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**TERRAIN EVALUATION OF THE DEMPSTER
HIGHWAY ACROSS THE EAGLE PLAINS AND
ALONG THE RICHARDSON MOUNTAINS,
YUKON TERRITORY**

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HIGHWAY ACROSS THE EAGLE PLAIN
AND ALONG THE RICHARDSON MOUNTAINS,
YUKON TERRITORY

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ABSTRACT

A detailed terrain classification was carried out on the Dempster Highway from Mile 166 to Mile 290.5, the Yukon Northwest Territories Border. The objective was to establish a rational basis for field testing and studying environmental impact. Terrain units were established on the basis of geology, vegetation, patterned ground and topography. The surface sediments are mainly outcrops of weathered shale and sandstone. The sandstone was found to be the most stable borrow and foundation material. The shale was mainly clay with high ice contents near the surface and is very unstable when thawed. The terrain has not been glaciated.

mile 166 = 267. Km

mile 290 = 467. Km

INTRODUCTION

The Dempster Highway begins at Mile 88 of the Klondike Highway 26 miles (41.8 Km) southeast of Dawson City, at the confluence of Klondike and North Klondike Rivers, and runs northeasterly through the north Central Yukon to the Northwest Territories (Figure 1). On completion, it will reach Fort MacPherson where it will junction with the Mackenzie Highway.

A study was initiated by the Department of Public Works in Whitehorse in co-operation with the University of Saskatchewan to study terrain and environmental problems in connection with construction of the highway. Detailed air-photo interpretation was used to define the basic terrain-vegetation units. Two summers were spent in the field observing construction operations and gathering some limited test data. Additional information on the geology was obtained from the Geological Survey of Canada and Chevron Standard Limited in Calgary.

The section from Mile 166 to 290.5 was mapped in detail. The terrain units were defined on the basis of geology, vegetation, and topography. The significance of the terrain units was established from observing construction and the performance of the existing road and limited test data. The significance of the terrain units beyond Mile 180 was established by extrapolation from completed sections of similar terrain units modified by field observation, test data, and environmental changes.

The objective was to establish a rational basis for field testing and analyzing environmental impact in the future.

The highway is located in the discontinuous permafrost zone according to Brown (1967). However, frozen ground was found in most of the highway corridor.

GEOLOGY

Geomorphology

The Eagle Plain and the Richardson Mountains are part of a large area in the Northern Yukon that has not been glaciated (Figure 2). The only surface deposits in the area related to glaciation are Quaternary fluvial and lacustrine deposits in the Bell River basin and along the Eagle River near its confluence with the Bell River.

The geomorphic processes in the area are mainly weathering, mass wasting, and erosion and deposition by water. A thin mantle of loess may also exist in the area. Some evidence was found of chemical weathering under forest vegetation.

Stratigraphy

Sediments outcrop along the highway ranging in age from Middle Cambrian to Tertiary. The rock types found in outcrops include shales, sandstones, siltstones and limestone. Stratigraphic cross-sections are shown in Figures 3, 4 and 5. These cross-sections were established from various sources of information including the work of Bamber (1972), Bamber and Waterhouse (1971), Martin (1972), Mountjoy (1967a and 1967b) and Mountjoy and Chamney (1969).

Structure

The Eagle Plain is composed of sedimentary rocks dipping gently to the west resulting in exposure of different strata along the eastern edge of the basin. Broad folds, generally trending north to northwest are the dominant structures in the Eagle Plain.

The Richardson Mountains south of the 67th Parallel represent a northward plunging anticline which can be seen clearly on the satellite photography in Figure 6. The highway from Mile 260 to

~ km 416

~ km 400
Mile 290 is located along the westward facing pediment slope of the mountains. Faulting is conspicuous in the mountain range and seismic data (Stevens and Milne, 1974) indicate that earthquake probability is high.

VEGETATION

The various forms of vegetation found along the route of the highway were grouped into five associations for engineering purposes. Each association consists of a plant community which is found in a characteristic physical environment. Each association encompasses a number of species of vegetation, however, only the most prominent forms are relevant to engineering implications.

Black Spruce - Sphagnum Association

The most prevalent plant association is black spruce and sphagnum moss with a scattering of tamarack, alders, willows, dwarf bush, Arctic Labrador tea, lichens, Arctic cotton grass and other small plants. This community was most commonly found on frozen, poorly drained, fine grained soils in the lower altitudes. The sediments were mostly weathered shale and alluvial deposits. The black spruce averages about five metres in height. The "treeline" or upper limit of tree growth was about 2,450 feet (735 metres) above sea level in the southernmost Eagle Plain but lowered to 2,200 feet (660 metres) near the Richardson Mountains.

Cottongrass Tussock Tundra Association

The second most prevalent plant association in the study area is the cottongrass tussock tundra. The tussocks are known colloquially as "nigger heads". This tundra represents poorly drained, fine grained

frozen mineral soil. It is most commonly found along the pediment slopes along the Richardson Mountains and at higher elevations in the Eagle Plain. The tundra forms very effective insulation restricting the active layer to less than one metre.

Lichen Association

The lichen association is confined to coarse-grained deposits in the Eagle Plain. A variety of cladonia lichen or "reindeer moss" is found on sandstone outcrops accompanied by dwarf birch, shrubs and some Arctic bearberry, low-bush cranberry and mushrooms. Under the lichen association, an organic mat and soil profile has developed. The denser and thicker the vegetation on the outcrop, the better developed and deeper the soil profile which is apparently related to chemical weathering.

Birch Association

The birch association was found along drainage courses on the slopes of ridges and gullies. It is composed of paper birch, alder, willow and other smaller plants which have an affinity for very wet conditions.

Floodplain Association

This association is limited to the Eagle River Valley along the highway corridor and Rock River and Cornwall Creeks in the Richardson Mountains. The succession of floodplain vegetation in order of increasing distance from the stream includes willows, alders, balsam poplar and white spruce. The white spruce delineate the borders of the active floodplain.

PATTERNED GROUND

Frost Polygons

Most polygons along the highway had four to six sides and often were irregular in form and were the raised type. The polygons were estimated to be as much as 60 feet (18 metres) across with separating fissures two to three feet (0.6 metres to 0.9 metres) which were open to a depth of two feet (0.6 metres).

Frost polygons were found primarily on fine-grained deposits usually poorly drained with high excess ice contents. They were found mainly along the pediments of the Richardson Mountains.

Solifluction and Creep

Solifluction appears to be a major geomorphic process in this region. This phenomenon usually indicates fine grained soils with high excess ice contents and slow downslope creep of surface materials.

Terrace-like solifluction was found in only a few areas in tundra-covered depressions between ridges.

Solifluction striping was more common especially on the western pediment slope of the Richardson Mountains. This type of ground pattern seemed to indicate more intense mass movements.

Silt Boils

Silt boils or mud circles are the most common permafrost feature observed in the highway corridor. They were found most commonly on fine grained sediments such as alluvial slopes, shale outcrops and on soil formed by chemical weathering. Poorly drained, ice-rich conditions appeared to be the most favourable site for silt boils to develop.

Beaded Streams

Many of the streams along the highway exhibit periodic enlargements of their channels apparently caused by thawing. They were found most commonly on shale-dominated terrain.

Felsenmeer

Felsenmeer is a term used to describe surficial fractured rock created by gelifraction of the underlying bedrock outcrop. Widespread deposits of this type occur along the highway route.

Other Patterns

Other unusual patterns were observed in the area such as lines and ribbed features; fine fissure patterns were also observed on some tundra areas. The significance of these features is unknown.

TERRAIN MAPPING

~ km 266 to km 344

Mile 166 to Mile 215 - The Eagle Plain Formation

Between 166 and Mile 176, the terrain consists of ridge and cliff-forming sandstone strata interbedded with thicker highly weathered shale beds. The thinly vegetated prominent ridges appear as white-toned bands on the aerial photographs. The shale beds have a continuous cover of vegetation which becomes thicker downslope. Along this section, the stratigraphy can be mapped on the aerial photographs by tonal differences between the beds of the two rock types (Figure 7).

Beyond Mile 176, the differentiation between strata is not nearly as apparent and the sandstone appears to be more susceptible to weathering (Figure 8).

Where the cover of vegetation on the sandstone is thick, a soil profile was found with an 'A' horizon consisting of low to medium plastic clay. This layer was found to be as thick as one metre under heavy tree cover. The clay was extremely unstable when it thawed causing severe construction problems.

The sandstone was found to contain 40 percent to 50 percent silt (particles smaller than 0.074 mm) by weight. The shale is mostly clay which is very unstable when it thaws. The sandstone is stable when dry but liquifies when saturated.

km 344

km 318

Mile 215 to Mile 217 - Lower Cretaceous Interval

The Lower Cretaceous interval is composed almost entirely of shale which is believed to be similar to the clay shale of the Eagle Plain Formation (Figure 9). Therefore within this zone, suitable construction material will be scarce. The low resistance to erosion indicated by the subdued relief probably indicates a low shearing resistance and instability when thawing occurs.

km 318

km 353

— Fly Camp Hill Area

Mile 217 to Mile 220.5 - The Ettrain Formation

The Ettrain Formation is composed of highly resistant limestone forming steep-sloped headlands and sharply defined ridges (Figure 10). The surface sediments consist of about 1 1/2 metres of highly disturbed felsenmeer. Below this depth, the sediment is hard and blocky. Test hole logs indicate that ice has accumulated in the felsenmeer deposits, especially near the surface.

The composition of the rock is mainly carbonate, but it has a texture similar to a sandstone. Therefore, it can be expected to have properties very similar to the sandstone of the Eagle Plain Formation. However, field observations indicate that it may be somewhat more stable than the Eagle Plain sandstone. Suitable borrow should be available from this Formation.

