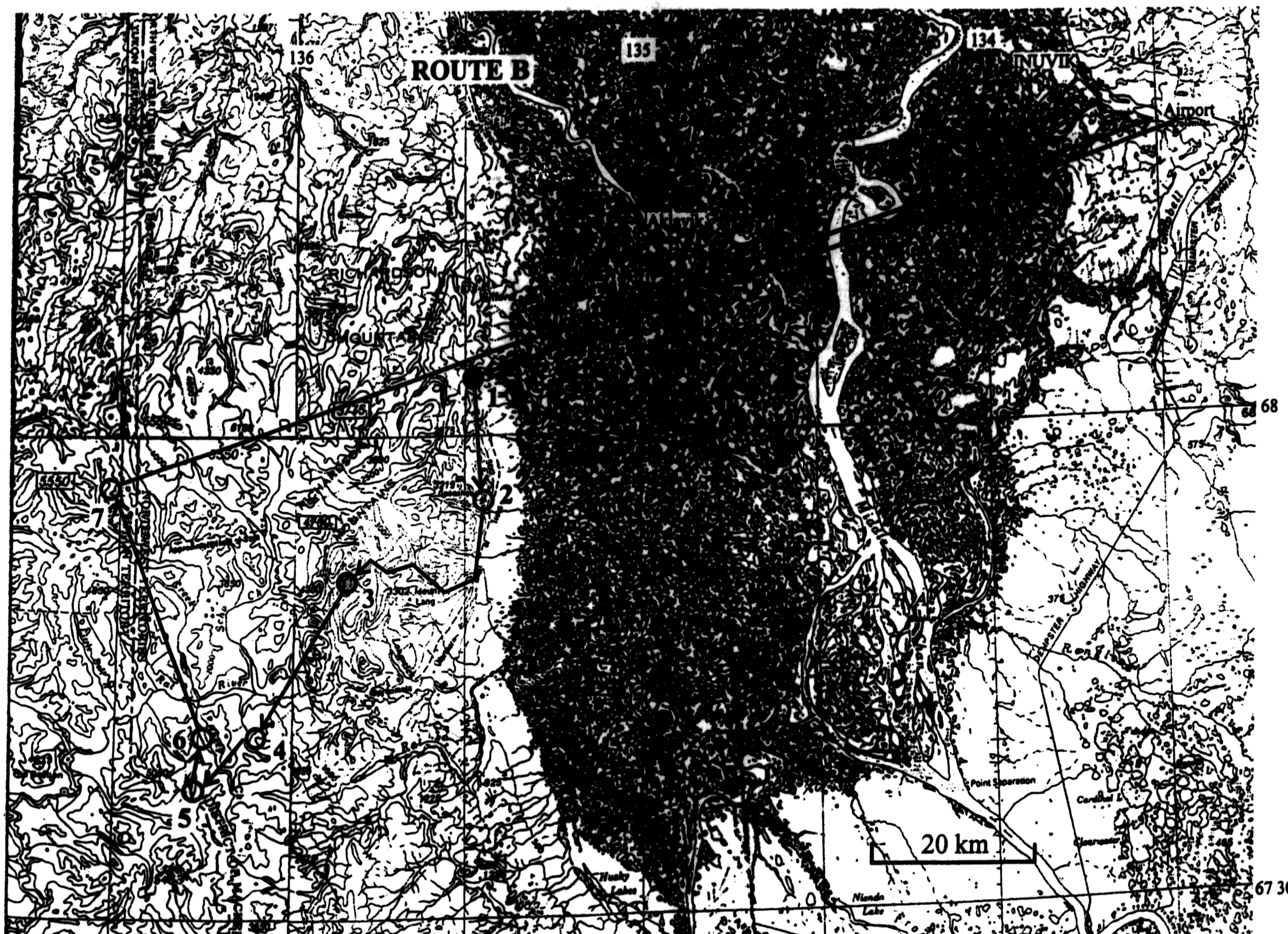
A. MANERIKAR
LICENSEE
NWT/NU



HIGHLIGHTED STOPS (1 AND 3) ARE THE SITES ACTUALLY VISITED



HIGHLIGHTED STOPS (1 AND 3)
ARE THE SITES ACTUALLY VISITED