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UPPER PALEOZOIC PETROLEUM GEOLOGY AND POTENTIAL, SOUTHERN EAGLE PLAIN, YUKON TERRITORY

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ABSTRACT

Of twenty wells penetrating upper Paleozoic rocks in southern Eagle Plain, five are considered oil, gas, or oil and gas discoveries; all involve Carboniferous and Permian sandstones and limestones. These discoveries represent one of the most significant oil shows between Mackenzie Delta and northeastern British Columbia.

Southern Eagle Plain is a small structural basin in the northern Yukon formed during post-Paleozoic compression. In subsurface the general structural grain is west-east, and all upper Paleozoic units outcrop on three sides and subcrop beneath Cretaceous cover on the north side. These mixed carbonate/clastic sequences have interfingering potential reservoir and source/seal units, all with northwest-southeast or west-east facies trends.

Although subsurface control is sparse, the upper Paleozoic potential reservoir units have defineable play types and mappable play areas. Information must be extrapolated between wells which penetrate various parts of the stratigraphic column and outcrops of variable quality and reliability. The presence of numerous facies changes and several unconformities confuse correlations. Subsurface data indicate a) truncation to the north and subcrop of all units beneath the Cretaceous, b) depositional slopes and thinning of all units to the south or southwest, and c) post-Paleozoic (Laramide?) folding of all units. Although there are numerous hydrocarbon shows in rocks of Cambrian to Cretaceous ages, all five discoveries are in Early Carboniferous Hart River and Early Permian Jungle Creek formations associated with linear folds. The main potential reservoir units are Hart River limestones and sandstones, Ettrain limestones, Jungle Creek sandstones, and possibly sandstones in the Imperial and Tuttle formations. The main potential source/seal units are Imperial, Ford Lake,

and Blackie formations and Jungle Creek and Cretaceous shales. Preliminary discussions of reservoir quality and suitable reservoir distribution maps are included, as an initial attempt to define the important play types.

The main play possibilities for upper Paleozoic units are a) Laramide? linear folds trending northwest-southeast or east-west (which likely account for most discoveries to date), b) basinward facies changes to shale to the south and southwest, c) unconformity subcrop beneath thick Lower Cretaceous shale, d) thin sandstone bodies encased in thick shale packages. Although Lower Paleozoic potential is small due to overmaturity, major basinward facies changes to shale occur toward the east throughout the Cambrian to Devonian carbonate sequence.

INTRODUCTION

In 1960 Western Minerals Chance #1 was spudded on the Chance Anticline north of Ogilvie Mountains in the northern Yukon. After penetrating Upper Devonian shales, high gas and oil flow rates were obtained from Carboniferous sandstone and limestone, and it became the first significant oil discovery north of 60°N since Norman Wells. Since that time, a total of nineteen more wells and thousands of kilometres of reflection seismic lines in southern Eagle Plain have helped elucidate the geology of this part of the Basin. Drilling in the 1960's led to four additional oil and gas discoveries, all from Upper Paleozoic reservoirs of the southern area, but more recent drilling has been disappointing. These hydrocarbon shows are the only Upper Paleozoic discoveries (and the only pre-Mesozoic oil except Norman Wells) in the Territories. It is important to note that the basin is in a relatively early stage of exploration with sparse subsurface control and only reconnaissance biostratigraphic/maturation data.

Eagle Plain is an intermontane basin which straddles the Arctic Circle in northern Yukon, about 200 kilometres southwest of Mackenzie Delta. It lies between Richardson Mountains to the east, the Porcupine River to the north and Ogilvie Mountains to the west and south (Fig.1). The southern part of the basin (65°30′ to 66°30′N, 136°00′ to 139°0′W) is an area about 10 000 square kilometres with significant petroleum exploration history, discoveries and potential, and is the focus of this paper. This preservational basin with subdued topography contains rocks of Cambrian to Cretaceous ages and is surrounded on the west, south and east by uplifted outcrop (and subcrop, to the north) belts of these subsurface units allowing close correlation between well and outcrop data.

My purpose is to focus attention on the area again by extracting and collating those parts of the excellent previous work of Bamber and Waterhouse (1971), Graham (1973), Martin (1972, 1973) and Pugh (1983), which bear upon hydrocarbon play definitions. I have incorporated my own core descriptions and subsurface mapping of individual reservoir units but have relied heavily on recently published maps (Norris, 1981, 1982, 1984) to delineate the distribution of potential reservoirs. The overall objective of this report is to more closely define and illustrate play concepts and play areas. My current work is concentrated on the Upper Paleozoic which includes all discoveries to date, but Mesozoic and Lower Paleozoic sequences also have good potential. This paper represents only a brief summary of preliminary work, meant to introduce the basic concepts of the area and act as background for more detailed study.

REGIONAL GEOLOGY

Tectonic Setting

During the Early Paleozoic northern Yukon was a relatively stable cratonic area (Porcupine Platform, Jeletzky, 1962) with predominantly shallow water carbonate deposition. These sediments passed through a major carbonate to shale facies change eastward into Richardson Trough, a rift-controlled(?) basin (Cecile, 1982, 1986) which persisted from Cambrian to Middle Devonian. This part of the stratigraphy approximately mirrors that east of Richardson Trough, indicating the northern Yukon was always a part of the North American Craton (Jeletzky, 1962; Pugh, 1983).

Upper Paleozoic facies belts first trended northwest-southeast along the western margin of the craton but were re-oriented to east-west or northeast-southwest as the Ancestral Aklavik Arch became active (Bamber and Waterhouse, 1971). A series of tectonic pulses from Late Devonian to Permian time resulted in several clastic wedges which are an integral part of the stratigraphy. Throughout the Upper Paleozoic shallow water clastic and carbonate facies pass south or southwest into predominantly basinal shale now exposed in the Ogilvie Mountains. According to evidence discussed by Bamber and Waterhouse (1971), northern Yukon likely lay at an approximate paleolatitude of 45°N during Late Paleozoic time.

Lower Mesozoic deposits are not preserved in southern Eagle Plain but thick sequences of Cretaceous sediments suggest the formation of a depositional (and now preservational) basin in the northern Yukon associated with Cordilleran deformation. The preserved extent of Cretaceous sediments outlines the limits of Eagle Plain basin.

Structural Setting

Eagle Plain basin is a structural depression surrounded by deformed belts which bring Paleozoic rocks to surface on all sides. Eagle Arch (Norris, 1981b), a pre-Mesozoic upwarp of Paleozoic strata beneath Eagle Plain and trending west-east, has resulted in deformation of the Paleozoic section into an elongate bowl-shape in the southern area. Thus the Upper Paleozoic potential reservoirs of southern Eagle Plain, which subcrop beneath the Mesozoic cover, are naturally isolated from those further north. Presumed Laramide-related linear anticlines, trending north-south or northwest-southeast, provide ample opportunity for localizing hydrocarbons and appear to account for all discoveries to date. These folds are up to 100 kilometres long, have up to hundreds of metres of closure, and affect the entire stratigraphic section.

The presence of the subsurface Eagle Arch to the north, the surface outcrop belt of Ogilvie mountains to the south, numerous anticlinal structures, and the thick Mesozoic cover all combine to produce a complex but favourable structural setting for hydrocarbon accumulation in the Paleozoic of southern Eagle Plain (Fig. 2).

General Stratigraphy and Depositional History

Details of the Paleozoic stratigraphy have been elucidated by Bamber and Waterhouse (1971), Martin (1972, 1973), Graham (1973), Miall (1973),and Pugh (1983) and only a brief summary is included here (see Figs. 3 and 10). Very thick Cambrian to Silurian dolomites ("Ronning"), thought to unconformably overlie Precambrian rocks, pass eastward and upward into a thick basinal shaley facies (Road River) of Richardson Trough (Pugh, 1983). This sequence is unconformably overlain by Lower and Middle Devonian dolomites (Kutchin or Gossage, Norris, 1985) and limestones (Ogilvie) which also pass eastward into basinal shale facies of Richardson Trough (Michelle and Road River).These major facies changes, striking approximately northwest-southeast at the eastern side of Eagle Plain basin, are not well documented in subsurface but should constitute a prime exploration target. Basinal shale facies could form a major potential source/seal sequence, and the adjacent carbonates represent significant potential reservoirs. Only five wells in southern Eagle Plain have penetrated Middle Devonian or older units, and two of these have recovered minor gas indications on DST (Fig. 4).

Thick marginal marine Upper Paleozoic sediments are a mixture of clastics and carbonates (see Fig. 5) and reflect a major change in the regional tectonic setting and sedimentation style. Carboniferous and Permian facies belts in Eagle Plain trend north-south in the west, and west-east in the south. Sediment source areas were to the north and northeast (Bamber and Waterhouse, 1971).

The Middle to Upper Devonian and Lower Carboniferous Canol, Imperial and Ford Lake formations are thick wedges of dark fine grained clastics. They thin to the south and southwestward into the basinal area and pass northeastward toward Richardson Mountains into a coarse grained clastic facies known as the Tuttle Formation (Pugh, 1983), (Fig. 5). This sediment package is related to contemporaneous uplift northeast of Eagle Plain, and whereas the shales represent a major potential source rock sequence, the enclosed sandstones have some reservoir potential.

Lower Carboniferous Hart River shallow shelf carbonates and clastics conformably succeed and pass southwest into the Ford Lake in the Eagle Plain subsurface and include the major reservoir units, (Fig.6). These are conformably overlain by Blackie Formation (Pugh, 1983) basinal spicular shale which in turn passes upward and northeastward into Unit 2 sandstone (Bamber and Waterhouse, 1971) and Ettrain Formation skeletal grainstone, the result of a Late Caroniferous period of quiescence, transgression and progradation. The Blackie may be a potential source/seal rock whereas the regressive shelf edge Ettrain carbonates have reservoir potential. Early or pre-Permian regional erosion and uplift to the north truncated part of the earlier sequences. The Lower Permian Jungle Creek Formation disconformably overlies older Paleozoic units in outcrop and a few southern Eagle Plain wells, (Fig. 6). A lower shale member (prominent in outcrop) and an upper shale member (preserved beneath the sub-Mesozoic unconformity in only a few wells) enclose a middle sandstone facies with major reservoir potential.

A total of twenty-one wells have penetrated Upper Paleozoic units and of these sixteen have recovered hydrocarbon indications on DST, of which five are considered as significant oil or gas discoveries (Fig. 7). I will discuss these reservoirs in more detail later.

Early Cretaceous deformation resulted in deposition of Cretaceous sediments which unconformably overlie the Upper Paleozoic. Thick Lower Cretaceous dark shale and siltstone with subtle coarsening-upward sequences act as an extensive seal rock over all older potential reservoirs and may have source rock potential. The Upper Cretacoeus Eagle Plain Formation, exposed at surface throughout the basin, comprises interbedded dark siltstone and fine grained sandstones. At the base is a marine sandstone (referred to in subsurface data as the "Blackie sandstone") which has tested minor to significant gas flows on DST. A total of eighteen wells have penetrated Cretaceous units in the study area and, of these, six have recovered gas shows on DST (Fig. 8).

The presence of the subsurface Eagle Arch, the sub-Cretaceous and sub-Permian unconformities, the interbedding of potential reservoir and source/seal rocks, and shelf to basin facies changes all combine to produce a complex but favourable setting for stratigraphic trapping in southern Eagle Plain. The stratigraphic and structural factors combine to form a local exploration province where play areas are confined and well-defined (65°50′ to 66°30′N, 136°30′ to 138°30′W) and play types are easily conceptualized for each potential reservoir unit (Fig. 6).

PETROLEUM GEOLOGY

Well Control and Method

Subsurface control in southern Eagle Plain is sparse (Fig. 9): only twenty wells penetrate some part of the Upper Paleozoic, and only four wells penetrate beneath the Devonian (Fig. 10). Most have been located on surface features overlying seismically-defined anticlines; either linear anticlines which appear to effect the entire stratigraphy, or deeper anomalies at the Devonian level. The several stratigraphic trap possibilities have not yet been tested systematically.

Hydrocarbon Shows and Discoveries

Of eleven wells drilled in southern Eagle plain to 1968 five were discoveries (one oil, two oil and gas, two gas) in Lower Carboniferous Hart River and Permian Jungle Creek formations and have "significant discovery areas" designated by Canada Oil and Gas Lands Administration (Fig. 11). All are associated with Laramide linear anticlines, the most likely trap mechanism. Approximate reserves for the area total up to $2.8 \times 10^9 m^3$ gas and $3.1 \times 10^6 m^3$ oil (T. Bird, COGLA, 1989, pers. comm.). In addition, there are minor gas shows and potential reservoir rocks in virtually every stratigraphic unit from Cambrian to Cretaceous. The best Upper Paleozoic potential reservoir rocks occur in Hart River, Jungle Creek and Ettrain formations, with minor potential in Imperial and Tuttle formations. Canol, Imperial, Ford Lake, Blackie, Jungle Creek and Albian shale formations all include potential source/seal rocks.