Mile 220.5 to Mile 225 - The Hart River Formation

The surface expression of the Hart River Formation consists predominantly of smoothly rounded hills, pediments, and wide shallow valleys indicating a material of low resistance to erosion (Figure 11). Field observations indicate that the sediment is mainly shale and laboratory tests indicated a plasticity index ranging from 20 percent to 50 percent. Water contents were in excess of the liquid limit in many samples.

In all probability, this terrain is extremely unstable. Landslides, slumps and flow features along stream banks and other slopes can be seen on the aerial photographs which support this conclusion.

Mile 225 to Mile 230 - "Unit 1" - Western Outcrop Interval

"Unit 1" is composed of silty shale with minor interbeds of sandstone. The unit has been deformed on a regional scale in this area, resulting in dipping arcuate ridges (Figure 12).

The cover of vegetation apparently protects a mantle of icy, unlithified material similar to the shale of the Eagle Plain Formation. The sandstone ridges which can be recognized by light tones on the aerial photographs will be the most suitable sources of borrow.

Slumping along stream banks indicates that the clay shale is very unstable when thawed. Therefore, preservation of vegetative cover over the shale is of primary importance. The liquid limit of the sandstone is 30 percent to 40 percent and the plasticity index from 7 percent to 16 percent.

Mile 230 to Mile 240 - The Imperial Formation Western Outcrop Interval

The Imperial Formation includes sandstone and shale similar to the Eagle Plain Formation (Figure 13). However, the environment is more severe as reflected in the vegetation. The shale beds support a sparse black spruce - sphagnum association whereas the ground surface is covered primarily by tussocks of Arctic Cottongrass. Sandstone outcrops support very little vegetation. Borrow prospects are confined to a concentration of sandstone near the western limit of the outcrop interval.

The shale beds are not suitable for borrow and the vegetation covering them should not be disturbed. Test drilling indicated excess ice contents near the surface decreasing with depth. Ice lenses one inch (2.5 cm) thick were found in the upper six feet (1.8 m). Little ice was evident below ten feet (3 m). However, at one site, a layer of massive ice 20 feet (6 m) thick was found below a thin cover of vegetation and mineral soil.

The floodplain of the Eagle River (Figure 14) is deeply incised into the Imperial Formation. The river meanders over a floodplain about 3,000 to 4,000 feet (900 to 1,200 metres) wide creating oxbow scars, oxbow lakes, infillings, cut-offs and other fluvial features. The dominant sediments are probably clays and silts because the river is eroded into shales and fine sandstones.

Mile 240 to Mile 248 - "Unit 1" - Eastern Outcrop Interval

Here the terrain is dominated by sandstone rather than shale (Figure 15). Most of the highway route has been located along a sandstone ridge. Again the most stable terrain and suitable sources of borrow are in the sandstone with the shale being relatively unstable. The sandstone can be identified on the aerial photographs by vegetation and tone patterns.

Mile 248 to Mile 257 - The Imperial Formation - Eastern Outcrop Interval

The bedrock sediments are predominately sandstone and siltstone with minor shale beds (Figure 16). The strata are finely bedded with varying dips resulting from regional folding. The terrain is apparently very stable and construction should proceed without difficulty. Laboratory tests indicated a plasticity index ranging from 5 percent to 14 percent and ice contents were low.

Mile 257 to Mile 271 - The Canol Formation

The Canol Formation marks the edge of the Eagle Plain where it joins the Richardson Mountains (Figure 17). The formation contains a narrow band of recessive shale and forms the pediment slope at the western edge of the mountains. Mass-wasting and creep are widespread.

Exposures of this formation at two locations on the western flank of the Richardson Mountains are composed of a dark grey to black shale. None of this material is suitable for borrow. However, fill can be obtained from nearby "flat-iron" ridge foothills of the Richardson Mountains where more resistant sediments exist. The vegetation on this terrain should not be disturbed prior to construction. Frost polygons are widespread indicating high ice contents.

It should be noted that the highway is located on side-hill along a pediment slope. This means that all run-off is perpendicular to the roadbed. Concentration or runoff downstream and ponding upstream could cause severe erosion or thawing respectively.

Mile 271 to Mile 284 - Devonian to Cambrian Strata

The strata which are mainly shales and siltstones have near vertical dips because they are part of the Richardson Mountain anticlinorium. Between Mile 271 and Mile 276, the highway follows

a depression between mountain ridges; between Mile 276 and Mile 284, the road traverses a pediment slope (Figure 18). Most of the surface material is alluvial in origin and is silty sand or silty clay.

Borrow will have to be obtained from the crests of mountain ridges which contain sandstone and a much more stable shale. The principal problems here are drainage and disturbance of vegetation covering fine-grained sediments.

~ km 454 - km 464. ^B

Mile 284 to Mile 290.5 - Lower Cretaceous to Jurassic Interval

The highway crosses four geological units in this interval. Between Mile 284 and Mile 287, huge fans are the principal surface deposit (Figure 19). Approximately four feet (1.2 m) of frozen unlithified material were observed in this area. High ice contents were observed in the sediments. Therefore, it will be imperative not to disturb the vegetation prior to construction and surface runoff will have to be carefully controlled.

Between Mile 287 and Mile 288, the highway location crosses a bank of relatively resistant Lower Cretaceous siltstone. Finally between Mile 288 and Mile 290.5 (Yukon-N.W.T. border), the location parallels the bedding along a narrow band of undifferentiated Lower Cretaceous - Upper Jurassic sediments.

The principal source of borrow in this area will be from hogback ridges such as those in Figure 20.

SUMMARY

The Dempster Highway is an enormously valuable field laboratory to study Arctic highway engineering problems in sedimentary deposits. It has been demonstrated that the terrain can be mapped in considerable detail into meaningful units from existing geological data, aerial photographic interpretation and field observations. The concept of

terrain units based on topography, geology, plant communities and patterned ground phenomena has been demonstrated. The next logical step would be to establish a supplementary field testing program and an environmental monitoring system based on the terrain units that have been identified. Drilling and geophysical logging would be the most effective means to fill in the regional stratigraphic model.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation for the assistance of Messrs J.C. Hudson, S.P. Baker, J.Y.C. Quong, R.K. Byram and R.K. Coates of the Department of Public Works in Whitehorse in enabling the field work to be carried out. The geology was established with the assistance of D.K. Norris and Owen Hughes of the Geological Survey of Canada and Paul Collier and Archie Graham of Chevron Standard Limited. Dr. J.S. Rowe of the Plant Ecology Department at the University of Saskatchewan assisted in the classification of the vegetation associations.

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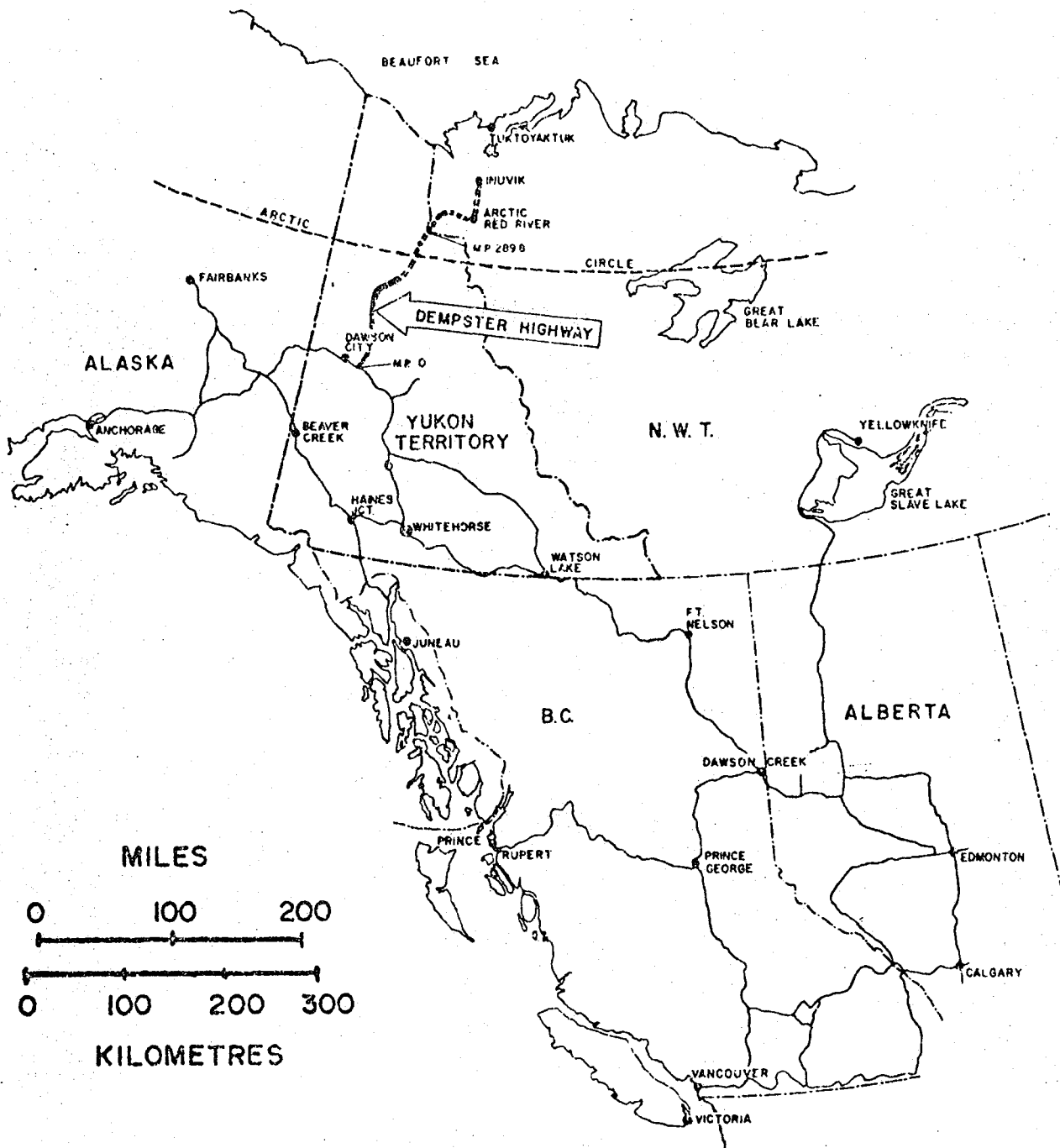


FIG.1. LOCATION OF DEMPSTER HIGHWAY

-COURTESY PUBLIC WORKS CANADA

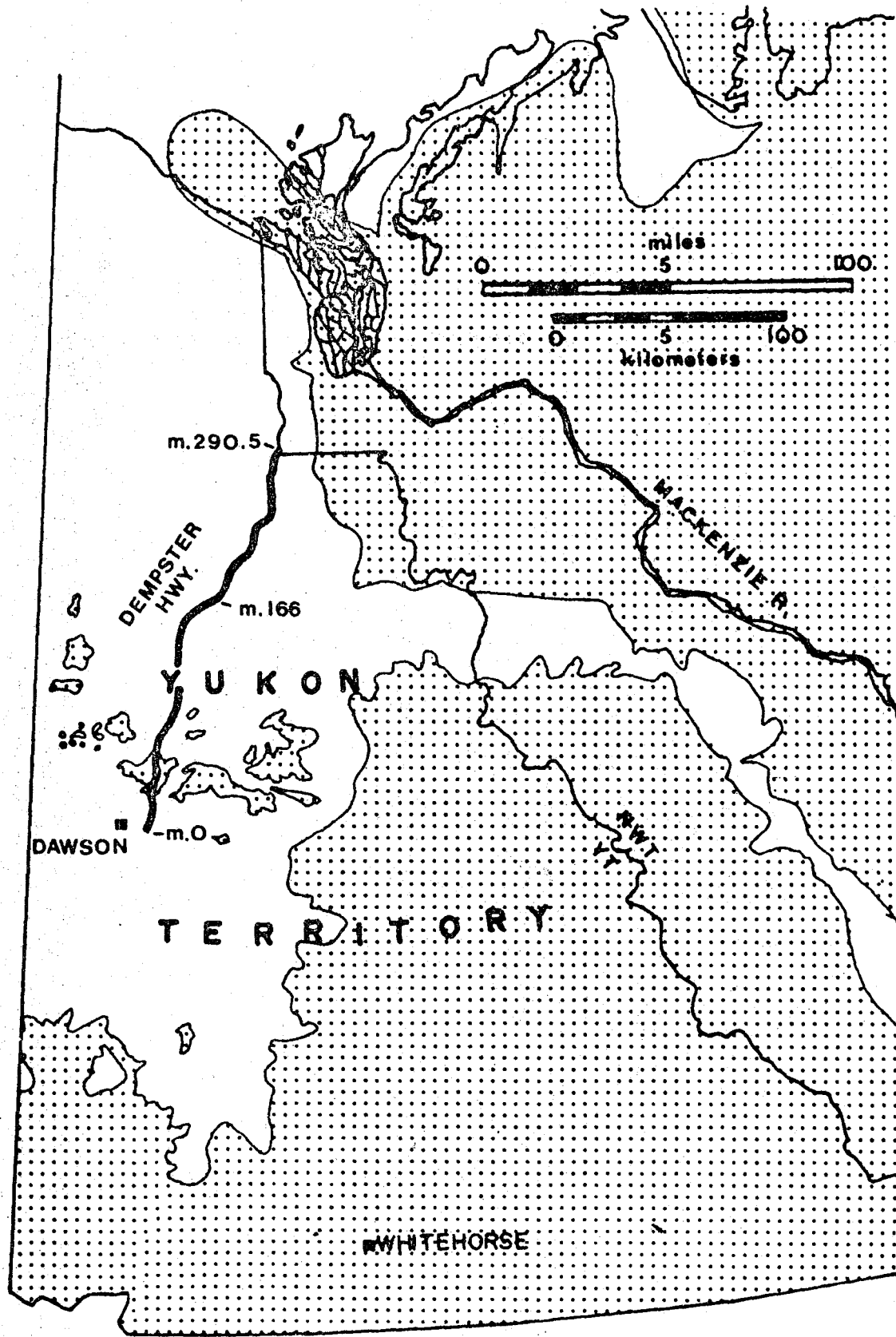


FIG. 2 MAP SHOWING EXTENT OF GLACIATION
 - after PREST (1969)

unglaciated

glaciated

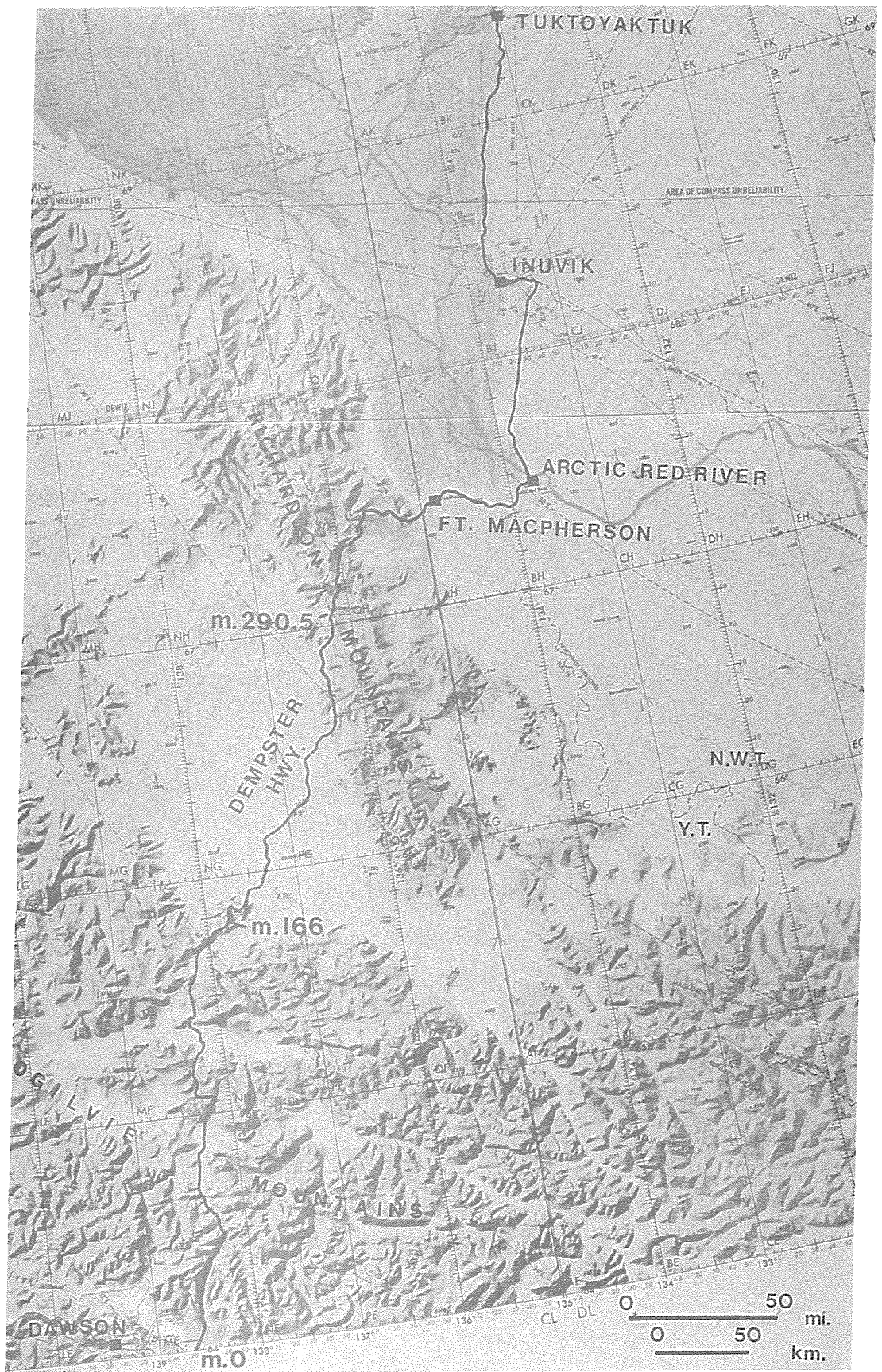
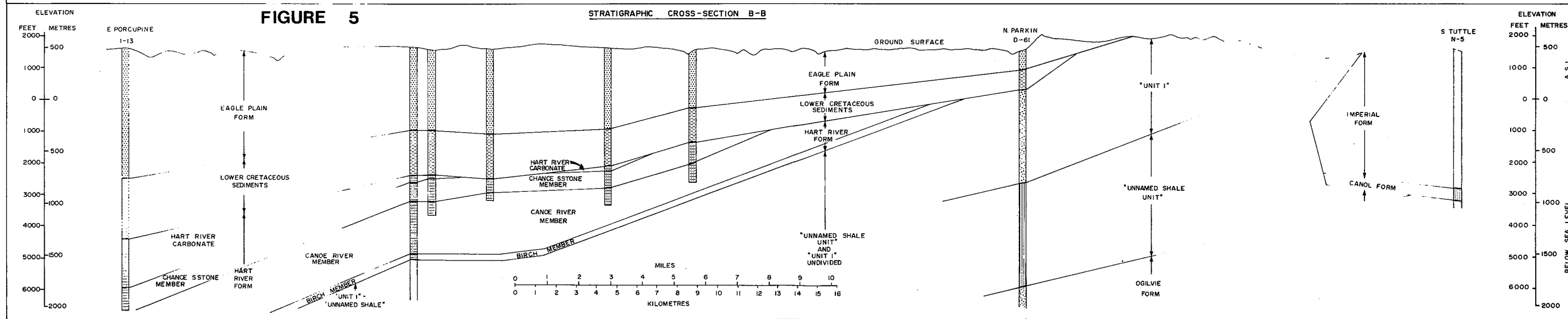
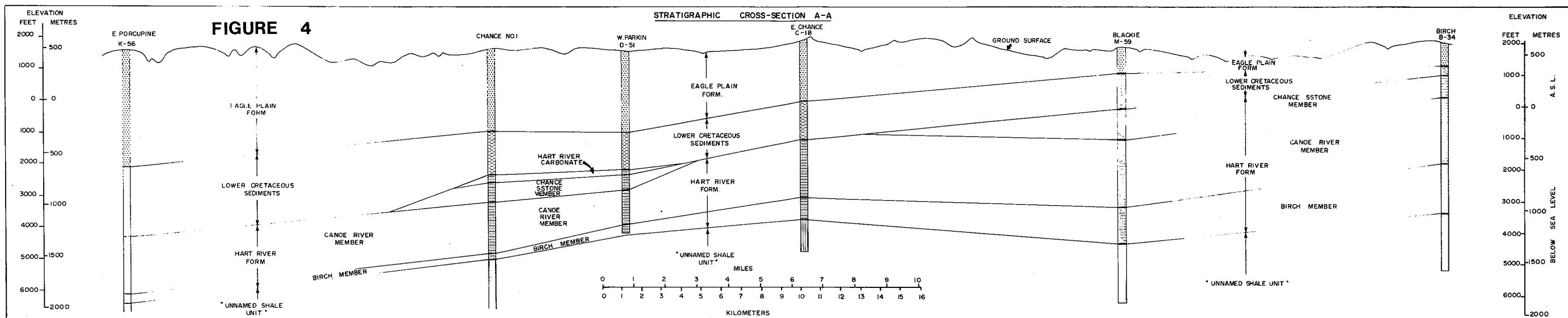