In particular, the Ford Lake Formation appears to be an oil and gas potential source rock. It is mature to marginally mature in southern Eagle Plain with a mixture of Type II and III organic matter and total organic carbon (T.O.C.) values up to 4% (Link and Bustin, 1989 a,b). In the Chance #1 well there is a hydrocarbon - depleted zone in the upper part of the Ford Lake and it represents the most likely source of the oil discoveries in the Chance Sandstone (Link and Bustin, 1989 a,b). The Imperial formation has moderate amounts of Type III organic matter (T.O.C. about 1%), is overmature with respect to oil, but could generate some gas (Line and Bustin, 1989 a,b). Limited data from the Blackie Formation suggests T.O.C. up to 5%, and the Type II and III organic matter is mature to marginally mature with some free hydrocarbon present in the Birch B-34 well (Link and Bustin, 1989 a,b). Analysis of palynomorphs and organic matter from the Ford Lake and Hart River formations in southeastern Eagle Plain indicate low to moderate maturity (Thermal Alteration Index 2 to 3+, conodent Colour Alteration Index 2 to 2.5) (Utting, 1989). Both units contain abundant amorphous kerogen suggesting they represent potential source rocks. Black bituminous shale of the Canol Formation has significant amounts of type II and III organic matter (T.O.C. up to about 9%) but probably became thermally mature in the Late Paleozoic and is currently overmature (Link and Bustin, 1989 a,b).

Seismically-Defined Factors

Graham (1973) published one north-south seismic line 26 kilometres long from near Chance G-08 toward the southern margin of the basin near South Chance D-63. I have included one northwest-southeast line 16 kilometres long from Chance #1 to the Blackie area (Fig. 12) (non-confidential, supplied by T. Bird, C.O.G.L.A.). Together they illustrate several important points relating to the petroleum potential of the Upper Paleozoic sequence in southern Eagle Plain as suggested by Graham (1973).

Briefly these are:

1) bowl-shaped basin with (Laramide) anticlines affecting Devonian to Cretaceous rocks (eg. Chance and Daglish anticlines),
2) southward depositional thinning of all units with convergence of dipping reflectors indicating a basinal depositional slope toward the south or southwest,
3) truncation of Upper Paleozoic units where they rise over Eagle Fold Belt to subcrop beneath the thick Albian shale,
4) limited extent of preserved Ettrain limestone,
5) limited preservation and angular discordance of the Jungle Creek Formation, present only as a thin wedge between two unconformities,
6) continuous south-dipping reflectors in Imperial-Ford Lake shales, possibly representing sandstone bodies.

In addition, the lines illustrate the presence of large closed antiformal structures on the top of the Middle Devonian Ogilvie Formation. These are independent of the Laramide anticlines which affect the entire stratigraphy and are also apparent on released time-structure maps on the top of the Ogilvie (Chevron Standard Ltd., 1971).

Main Reservoir Units

Hart River Formation, lower limestone member

The lower half of the Hart River (Fig. 13) consists of thinly bedded micritic crinoidal limestone with interbeds of dolomite, chert, and dark bioturbated shale. In the southeast, beyond the main area of shallow marine carbonate deposition, the basal part may have thin interbeds of well burrowed, laminated very fine to coarse grained sandstone and siltstone.

The structural low axis for the Hart River trends west-east, located just south of the Chance and Birch wells (Fig. 14). The lower limestone member rises northward to a subcrop erosional limit along a belt 15 km wide by 75 km long just north of the Chance wells, and rises southward to outcrop at the southern margin of the basin: a maximum potential play area of 60 km by 75 km (Fig. 15). Up to 500 m of clean carbonate thins markedly to the south toward outcrop. Generally porosity is fair though fracturing is common. The unit has tested good flows of gas (up to 283 x $10^3 m^3/d$), oil (up to 290 m) and salt water at the Chance #1, J-19 and G-08 wells.

Hart River Formation, Chance Sandstone Member (Martin, 1972)

Thick units (3-50 m) of grey to buff, salt-and-pepper, very fine to very coarse grained sandstone (generally fine to medium grained) occur in the middle part of the Hart River. They are fair to well sorted, bedded or massive and uniform, may have low angle lamination and some floating pebbles. Interbedded dark sandy burrowed siltstones, oil stain and calcite cement are common. The sandstone is generally porous and permeable, with porosity ranging 5-22% (generally 10-15%) and permeability ranging 0-2000 md (generally 100-500 md) (core analysis and porosity logs). Figure 16 illustrates a sample core description from Chance #1.

The structural low axis for the Hart River trends west-east just south of the Chance wells (Fig. 14) and this unit rises northward to subcrop just north of this in a belt 10 km wide by 40 km long trending west southwest-east southeast at the Chance wells. Up to 130 m of clean sandstone, thickest at the Chance wells, thins depositionally southward, eastward and westward to zero before outcrop (Fig. 17). The maximum potential play area is 30 km by 50km. The unit has tested minor to good gas flows (up to 230 x $10^3 m^3$/d) and good oil or condensate recoveries (up to 610 m). The Chance sandstone represents four of five discoveries to date in Eagle Plain Basin and has been the main exploration target.

Hart River Formation, upper limestone member

Preserved above the Chance sandstone in many wells are interbedded buff micritic limestones and dark calcareous shales. These sediments typically have abundant crinoid fragments, burrowing and minor thin very fine sandstone beds. Porosity is poor to fair and reservoir quality is less than the other members of the Hart River.

The structural low axis for the Hart River trends west-east (Fig. 15) and the unit rises northward to an erosional limit at the Chance wells, forming a subcrop belt 3 km wide by 75 km long. Up to 200 m of clean carbonate thins southward to outcrop at the southern margin of the basin (Fig. 19): a maximum play are of 40 km by 75 km. Two DST's have recovered very minor gas shows at the subcrop limit on the Chance anticline.

Ettrain Formation

In a few wells and in outcrop on the west and east sides of southern Eagle Plain basin is preserved light brown skeletal and cherty limestone (Fig. 19). This regressive shallow marine shelf margin sandy packstone is relatively poorly known in subsurface but may have fair porosity and reservoir quality.

The structural low axis for the Ettrain trends west northwest-east southeast near the position of the Blackie M-59 well (Fig. 20). The unit rises northward to an erosional limit south of the Chance wells forming a west-east subcrop belt 5 km wide y 50 km long. At least 226 m of clean carbonate, with thickest preservation in the western subsurface, thins to an erosional limit beneath the sub-Permian unconformity to the north, and to the south (Fig. 21): a maximum play area of 30 by 75 kilometres. The underlying and correlative Blackie Formation may be a potential source rock, but only one DST has recovered gas and lack of adequate seal rock may decrease the potential.

Jungle Creek Formation, middle sandstone member

Thick units (3-30 m) of sandstones occur in a few wells preserved between unconformities (Fig. 22). The sandstone is light to dark grey, salt and pepper, very fine grained to conglomerate (but generally medium to coarse grained sandstone with some pebble beds). There are thin interbeds of burrowed fine sandstone or siltstone, and the sandy facies thins to the south. Beds are generally up to 1 m thick, commonly massive or with vague low angle lamination, and with radically varying grain sizes. The sandstone is poor to well sorted and porosity and permeability are fair to excellent. Porosity ranges 5 to 23% (generally 15 to 20%) and permeability ranges 0 to 22000 md (generally 100 to 200 md) (core analysis and porosity logs). Figure 23 illustrates a sample core description from Blackie M-59.

The structural low axis for Jungle Creek Formation trends west-east and the unit rises to the north to a subcrop belt 15 km by 75 km south of the Chance wells (Fig. 24). There is up to 166 m of clean sandstone known updip from the structural low and there is a maximum play are of 30 km by 75 km (Fig. 25). A number of DST's have recovered minor to good gas flows up to 99 x 10^3 m^3/d and there is one oil-cut mud recovery. One gas discovery in southern Eagle Plain (Blackie M-59) is from the Jungle Creek sandstone and this is the obvious secondary target horizon in the Upper Paleozoic. The unit resembles and is correlative to the productive Echooka Member (Saddlerochit Formation) of Prudhoe Bay.

SUMMARY OF PLAY POSSIBILITIES

Structural Traps

Laramide Folds, Upper Paleozoic Reservoirs

Laramide-related linear anticlines trending north-south or northwest-southeast provide the best known trap possibilities. They are up to 100 km long and often double-plunging, with up to hundreds of metres of closure (Martin, 1973). These affect the entire Upper Paleozoic and Mesozoic sections, where there are many interbedded reservoir and seal units, and are expressed on seismic and at surface (Norris, 1984). They are numerous and likely account for at least four of the five discoveries to date (Chance #1, Chance G-08, Birch B-34, Blackies M-59) in Chance and Jungle Creek sandstones (Fig. 27).

Stratigraphic Traps

Basinward Facies Changes, Upper Paleozoic Reservoirs

A series of Upper Paleozoic "reservoir to nonreservoir" facies changes occur in the basinal (south or southwest) direction, updip toward the outcrop belts at the southern margin of the basin (Fig. 27). These include thinning and/or pinchout of Hart River limestone, Chance sandstone, Unit 2 sandtone, Ettrain limestone and Jungle Creek sandstone. They could be mapped by correlation of well, seismic and outcrop data. The play type is subtle and has received little attention to date, although the minor gas show from the Jungle Creek at S. Chance D-63 may be of this variety.

Thin Sandstones in Upper Paleozoic-Mesozoic Shales

Thin but extensive porous sandstone bodies are present in the shale packages of the Upper Paleozoic and Cretaceous. These are encased in potential source/seal rock, some have fair to good reservoir quality and can be correlated with seismic reflectors. These include sandstones in the Imperial (minor gas show), Ford Lake, Albian shale (minor gas shows) and Eagle Plain Formation (minor gas shows). Exploration for subtle traps with restricted play areas and thin reservoirs would be difficult with the present limited data and understanding.

Basinward Facies Changes, Lower Paleozoic Reservoirs

The Lower Paleozoic carbonate sequences of Porcupine Platform pass through major facies changes updip to shale into Richardson Trough on the eastern and northern sides of Eagle Plain Basin. The facies fronts are seismically-mappable (Chevron Standard Ltd., 1971) and a minor gas show from the Ogilvie (South Tuttle N-5) offers encouragement. This play may have some potential for the future although data currently available suggests the rocks are overmature (Link and Bustin, 1989 a,b).

Stratigraphic/Structural Traps

Unconformity-Subcrop, Upper Paleozoic Reservoirs

In southern Eagle Plain Basin all Upper Paleozoic units rise structurally toward the north (Eagle Fold Belt) to subcrop under the Lower Cretaceous shale in a belt about 40 km wide by 80 km long. Potential reservoir and source rocks are interbedded throughout the sequence and the entire belt is overlain by thick Albian shale, a potential seal rock (Fig. 27). Each of the potential reservoir units has a relatively narrow subcrop belt which can be mapped with geological and geophysical subsurface data. Some of the present test shows and discoveries may reflect this play type: for example, the gas and oil discovered at Chance J-19 is apparently trapped in Chance sandstone at subcrop.

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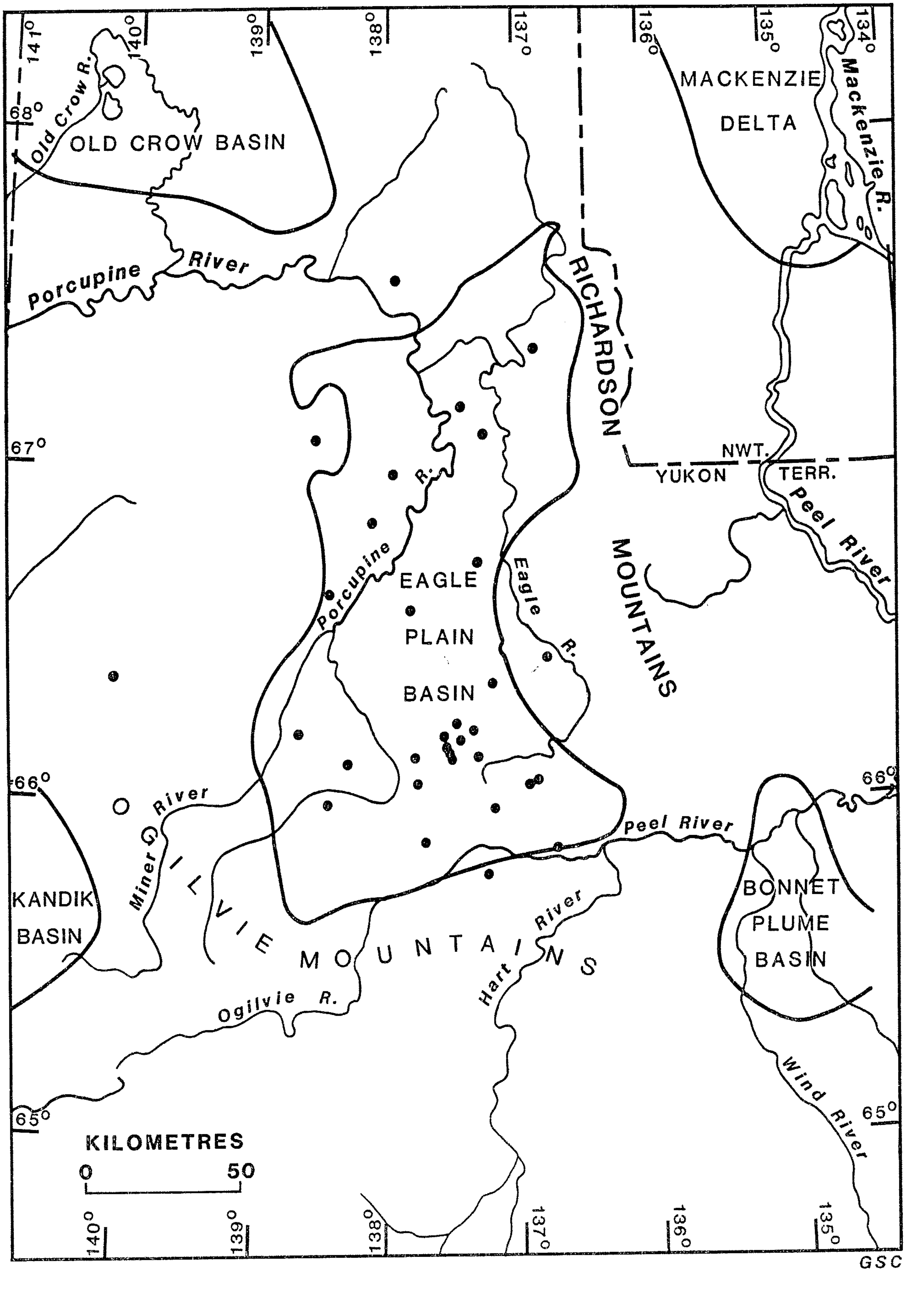
LIST OF FIGURES