Figure 3. Detailed location of the Dempster Highway and Stratigraphic cross-section.



EXPLANATION OF SYMBOLS USED IN AIRPHOTO MAPPING

a.f	-	alluvial fan
assoc.	-	association
blsp.	-	black spruce
b. pop.	-	balsam poplar
fel.	-	felsenmeer
nig.	-	niggerhead (cottongrass tussock)
poly.	-	polygon
s.b. or sb	-	silt boil
solif.	-	solifluction
sphg.	-	sphagnum
s. stone	-	sandstone
whsp.	-	white spruce
will.	-	willow

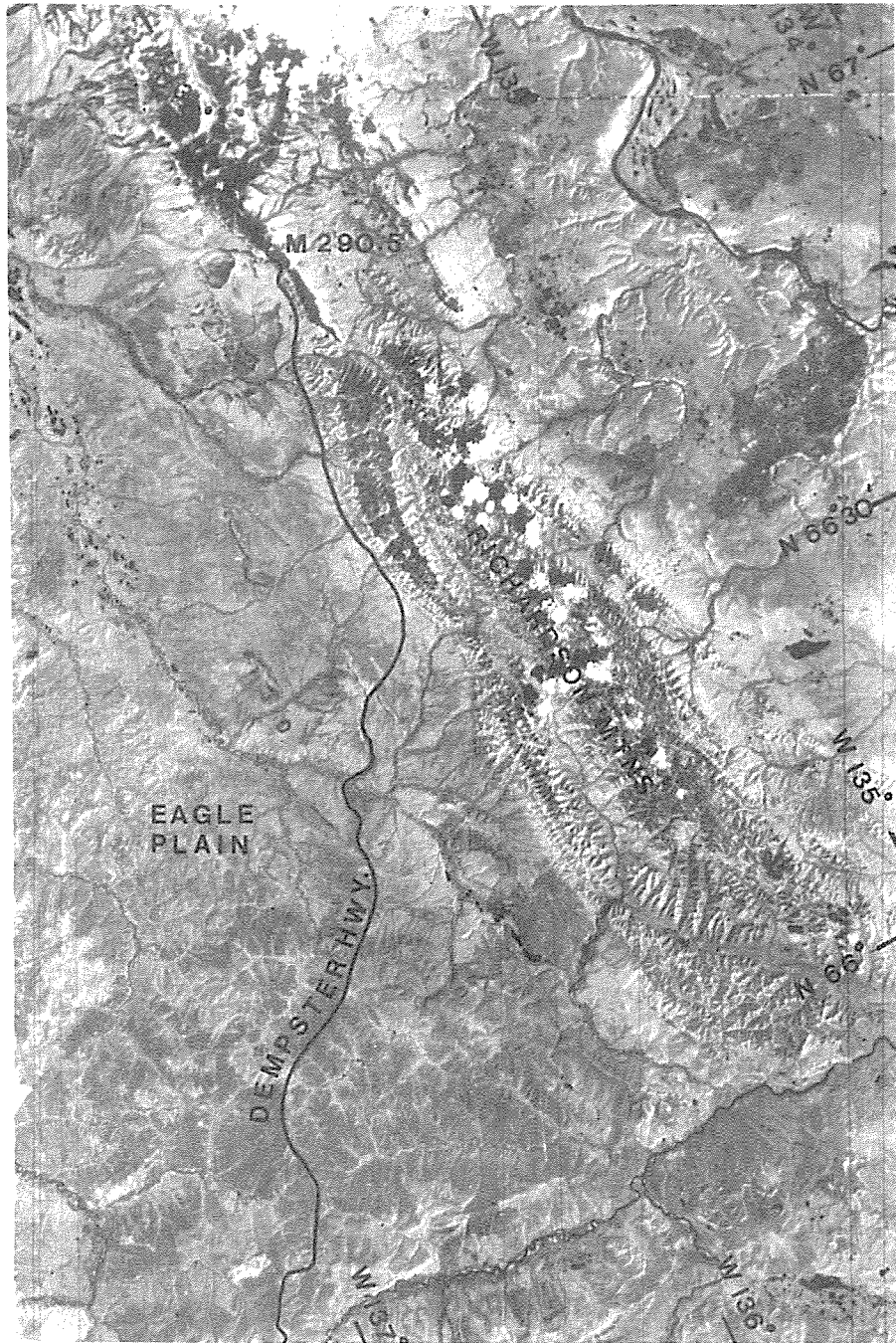


Figure 6. Earth Resources Technology satellite image number E-1367-20150-7 showing the Eastern Eagle Plain and the anticlinorium of the Richardson Mountains.

Scale

25 miles

25 km

Figure 7. Terrain of the interbedded sandstone and shale of the Eagle Plain Formation. The light bands are sandstone and the darker bands are shale. The thick black lines are tangent lines of the highway route; curves are not shown.

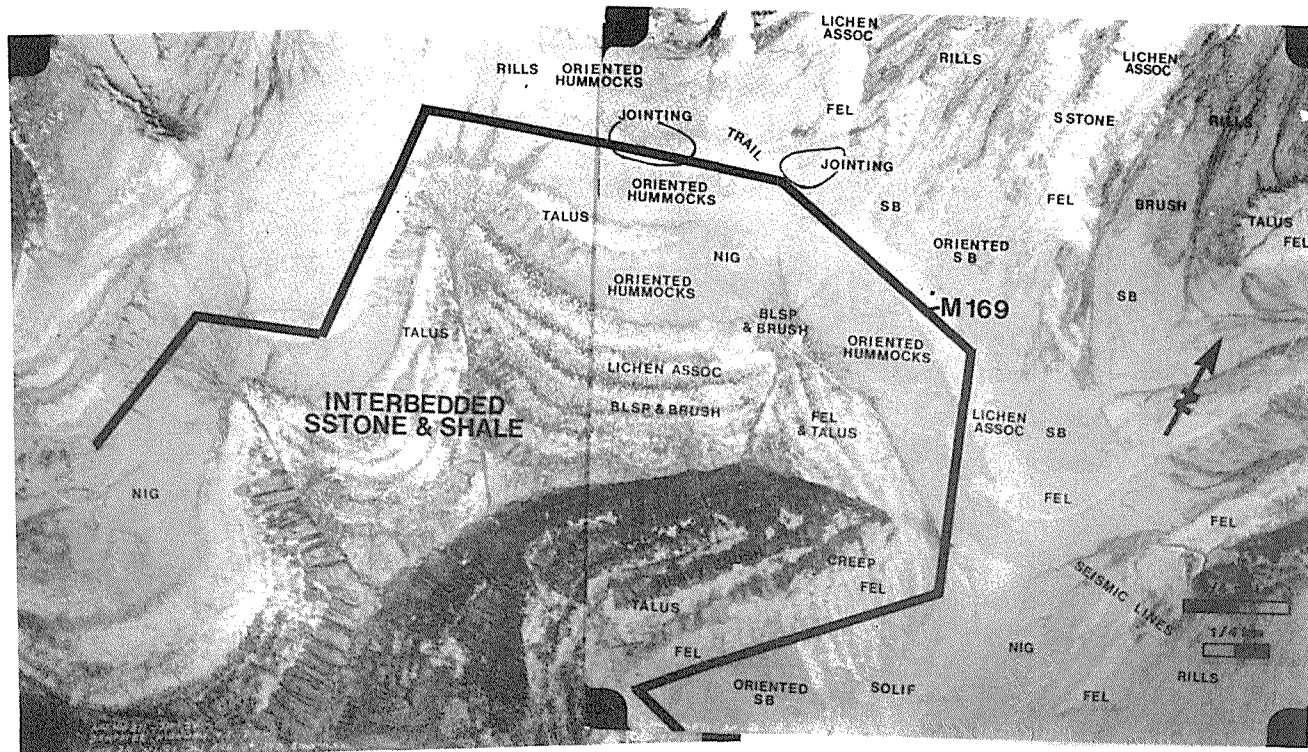


Figure 8. The Eagle Plain Formation beyond Mile 176 where the differentiation between sandstone and shale is not so apparent.