FIGURE 1.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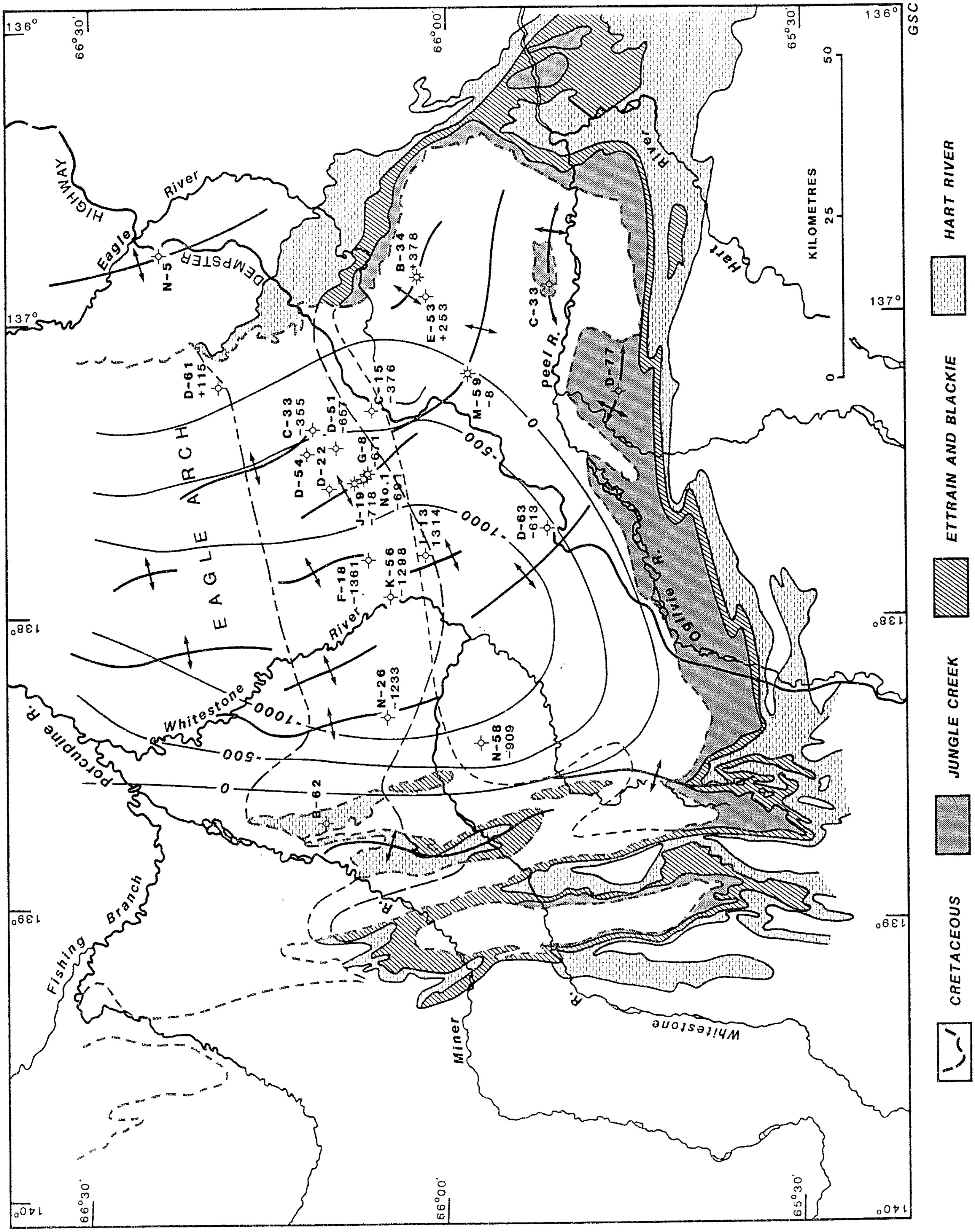
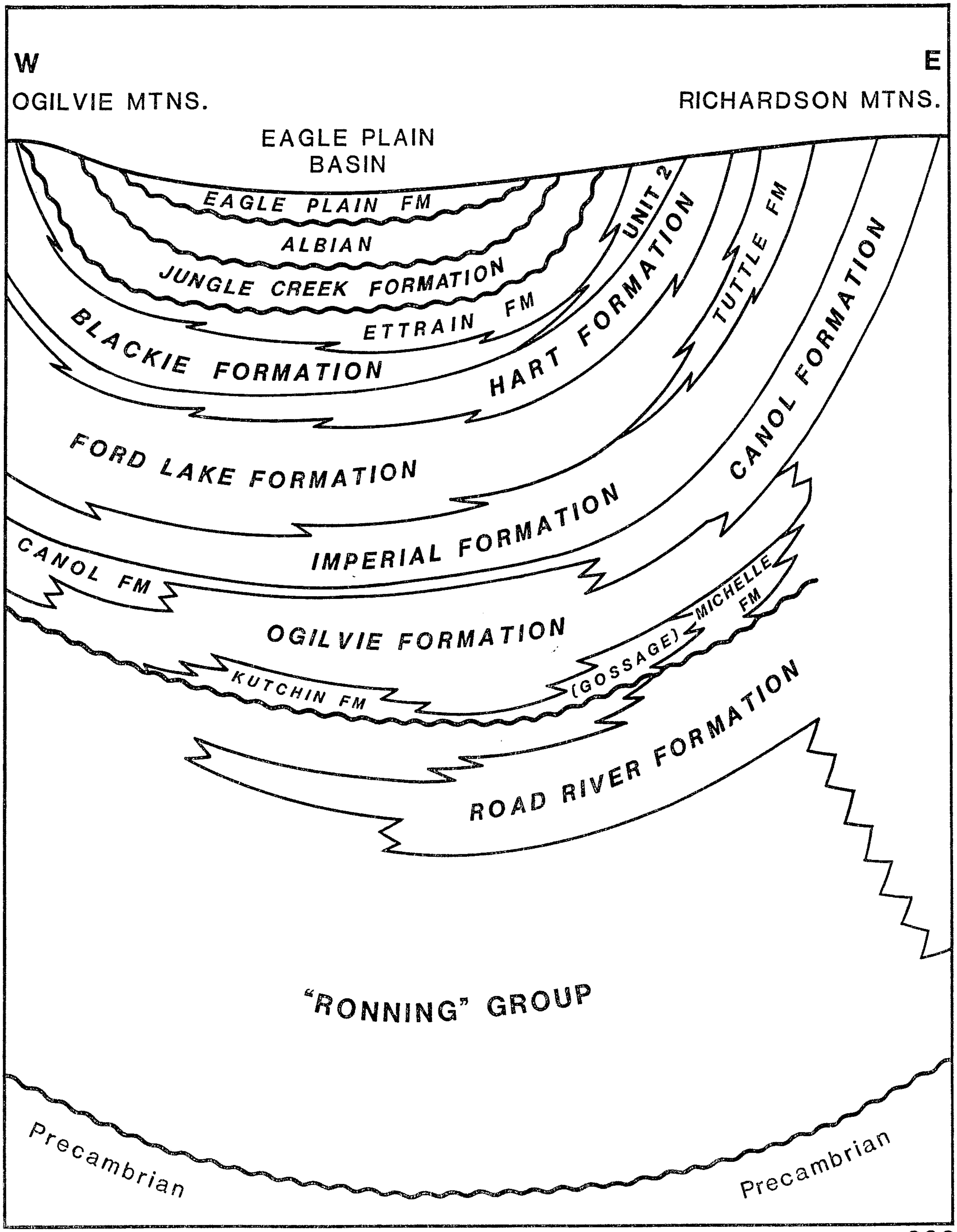
Old Crow R.
Porcupine River
MACKENZIE
DELTA
Mackenzie R.
RICHARDSON
MOUNTAINS
NWT.
YUKON TERR.
Peel River
EAGLE
PLAIN
BASIN
Porcupine R.
Eagle R.
Miner River
OGILVIE MOUNTAINS
Peel River
Hart River
Ogilvie R.
KANDIK
BASIN
BONNET
PLUME
BASIN
Wind River
KILOMETRES
0
50
141°
140°
139°
138°
137°
136°
135°
134°
68°
67°
66°
65°
GSC

FIGURE 2.



136°
66°30'
66°00'
65°30'
136°
137°
138°
139°
140°
GSC
KILOMETRES
0
25
50
DEMPSTER
HIGHWAY
Eagle
River
EAGLE ARCH
Peel R.
Hart
River
Ogilvie R.
Whitestone
River
Porcupine R.
Fishing Branch
Miner
R.
Whitestone
N-5
D-61
+115
C-33
-355
D-51
-657
D-54
D-22
G-8
-671
J-19
-718
No.1
-691
C-15
-376
B-34
+378
E-53
+253
C-33
M-59
-8
D-77
D-63
-613
F-18
-1361
K-56
-1298
I-13
1314
N-26
-1233
N-58
-909
B-62
0
-500
-1000
CRETACEOUS
JUNGLE CREEK
ETTRAIN AND BLACKIE
HART RIVER

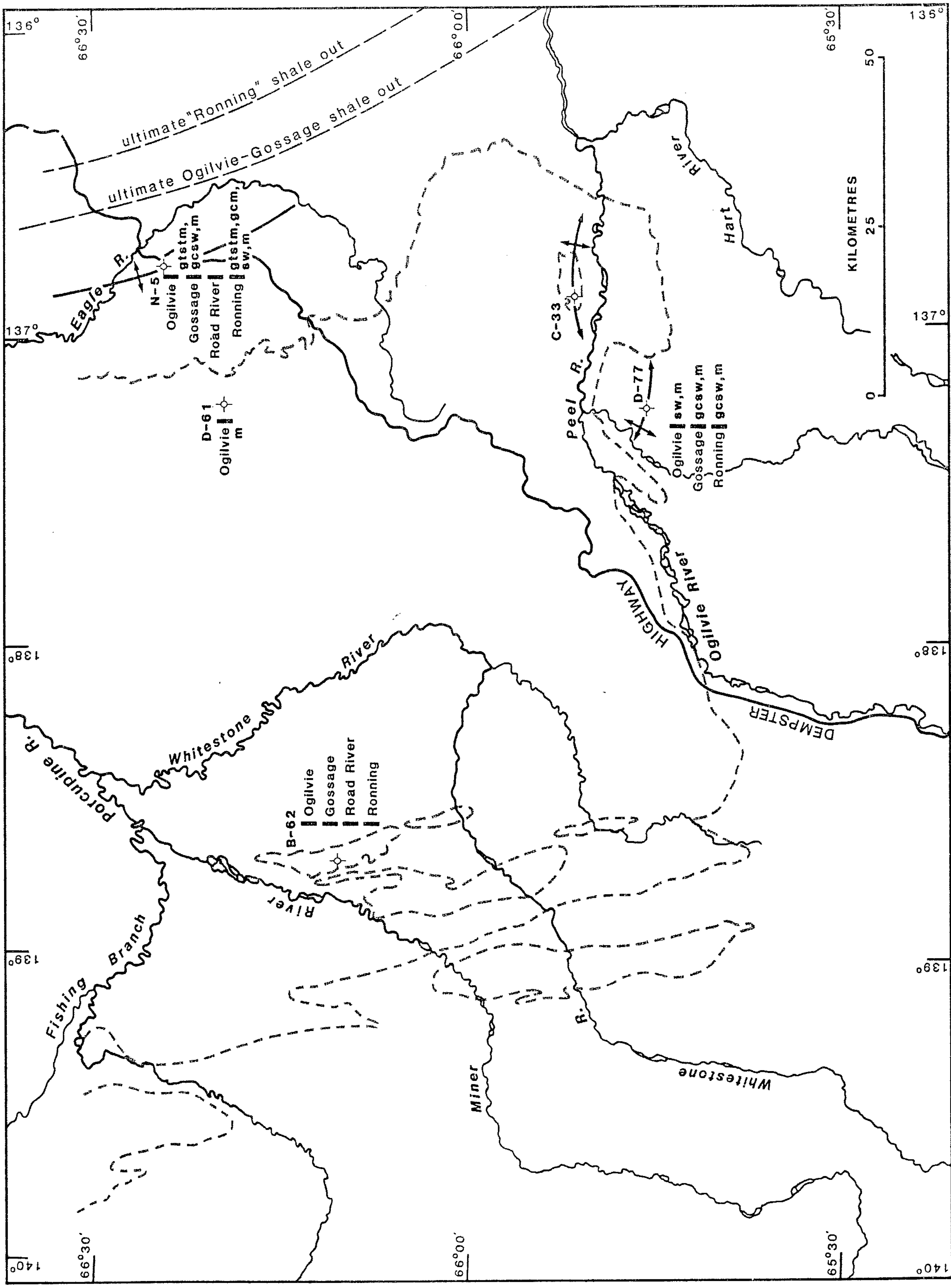
FIGURE 3.