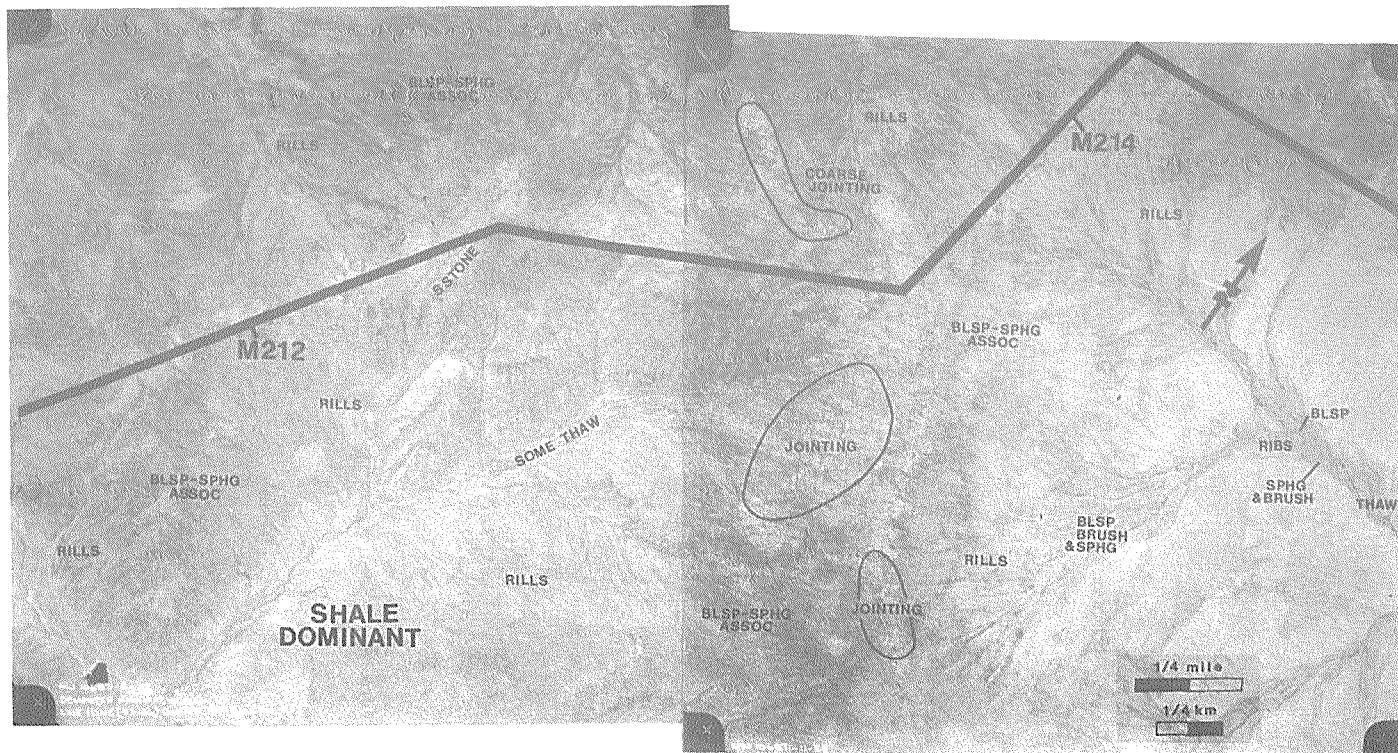


Figure 9. The Lower Cretaceous shale interval.

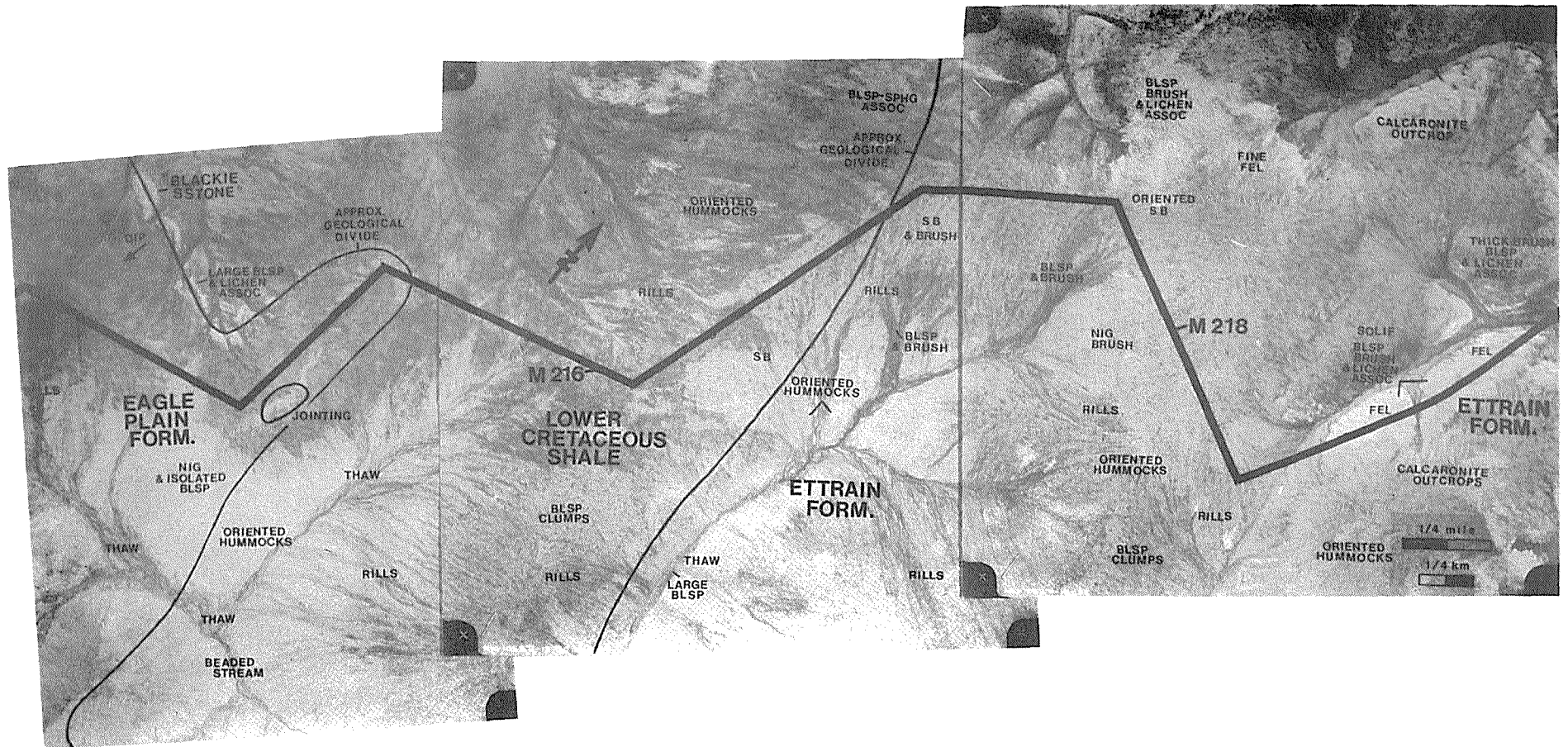


Figure 10. Ridges and mit-like plateaus formed by the resistant limestone of the Ettrain Formation.

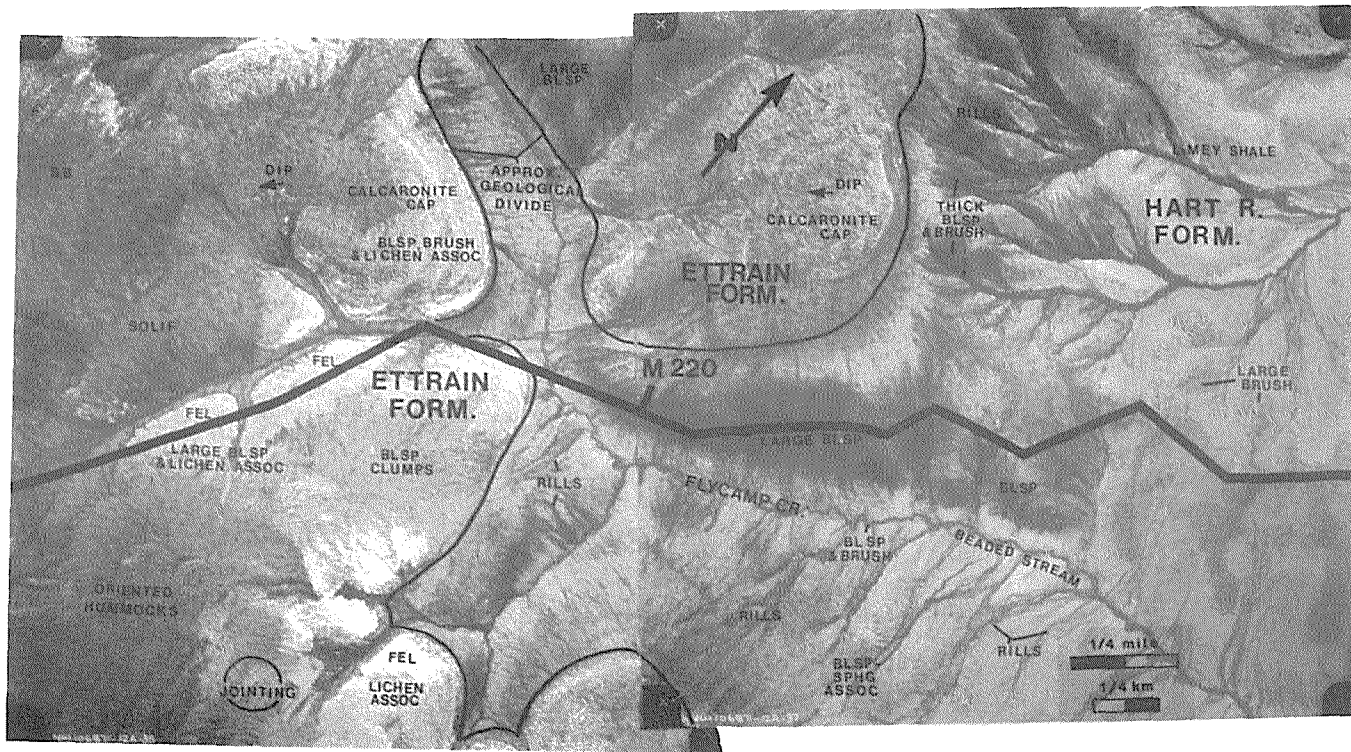


Figure 11. Shale slopes of the Hart River Formation.

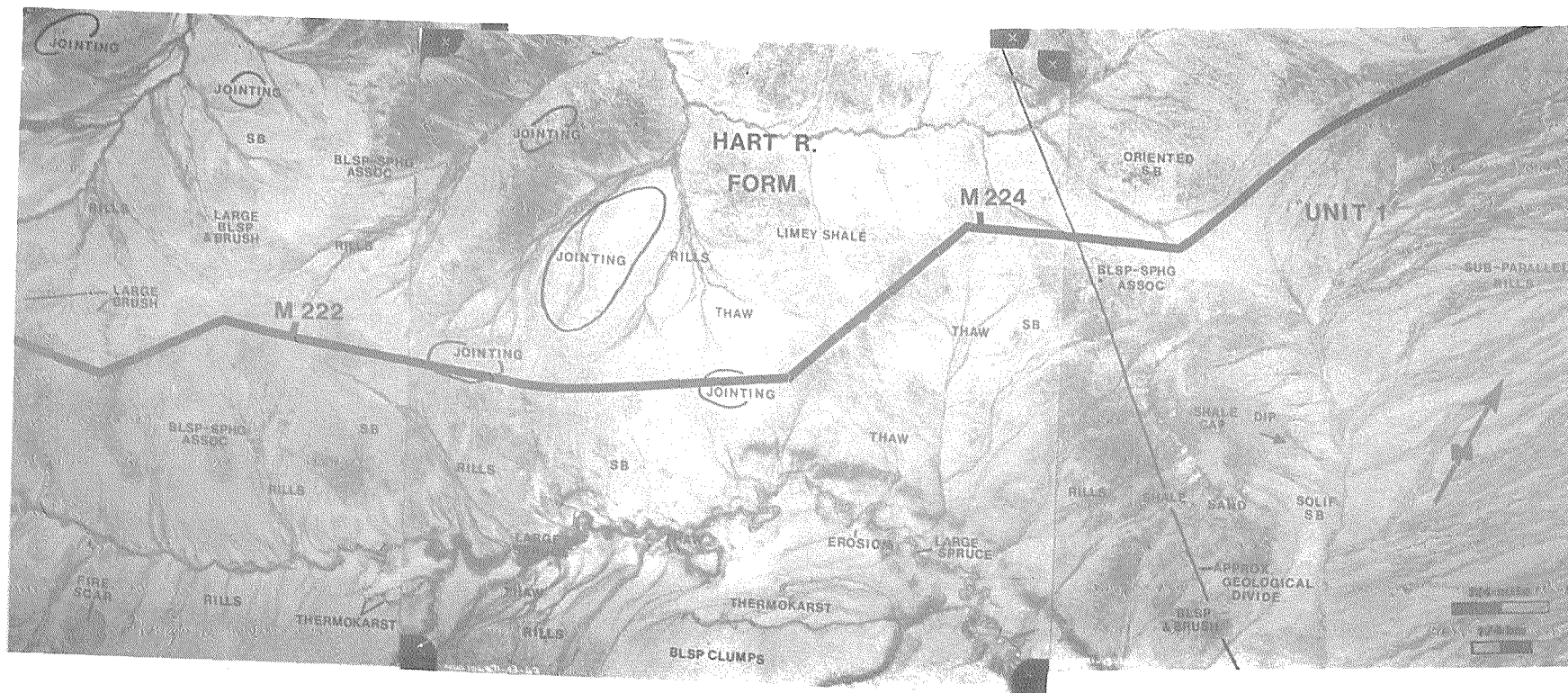


Figure 12. Shale and light-toned sandstone ridges of "Unit 1" - Western outcrop interval.

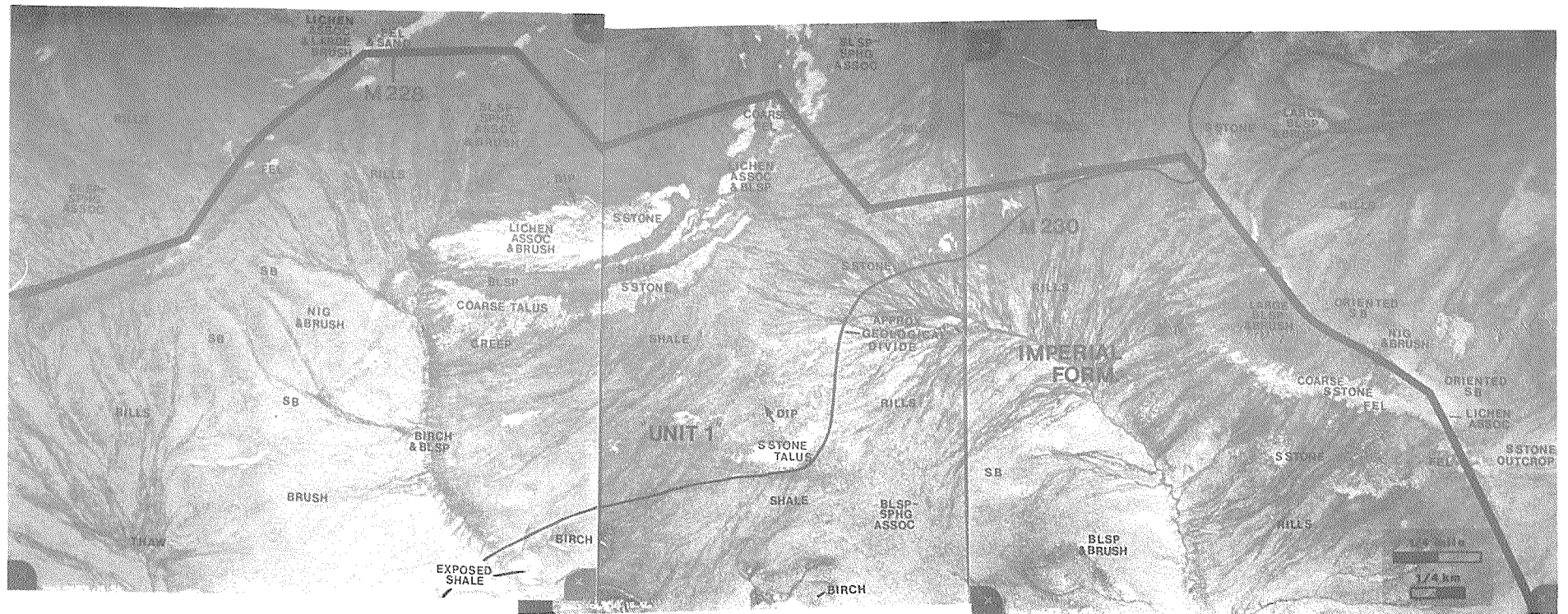


Figure 13. Sandstone and shale slopes of the Imperial Formation, western outcrop interval.

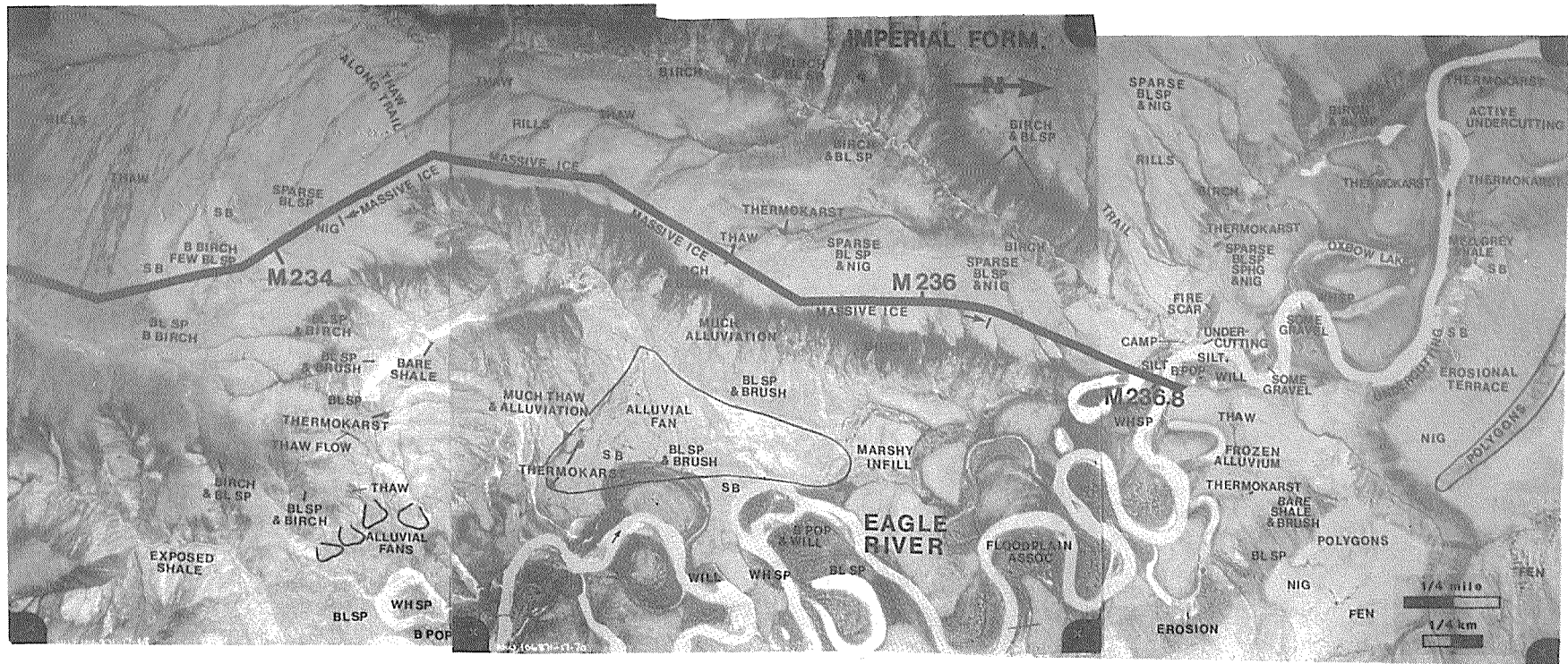


Figure 14. Floodplain of the Eagle Plain.