W
E
OGILVIE MTNS.
RICHARDSON MTNS.
EAGLE PLAIN BASIN
EAGLE PLAIN FM
ALBIAN
JUNGLE CREEK FORMATION
UNIT 2
ETTRAIN FM
BLACKIE FORMATION
HART FORMATION
TUTTLE FM
CANOL FORMATION
FORD LAKE FORMATION
IMPERIAL FORMATION
CANOL FM
OGILVIE FORMATION
MICHELLE FM
(GOSSAGE)
KUTCHIN FM
ROAD RIVER FORMATION
"RONNING" GROUP
Precambrian
Precambrian

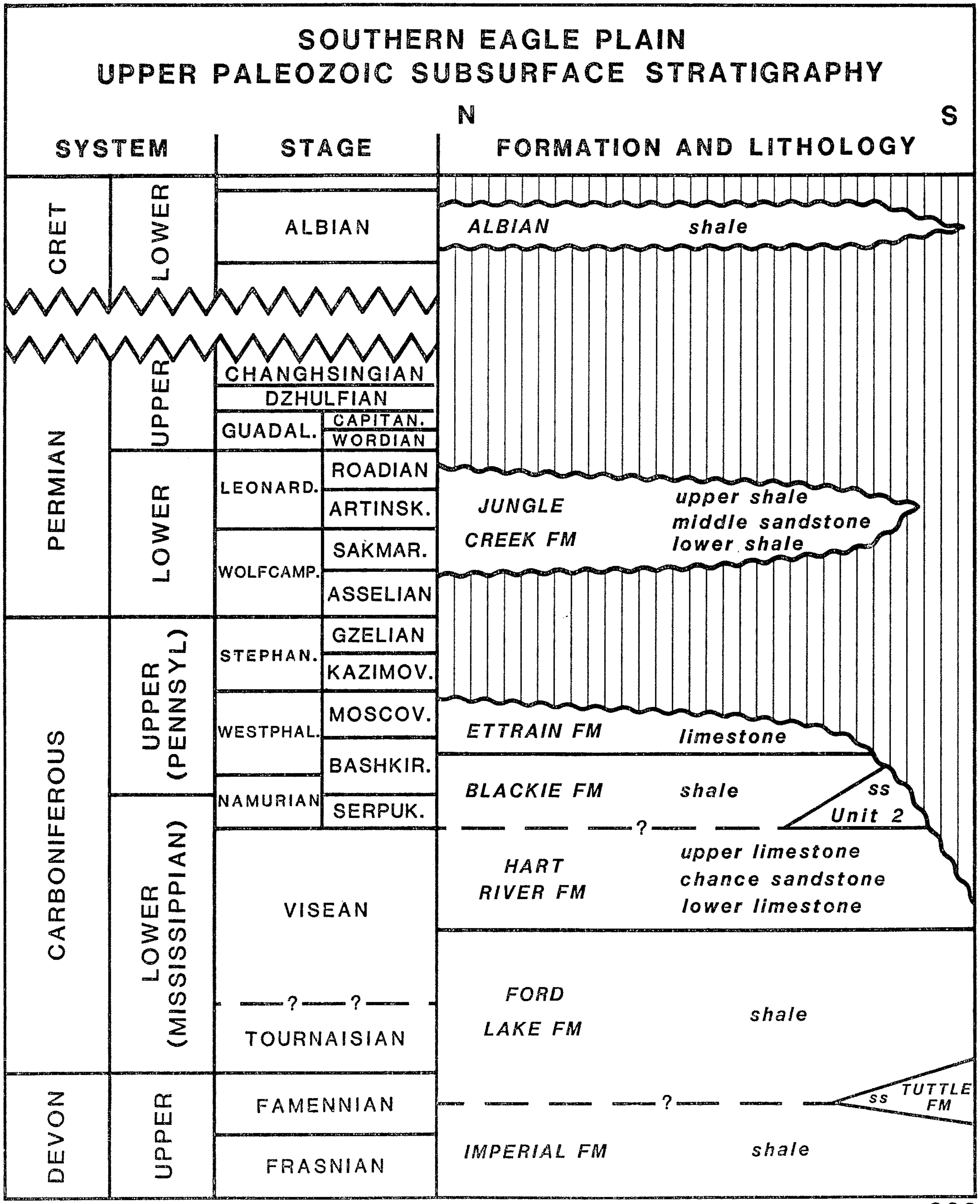
GSC

FIGURE 4.



ultimate "Ronning" shale out
ultimate Ogilvie-Gossage shale out
Eagle R.
N-5
Ogilvie gtstm,
Gossage gcsw,m
Road River
Ronning gtstm,gcm, sw,m
D-61
Ogilvie m
C-33
D-77
Ogilvie sw,m
Gossage gcsw,m
Ronning gcsw,m
Peel R.
Hart River
Ogilvie River
DEMPSTER HIGHWAY
Whitestone River
Porcupine R.
B-62
Ogilvie
Gossage
Road River
Ronning
River
Fishing Branch
Miner R.
Whitestone
KILOMETRES
0
25
50
136°
137°
138°
139°
140°
66°30'
66°00'
65°30'
GSC

FIGURE 5.


SOUTHERN EAGLE PLAIN
UPPER PALEOZOIC SUBSURFACE STRATIGRAPHY
N
S
SYSTEM
STAGE
FORMATION AND LITHOLOGY
CRET
LOWER
ALBIAN
ALBIAN
shale
PERMIAN
UPPER
CHANGHSINGIAN
DZHULFIAN
GUADAL.
CAPITAN.
WORDIAN
LOWER
LEONARD.
ROADIAN
ARTINSK.
WOLFCAMP.
SAKMAR.
ASSELIAN
JUNGLE
CREEK FM
upper shale
middle sandstone
lower shale
CARBONIFEROUS
UPPER
(PENNSYL)
STEPHAN.
GZELIAN
KAZIMOV.
WESTPHAL.
MOSCOV.
BASHKIR.
NAMURIAN
SERPUK.
ETTRAIN FM
limestone
BLACKIE FM
shale
ss
Unit 2
?
LOWER
(MISSISSIPPIAN)
VISEAN
? ?
TOURNAISIAN
HART
RIVER FM
upper limestone
chance sandstone
lower limestone
FORD
LAKE FM
shale
DEVON
UPPER
FAMENNIAN
FRASNIAN
?
ss
TUTTLE
FM
IMPERIAL FM
shale

GSC

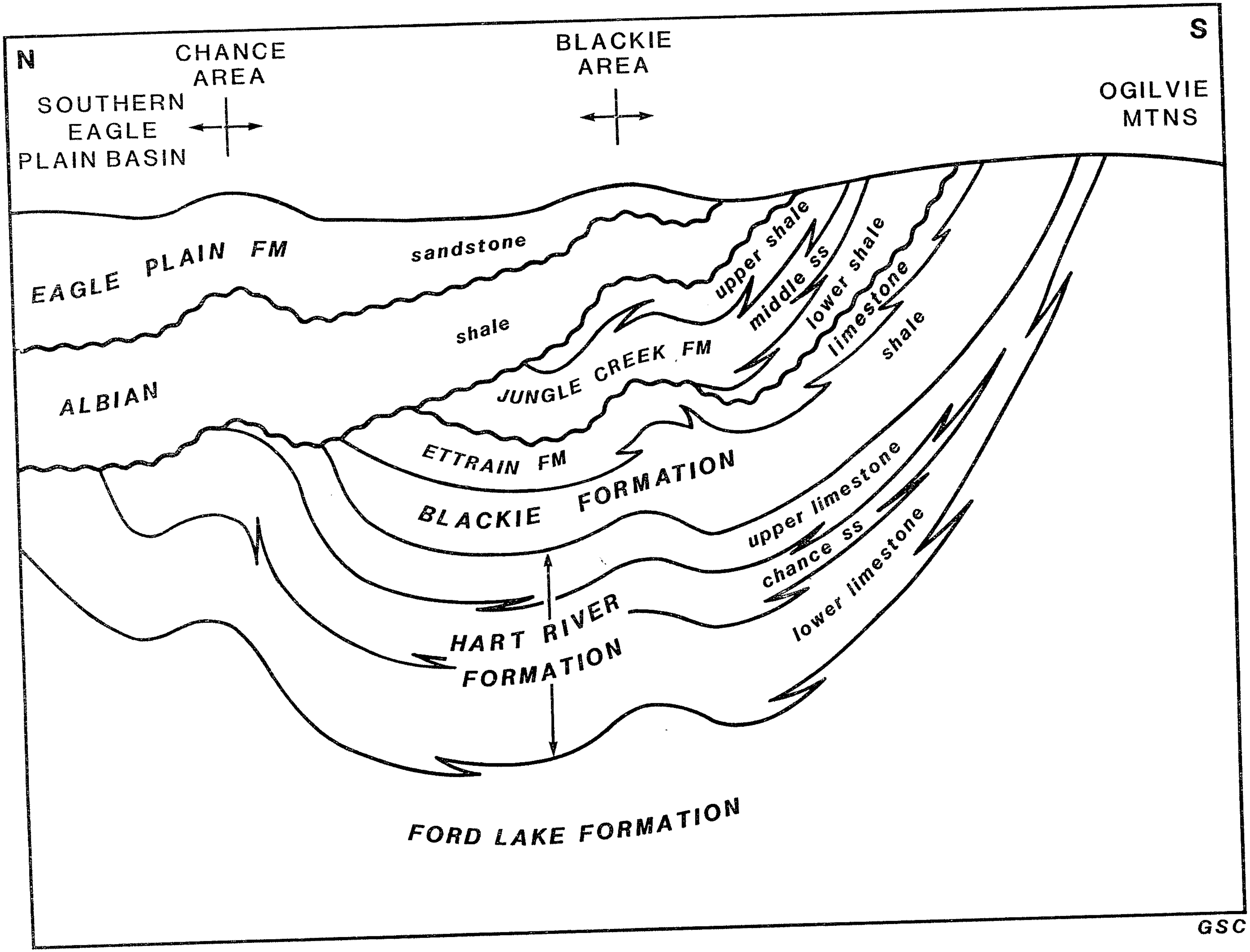

N
S
CHANCE AREA
BLACKIE AREA
SOUTHERN EAGLE PLAIN BASIN
OGILVIE MTNS
EAGLE PLAIN FM
sandstone
shale
ALBIAN
upper shale
middle ss
lower shale
limestone
shale
JUNGLE CREEK FM
ETTRAIN FM
BLACKIE FORMATION
upper limestone
chance ss
lower limestone
HART RIVER FORMATION
FORD LAKE FORMATION
GSC

FIGURE 6.

CORE CONTROL

WELL	FORMATION
B-62	*Ford Lake*
	Imperial
N-26	*Hart River*
F-18	*Hart River*
K-56	*Hart River*
I-13	*Jungle Creek*
J-19	*Hart River*
No.1	*Hart River*
	Imperial
D-63	*Jungle Creek*
C-33	*Hart River*
D-51	*Hart River*
G-8	*Hart River*
M-59	*Hart River*
	Ford Lake
B-34	*Jungle Creek*
	Hart River
E-53	*Jungle Creek*

DRILL-STEM TESTS

WELL	FORMATION	RECOVERIES
N-26	*Hart River*	gcm,m
N-58	*Jungle Creek*	mcsw
F-18	*Hart River*	gtstm m
K-56	*Hart River*	gtstm
I-13	*Jungle Creek*	gtstm sw,gcm
	Hart River	gtstm m
J-19	*Hart River*	gas cond
No.1	*Hart River*	gas,oil,sw
	Imperial	gas
D-63	*Jungle Creek*	gtstm,gcm
C-33	*Hart River*	m
D-51	*Hart River*	gtstm,oil, ocm,sw
G-8	*Hart River*	gtstm oil gcm,sw
D-61	*Hart River*	gcfwm
C-18	*Ettrain*	gas
	Hart River	gas cond csw
M-59	*Jungle Creek*	gas mcw,m
	Blackie	gtstm gcm
B-34	*Jungle Creek*	ocm,wcm
	Hart River	gas,gcm,sw
E-53	*Jungle Creek*	gcmcw,m