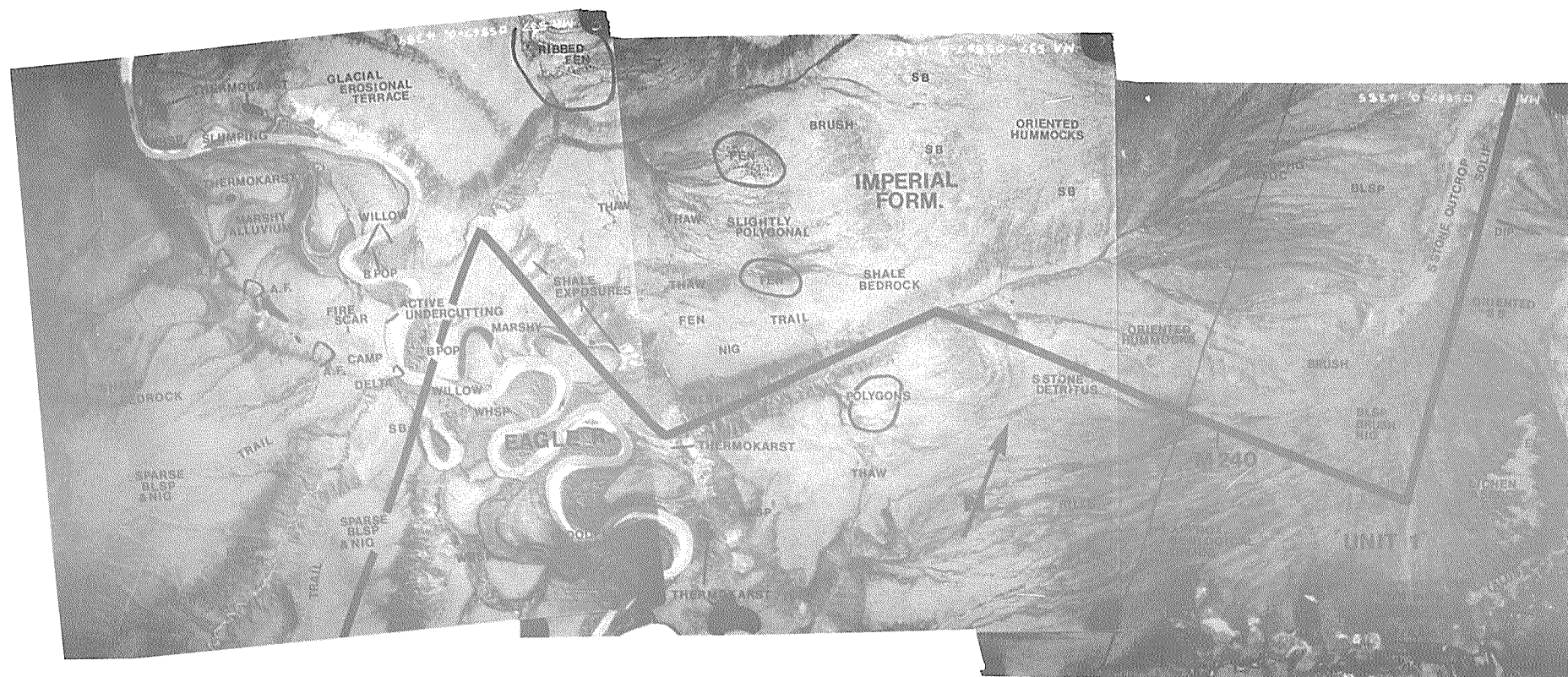


Figure 15. Dominant sandstone of "Unit i" - eastern outcrop interval.

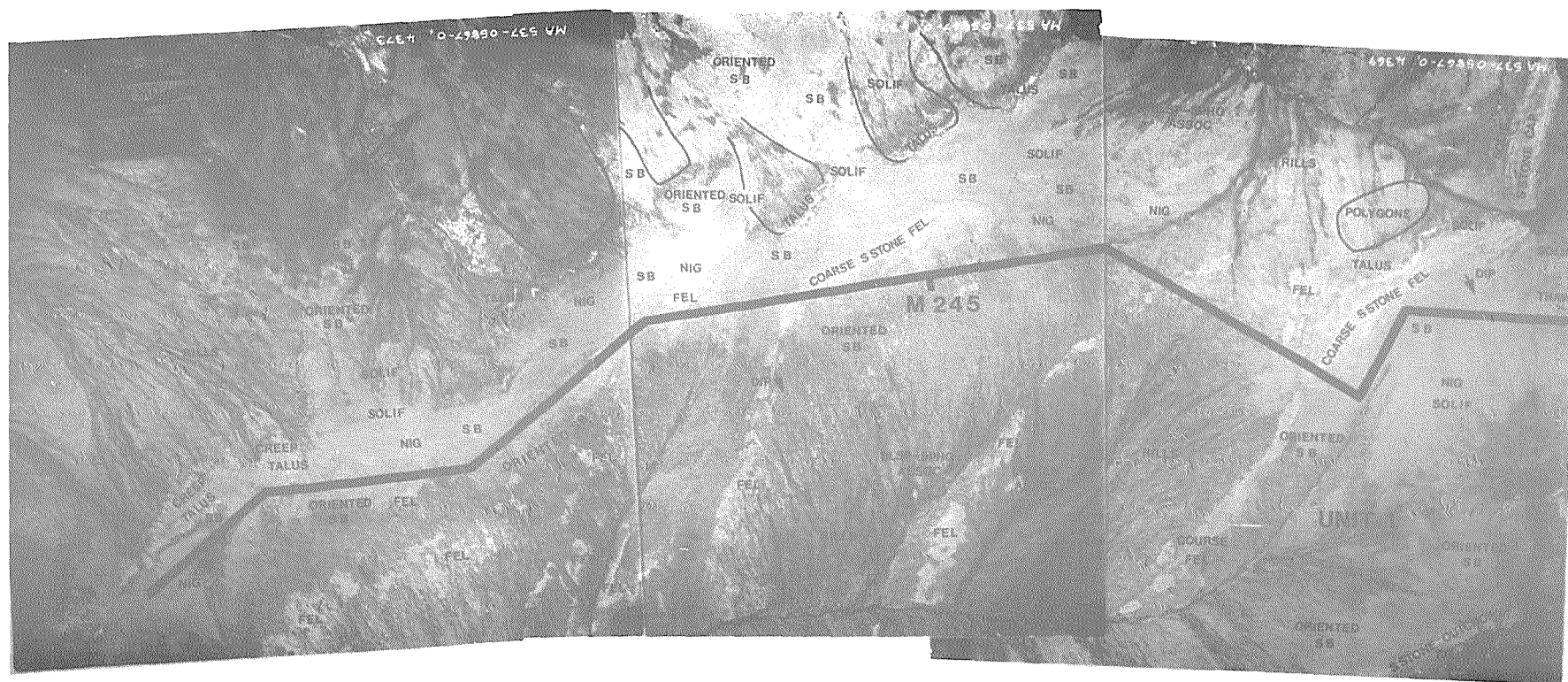


Figure 16. Finely interbedded sandstone and siltstone dominate the Imperial Formation eastern outcrop interval.

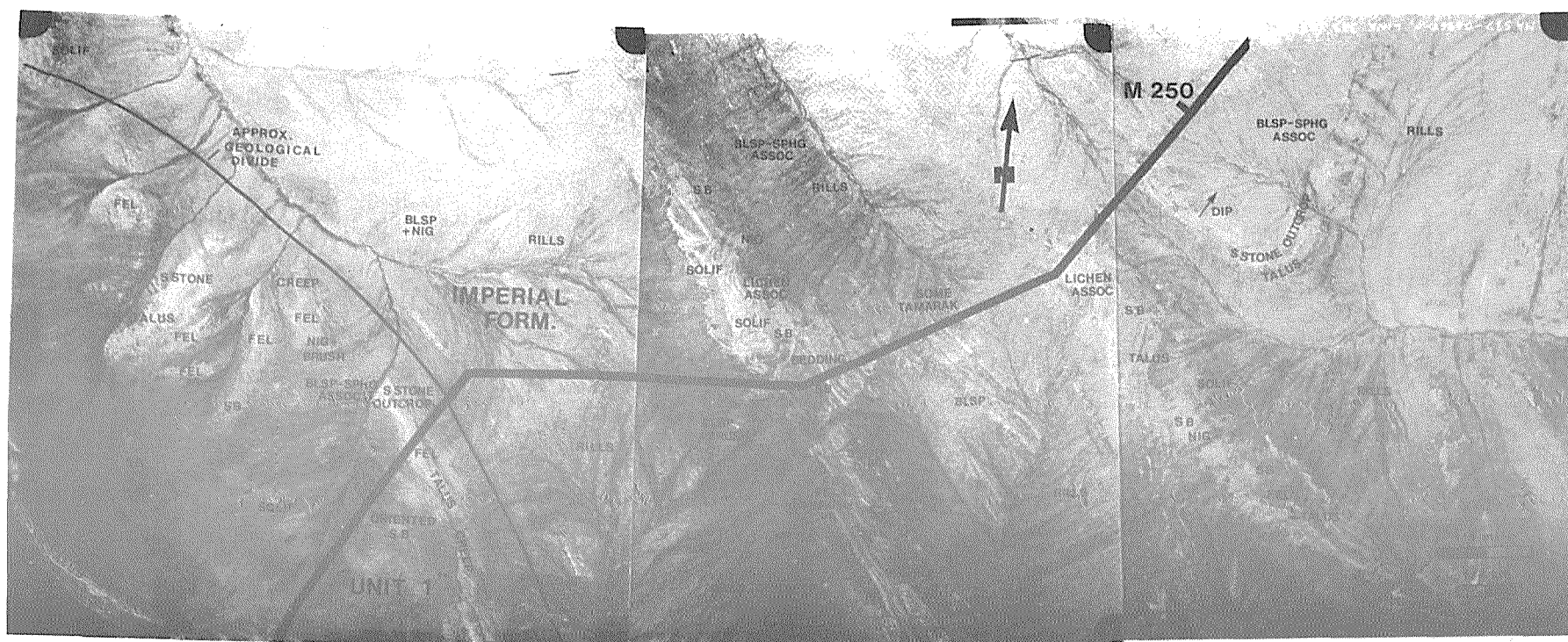


Figure 17. The pediment slope of the Richardson Mountains representing the clay shale of the Canol Formation.