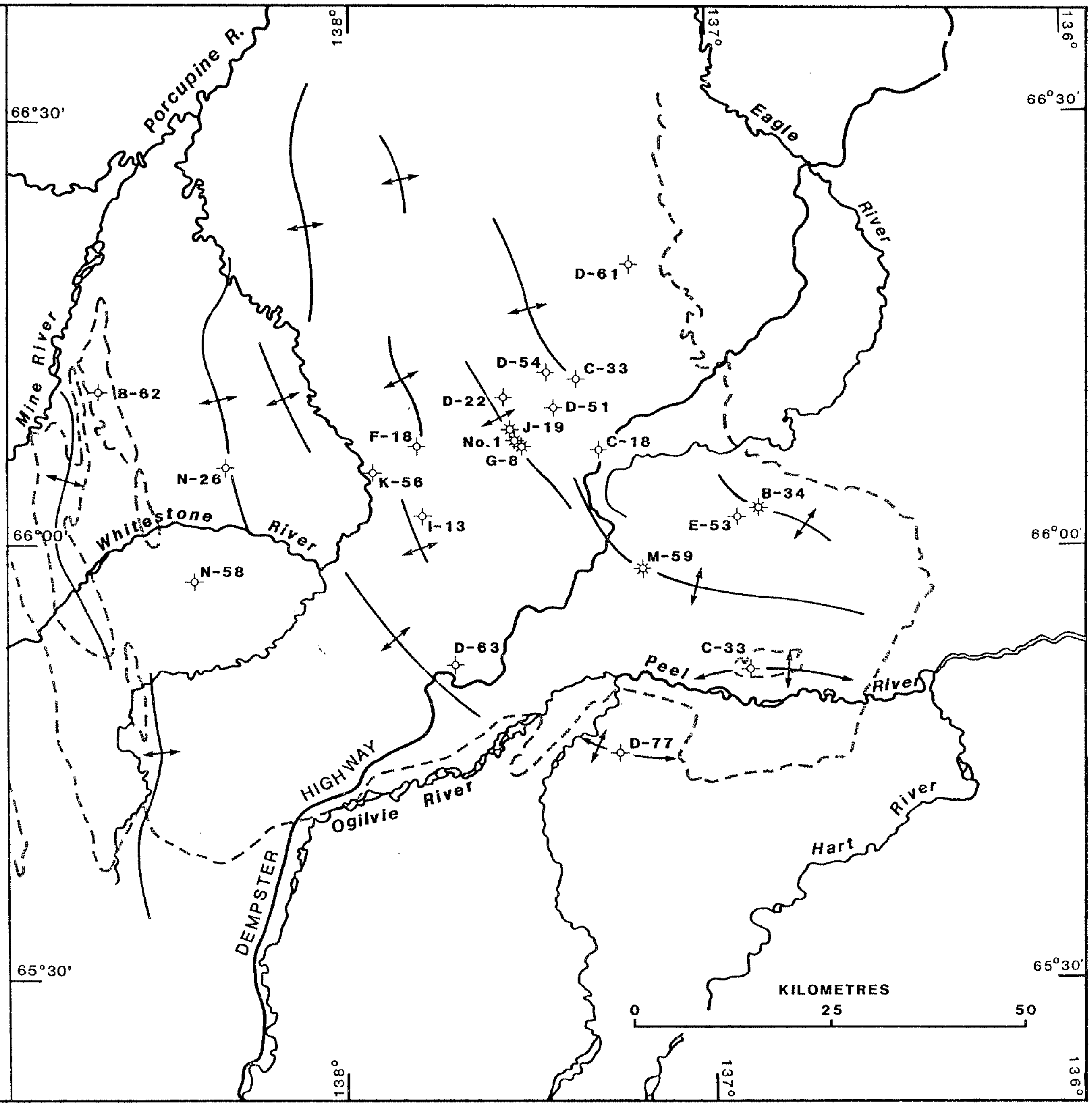


FIGURE 7.

GSC

FIGURE 8.

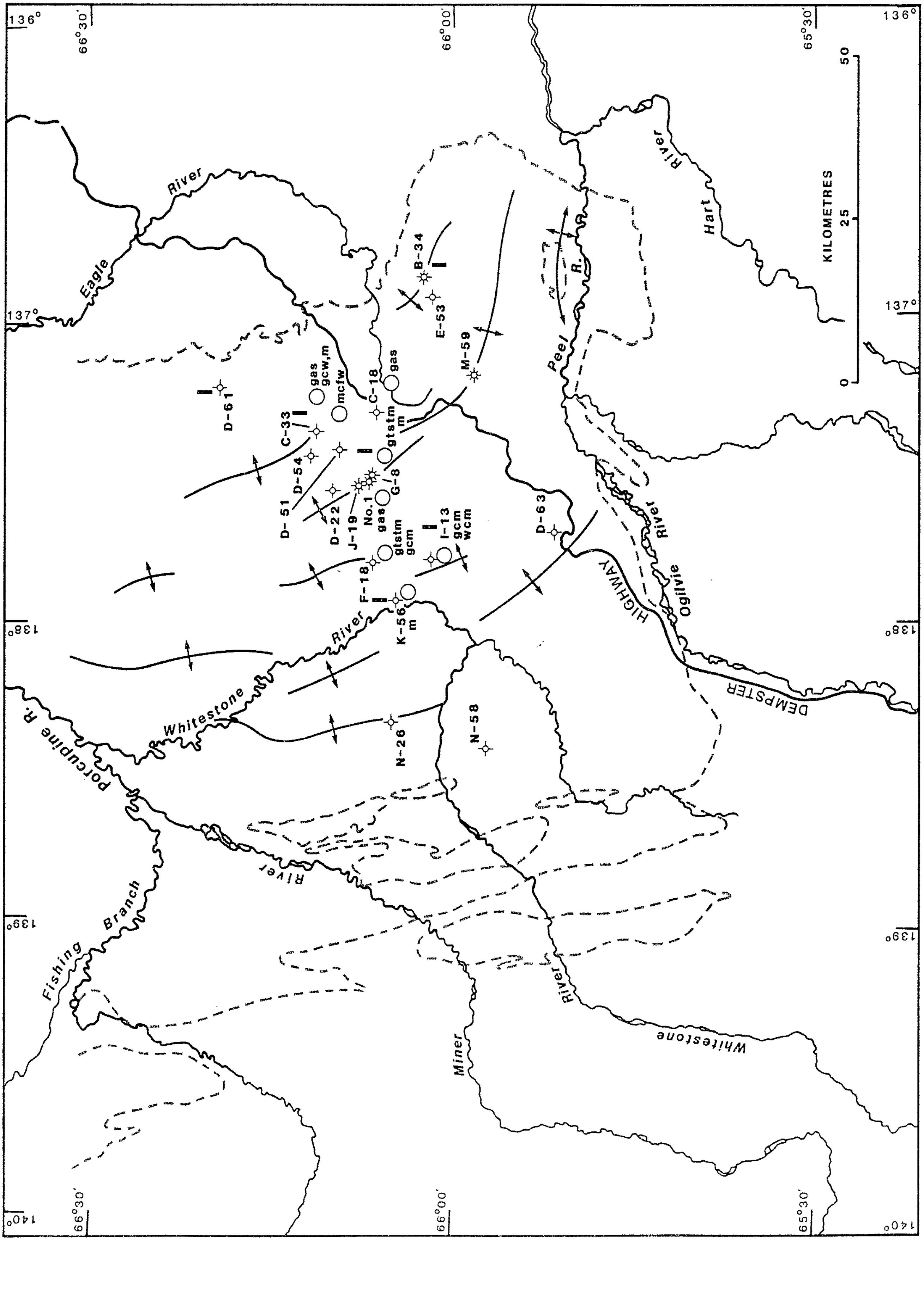
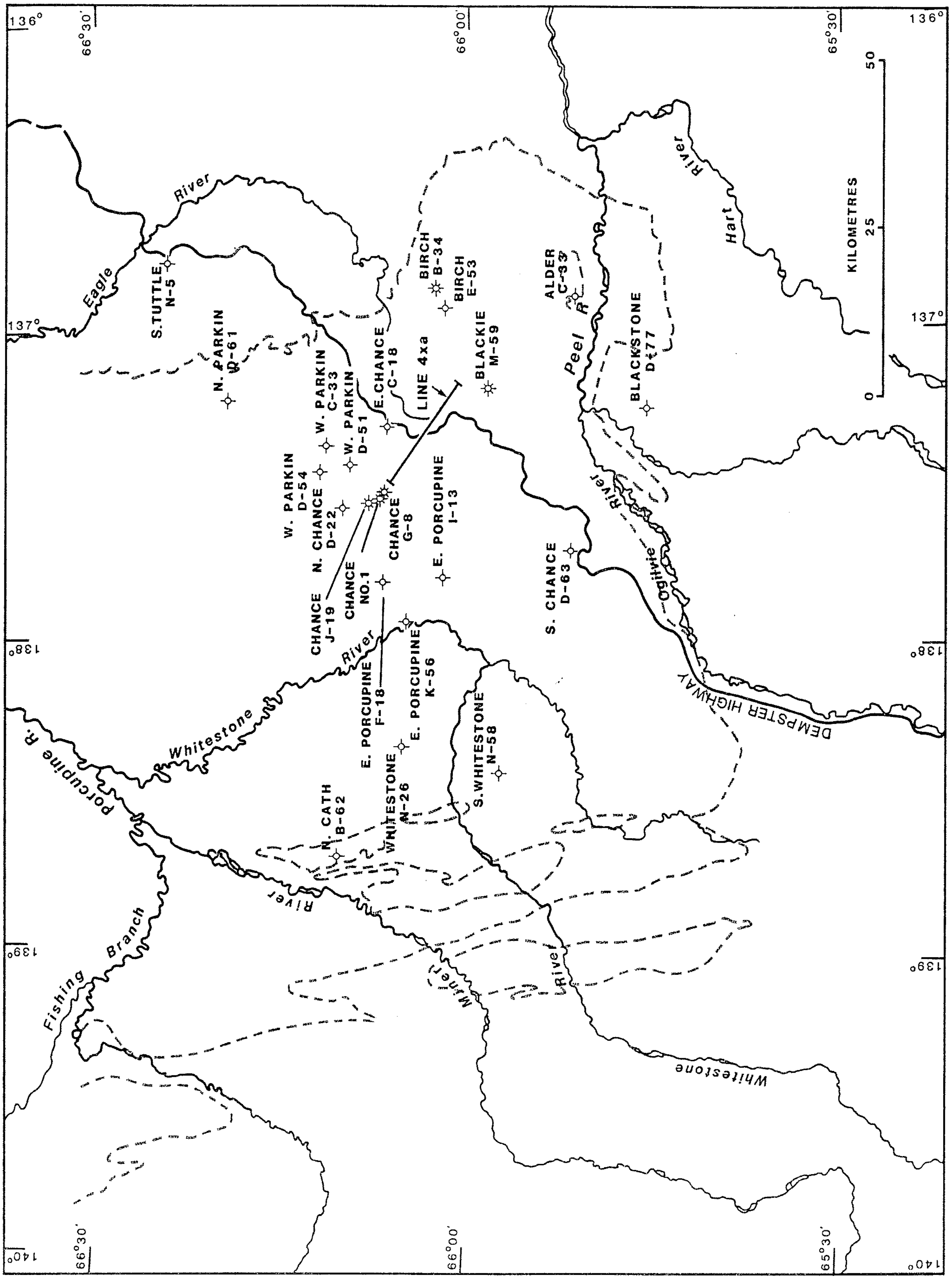
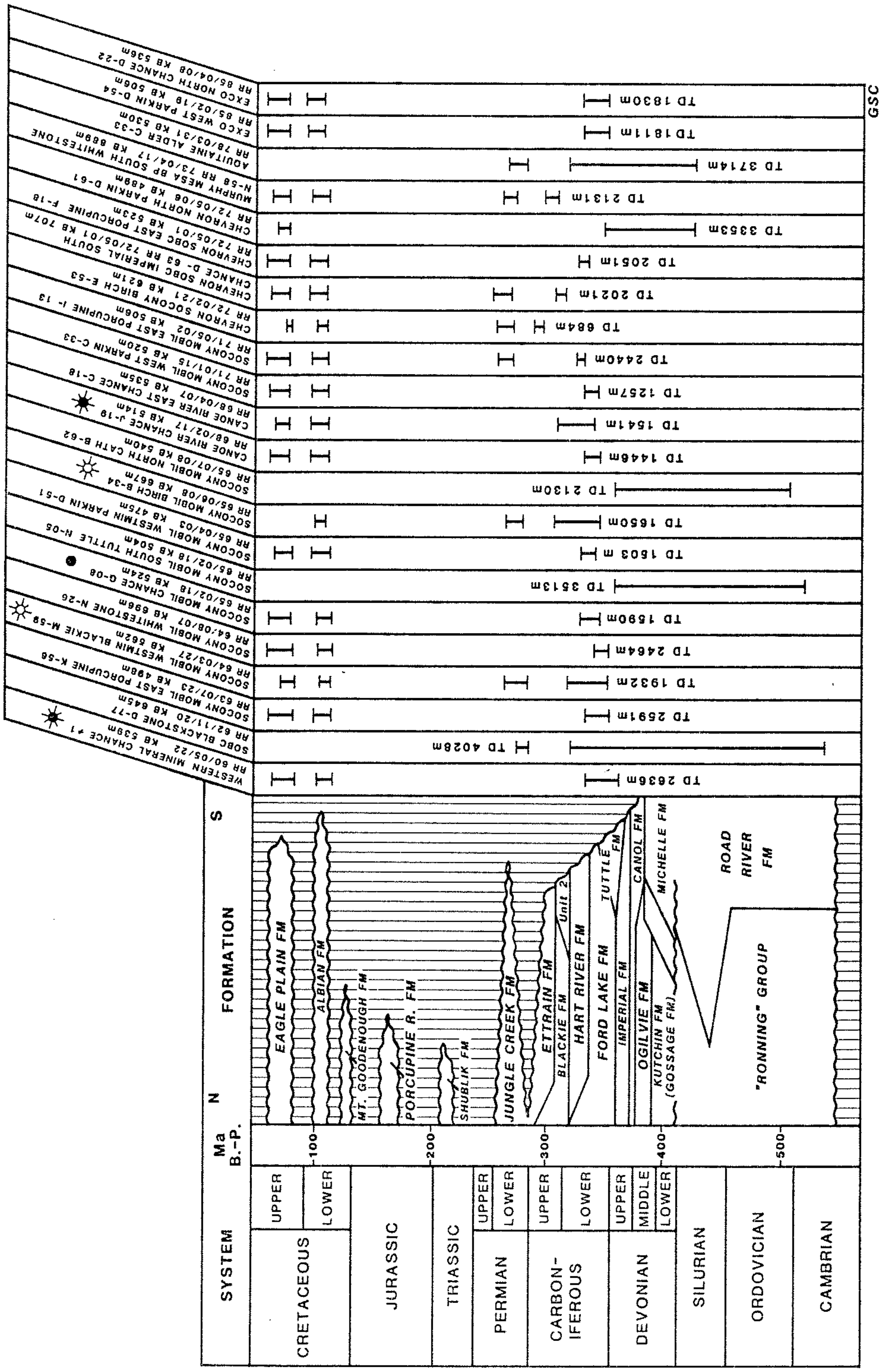

GSC
136°
66°30'
66°00'
65°30'
137°
138°
139°
140°
KILOMETRES
0
25
50
Eagle
River
Peel
R.
Hart
River
Ogilvie
River
DEMPSTER
HIGHWAY
Whitestone
River
Porcupine R.
River
Fishing
Branch
Miner
River
Whitestone
B-34
E-53
M-59
C-18
gas
gas
gcw,m
mcfw
D-61
C-33
D-54
D-51
gtstm
m
G-8
D-22
J-19
No.1
gas
I-13
gcm
wcm
gtstm
gcm
D-63
F-18
K-56
m
N-26
N-58

FIGURE 9.