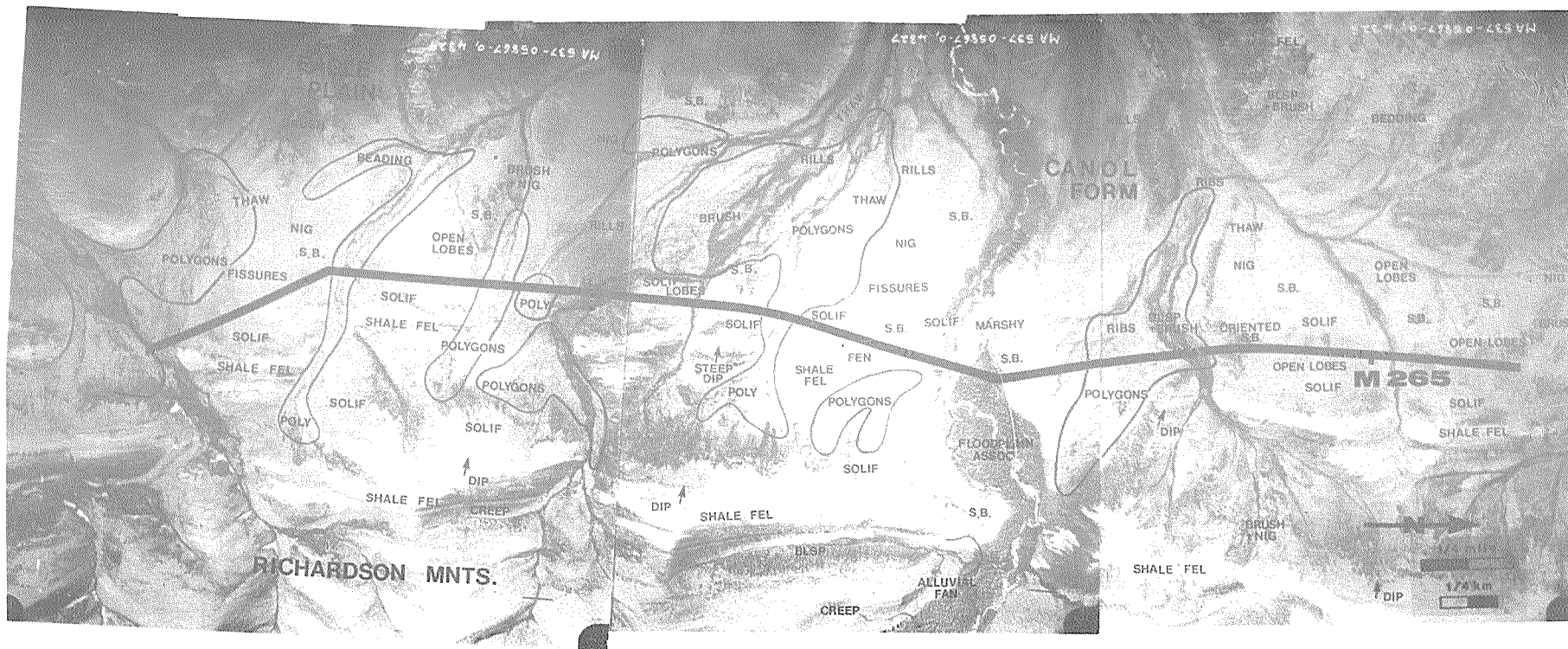
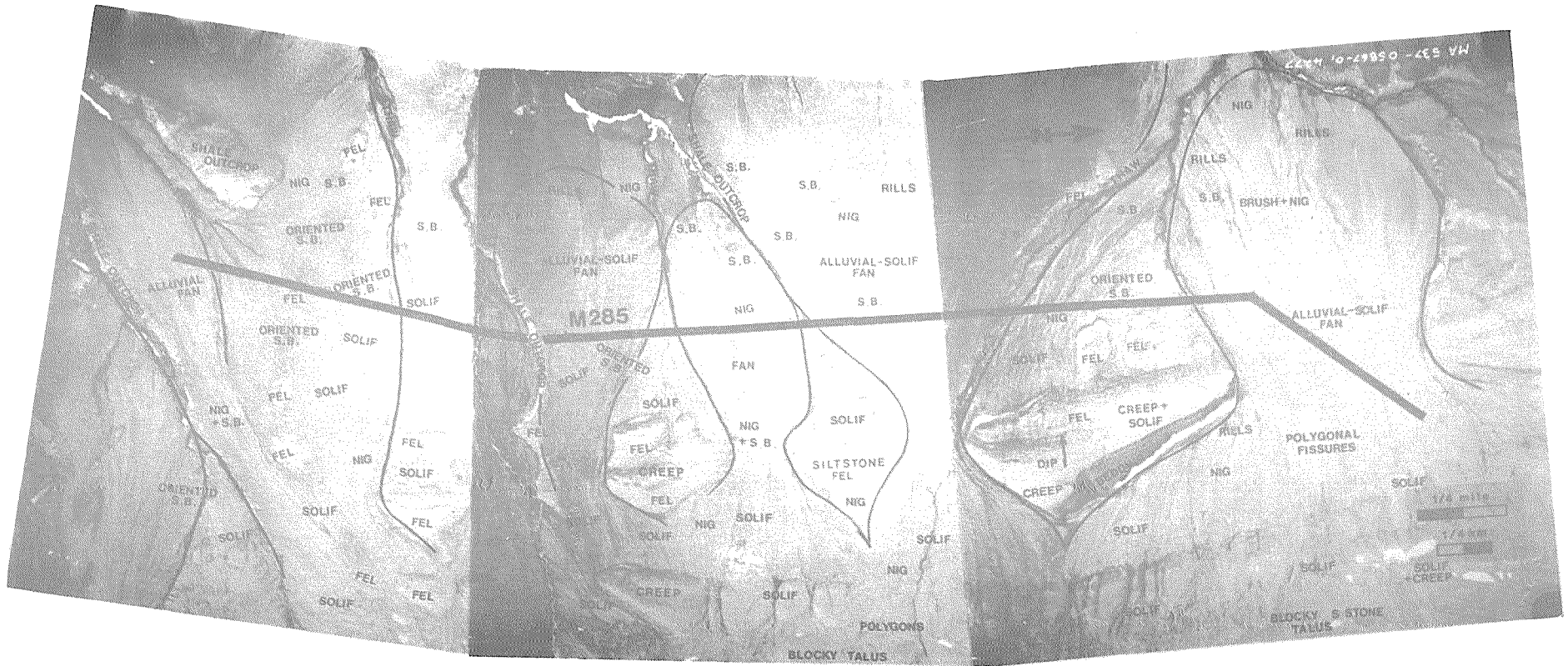


Figure 19. Large alluvial fans of the Lower Cretaceous interval.



LIST OF RESEARCH PAPERS

- | | Report No. |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Geotechnical Analysis of Pleistocene Deposits in Southern Saskatchewan
by E.K. Sauer, Presented to the 26th Annual Canadian Geotechnical Conference, Toronto, October, 1973. | RP - 1 |
| On Total, Matric and Osmotic Suction
by J. Krahn and D.G. Fredlund, Soil Science Journal, Volume 114, No. 5, November, 1972. | RP - 2 |
| Some Fatigue Considerations in the Design of Asphalt Concrete Pavements
by A.T. Bergan and R.W. Culley, Symposium on Frost Action Roads, Report II, Oslo, Norway, October, 1973. | RP - 3 |
| Characterization of Freeze-Thaw Effects on Subgrade Soils
by A.T. Bergan and D.G. Fredlund, Symposium on Frost Action Roads, Report II, Oslo, Norway, October, 1973. | RP - 4 |
| Pressure Response Below High Air Entry Discs
by D.G. Fredlund and N.R. Morgenstern, Third International Research and Engineering Conference on Expansive Soils, Haifa, Israel, August, 1973. | RP - 5 |
| Moving Grain in the 70's
by Gordon A. Sparks, Annual Conference of the Roads and Transportation Association of Canada, Halifax, Canada, October, 1973. | RP - 6 |
| Optimal Spacing of Country Elevators in Western Canada
by Gordon A. Sparks, Annual Conference of the Transportation Research Forum, Cleveland, U.S.A. October, 1973. | RP - 7 |
| Frost Action on Roads - O.E.C.D. Symposium, A Summary Prepared for North American Practice
by R.W. Culley & A.T. Bergan, presented to the Roads and Transportation Association of Canada, Annual Conference, Toronto, Sept. 1974. | RP - 8 |
| Terrain Evaluation of the Dempster Highway Across the Eagle Plain and Along the Richardson Mountains, Yukon Territory,
by N.W. Richardson and E.K. Sauer, Presented at the 27th Annual Geotechnical Conference, November, 1974, Edmonton, Alberta. | RP - 9 |