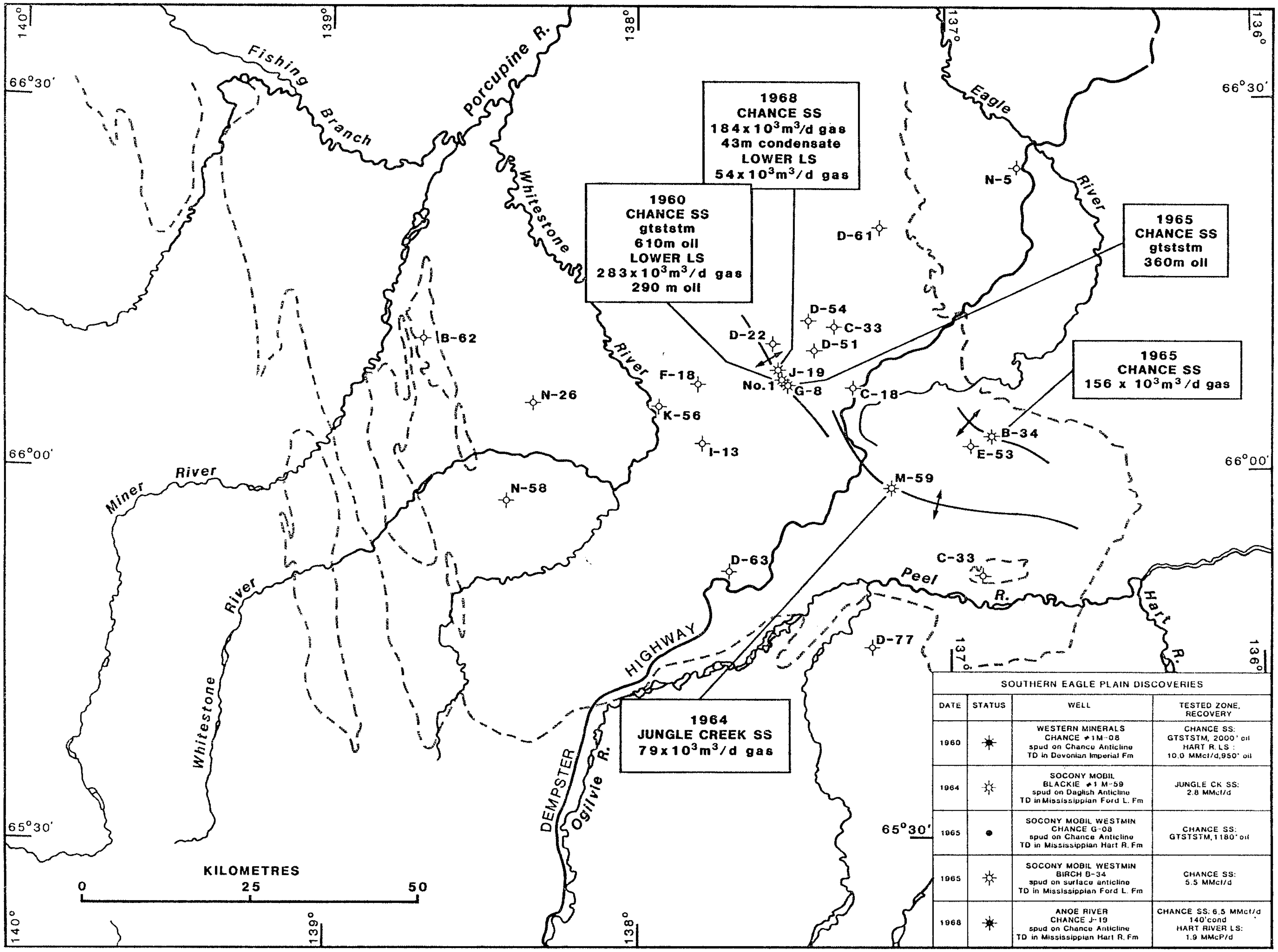


GSC
136°
137°
138°
139°
140°
66°30'
66°00'
65°30'
KILOMETRES
0
25
50
Eagle
River
Peel
R.
Hart
River
Ogilvie
River
DEMPSTER HIGHWAY
Whitestone
River
Porcupine R.
Porcupine
River
Fishing
Branch
Miner
River
Whitestone
S.TUTTLE
N-5
N. PARKIN
D-61
W. PARKIN
C-33
W. PARKIN
D-51
W. PARKIN
D-54
E.CHANCE
C-18
LINE 4xa
BIRCH
B-34
BIRCH
E-53
BLACKIE
M-59
ALDER
C-33
BLACKSTONE
D-77
N. CHANCE
D-22
CHANCE
G-8
CHANCE
J-19
CHANCE
NO.1
E. PORCUPINE
I-13
S. CHANCE
D-63
E. PORCUPINE
K-56
E. PORCUPINE
F-18
S.WHITESTONE
N-58
WHITESTONE
N-26
N. CATH
B-62

FIGURE 10.



SYSTEM
CRETACEOUS
UPPER
LOWER
JURASSIC
TRIASSIC
PERMIAN
CARBON-IFEROUS
DEVONIAN
MIDDLE
SILURIAN
ORDOVICIAN
CAMBRIAN
Ma B.-P.
100
200
300
400
500
FORMATION
EAGLE PLAIN FM
ALBIAN FM
MT. GOODENOUGH FM
PORCUPINE R. FM
SHUBLIK FM
JUNGLE CREEK FM
ETTRAIN FM
BLACKIE FM
HART RIVER FM
Unit 2
FORD LAKE FM
TUTTLE FM
IMPERIAL FM
CANOL FM
OGILVIE FM
KUTCHIN FM (GOSSAGE FM)
MICHELLE FM
ROAD RIVER FM
"RONNING" GROUP
GSC



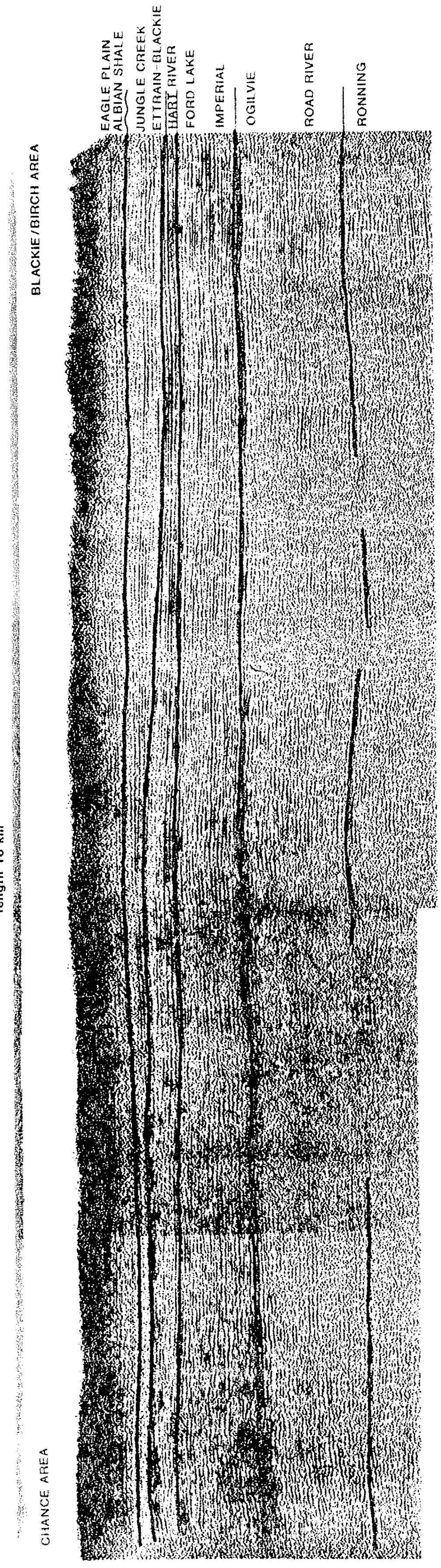
SOUTHERN EAGLE PLAIN DISCOVERIES

DATE	STATUS	WELL	TESTED ZONE, RECOVERY
1960	✸	WESTERN MINERALS CHANCE #1M-08 spud on Chance Anticline TD in Devonian Imperial Fm	CHANCE SS: GTSTSTM, 2000' oil HART R. LS: 10.0 MMcf/d, 950' oil
1964	☼	SOCONY MOBIL BLACKIE #1 M-59 spud on Daglish Anticline TD in Mississippian Ford L. Fm	JUNGLE CK SS: 2.8 MMcf/d
1965	•	SOCONY MOBIL WESTMIN CHANCE G-08 spud on Chance Anticline TD in Mississippian Hart R. Fm	CHANCE SS: GTSTSTM, 1180' oil
1965	☼	SOCONY MOBIL WESTMIN BIRCH B-34 spud on surface anticline TD in Mississippian Ford L. Fm	CHANCE SS: 5.5 MMcf/d
1968	✸	ANOE RIVER CHANCE J-19 spud on Chance Anticline TD in Mississippian Hart R. Fm	CHANCE SS: 6.5 MMcf/d 140' cond HART RIVER LS: 1.9 MMcf/d

FIGURE 11.

GSC

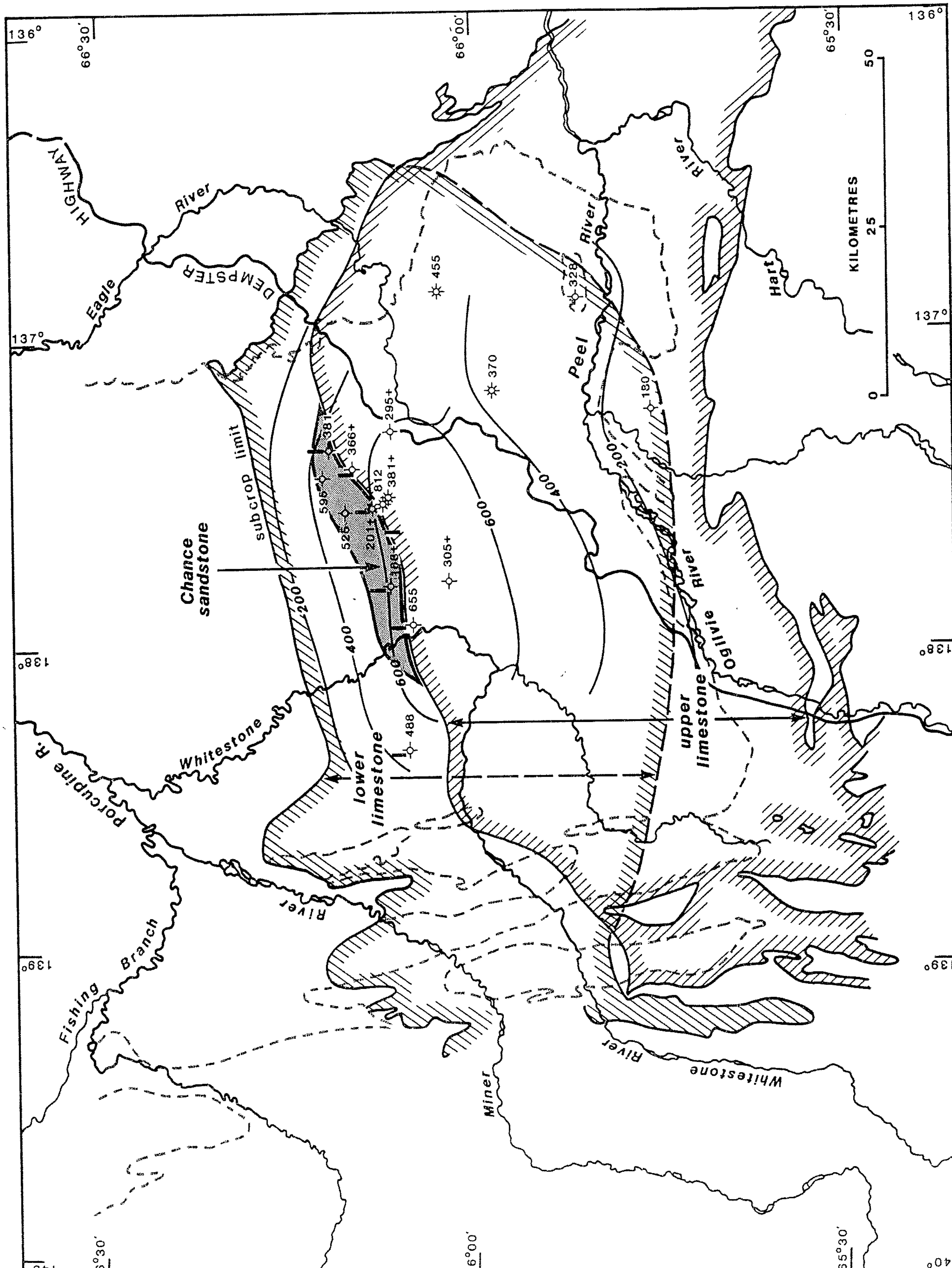
FIGURE 12.



SOUTHEASTERN EAGLE PLAIN

(LINE 4XA,CHEVRON STANDARD LTD.,1971)
length 16 km

FIGURE 13.



GSC
136°
137°
138°
139°
140°
66°30'
66°00'
65°30'
KILOMETRES
0
25
50
DEMPSTER
HIGHWAY
Eagle
River
Peel
River
Hart
River
Ogilvie
River
Whitestone
Whitestone
River
Porcupine R.
River
Fishing
Branch
Miner
Chance sandstone
subcrop limit
lower limestone
upper limestone
200
400
600
455
370
329
180
295+
381
366+
595
812
381+
525
201+
188+
305+
655
488

FIGURE 14.

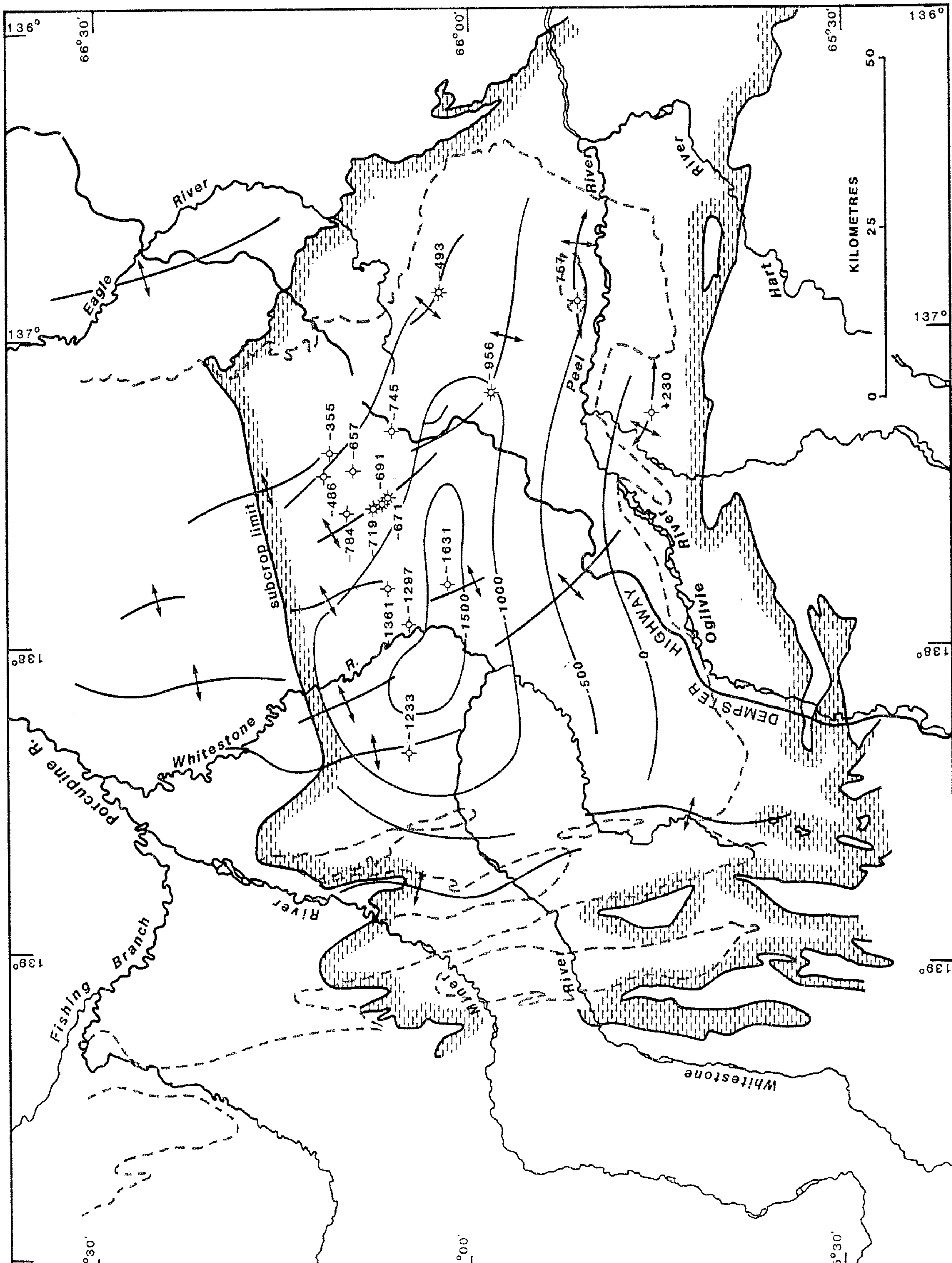
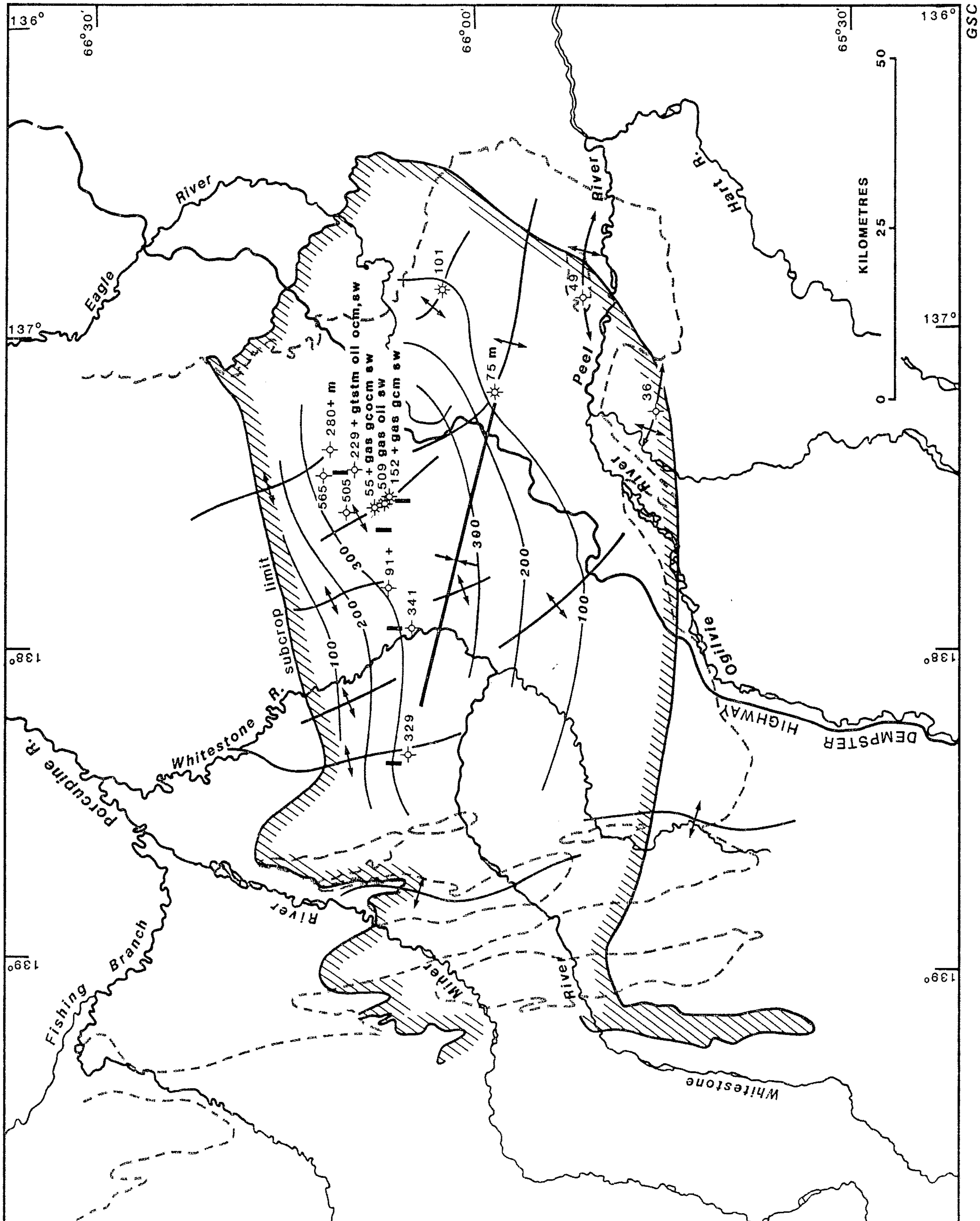

GSC
KILOMETRES
0
25
50
136°
137°
138°
139°
140°
66°30'
66°00'
65°30'
Eagle River
Peel River
Hart River
Ogilvie River
DEMPSTER HIGHWAY
Whitestone R.
Whitestone
Porcupine R.
Fishing Branch
Miner River
subcrop limit
0
-500
-1000
-1500
-493
-757
-956
+230
-745
-355
-657
-486
-691
-784
-719
-671
-1631
-1297
-1361
-1233

FIGURE 15.


136°
66°30'
66°00'
65°30'
137°
138°
139°
140°
KILOMETRES
0
25
50
GSC
Eagle
River
Peel
River
Hart R.
Ogilvie
River
DEMPSTER HIGHWAY
Whitestone R.
Porcupine R.
Fishing Branch
River
Miner
River
Whitestone
subcrop limit
280+ m
229 + gtstm oil ocm,sw
55 + gas gcocm sw
509 gas oil sw
152 + gas gcm sw
565
505
91+
341
329
101
49
75 m
36
300
200
100

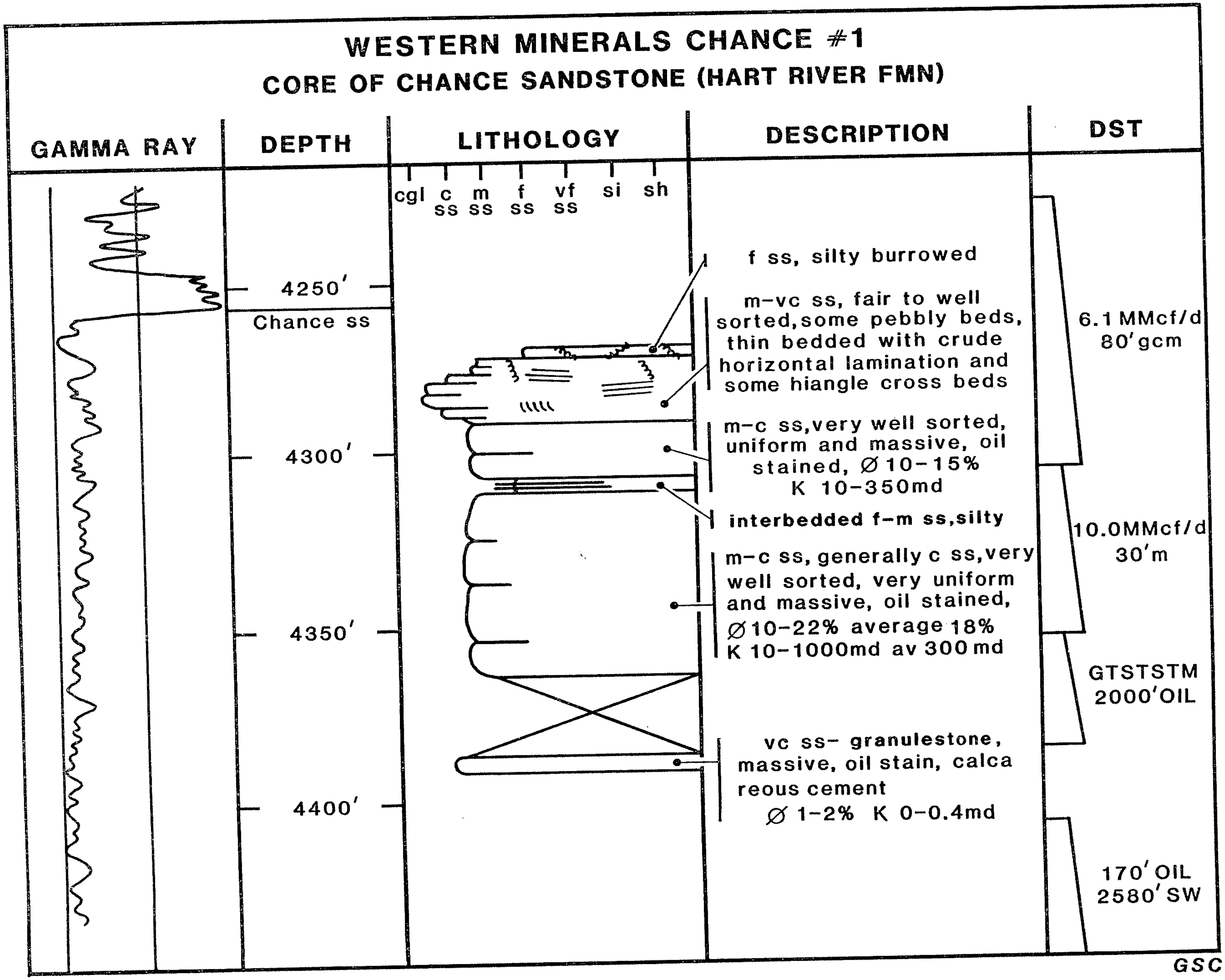

WESTERN MINERALS CHANCE #1
CORE OF CHANCE SANDSTONE (HART RIVER FMN)
GAMMA RAY
DEPTH
LITHOLOGY
DESCRIPTION
DST
cgl
c ss
m ss
f ss
vf ss
si
sh
4250'
Chance ss
4300'
4350'
4400'
f ss, silty burrowed
m–vc ss, fair to well sorted, some pebbly beds, thin bedded with crude horizontal lamination and some hiangle cross beds
m–c ss, very well sorted, uniform and massive, oil stained, Ø10–15% K 10–350md
interbedded f–m ss, silty
m–c ss, generally c ss, very well sorted, very uniform and massive, oil stained, Ø10–22% average 18% K 10–1000md av 300md
vc ss– granulestone, massive, oil stain, calca reous cement Ø 1–2% K 0–0.4md
6.1 MMcf/d 80'gcm
10.0MMcf/d 30'm
GTSTSTM 2000'OIL
170' OIL 2580' SW
GSC

FIGURE 16.

FIGURE 17.

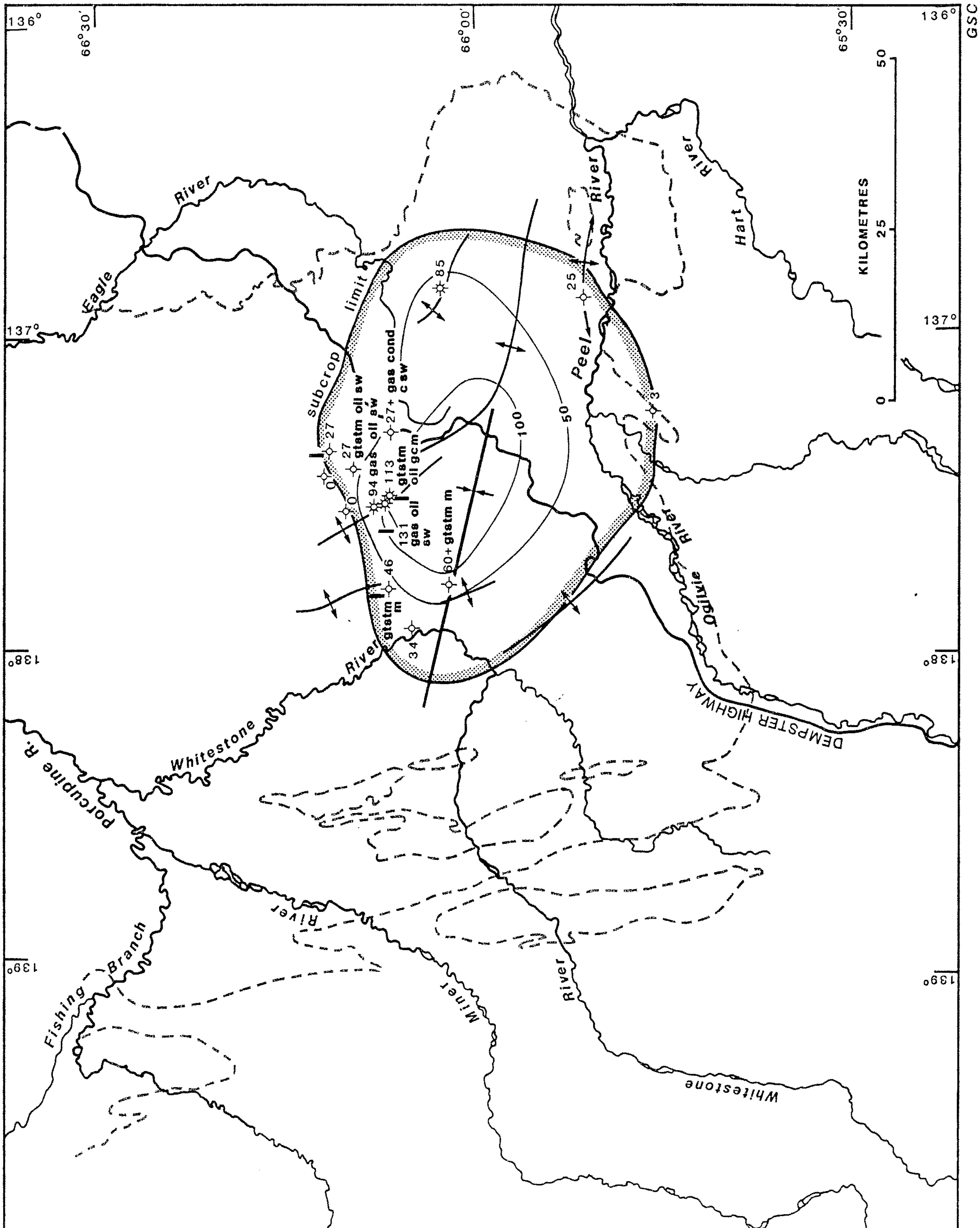
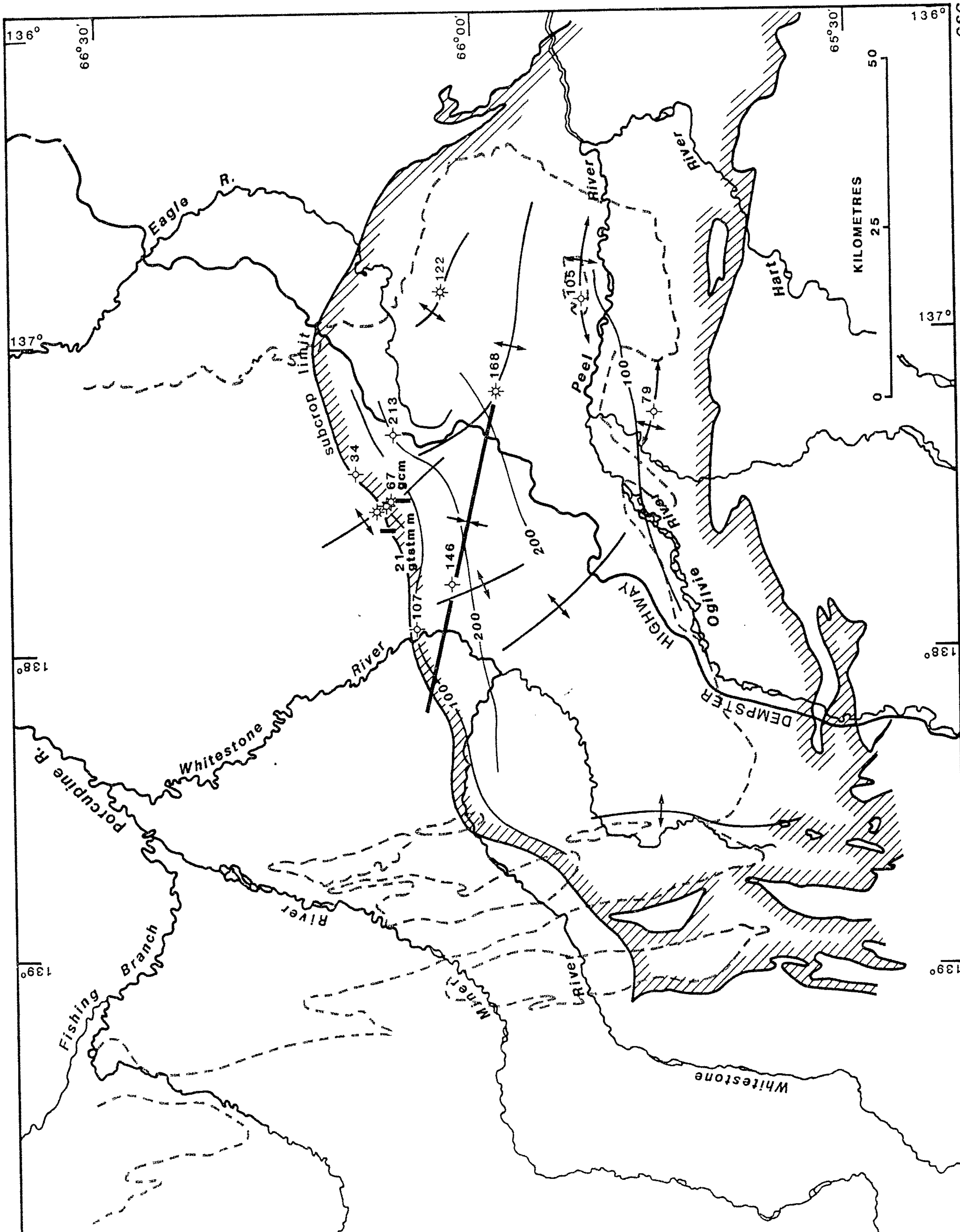
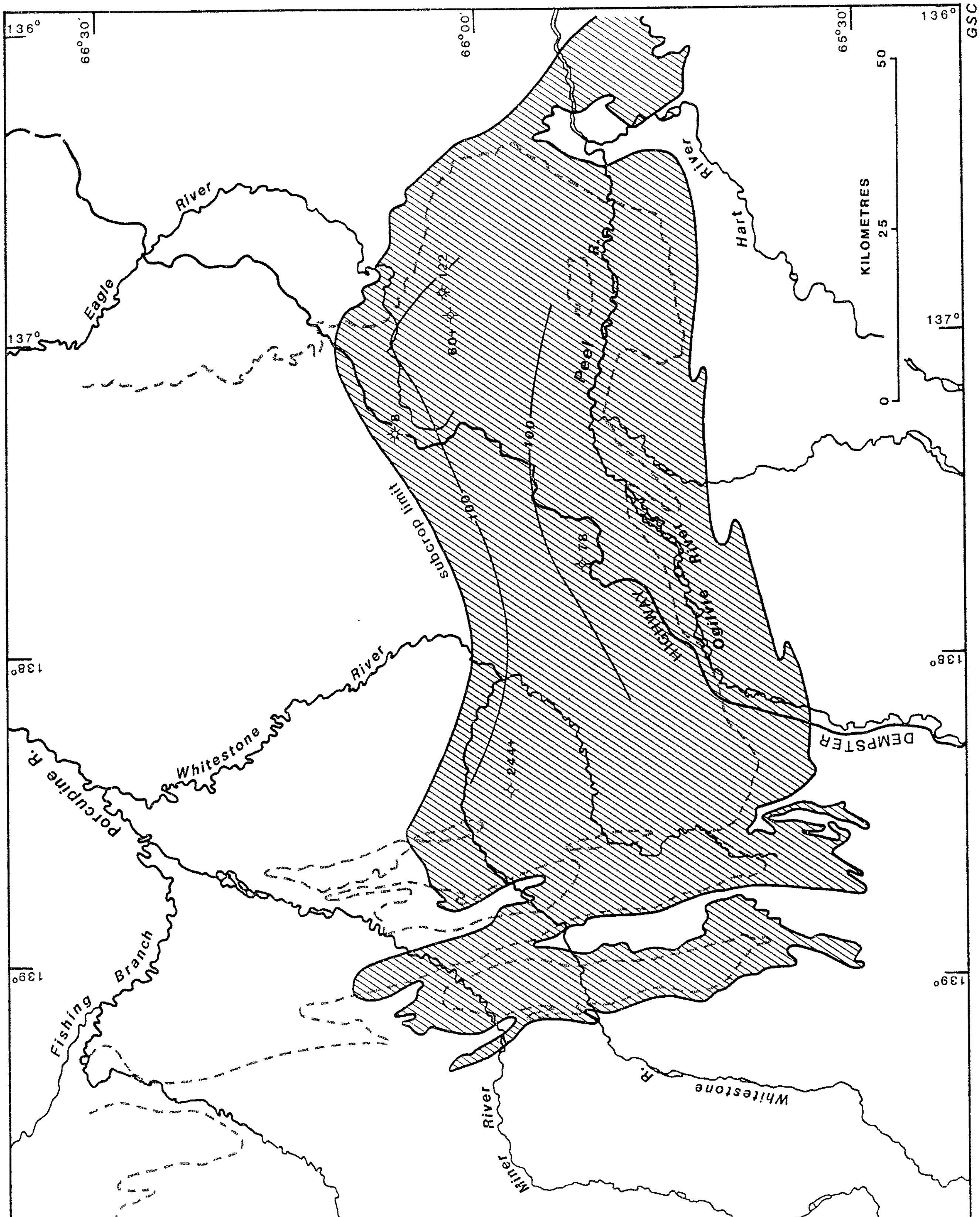

136°
66°30'
66°00'
65°30'
136°
GSC
137°
137°
138°
138°
139°
139°
140°
66°30'
66°00'
65°30'
140°
KILOMETRES
0
25
50
Eagle
River
Peel
River
Hart
River
Ogilvie
River
DEMPSTER HIGHWAY
Whitestone
River
Porcupine R.
Fishing
Branch
Miner
River
River
Whitestone
Subcrop
limit
85
25
3
50
100
27
gtstm oil sw
27
oil sw
gas
27+ gas cond
c sw
0
94
113
gtstm
oil gcm
0
131
gas oil
sw
60+ gtstm m
46
gtstm
m
gtstm
m
34
2

FIGURE 18.



GSC
136°
137°
138°
139°
140°
66°30'
66°00'
65°30'
KILOMETRES
0
25
50
Eagle R.
Peel River
Hart River
Ogilvie River
DEMPSTER HIGHWAY
Whitestone River
Porcupine R.
Fishing Branch
Miner River
Whitestone
subcrop limit
122
168
213
34
67
gcm
21
gtstmm
146
107
105
79
100
200

FIGURE 19.



136°
66°30'
66°00'
65°30'
136°
GSC
50
25
0
KILOMETRES
Eagle
River
Hart
River
Peel
R.
subcrop limit
HIGHWAY
Ogilvie
River
DEMPSTER
Whitestone
River
Porcupine R.
Fishing
Branch
Miner
River
Whitestone
R.
137°
138°
139°
140°
122
60+
8
100
100
78
244+

FIGURE 20.

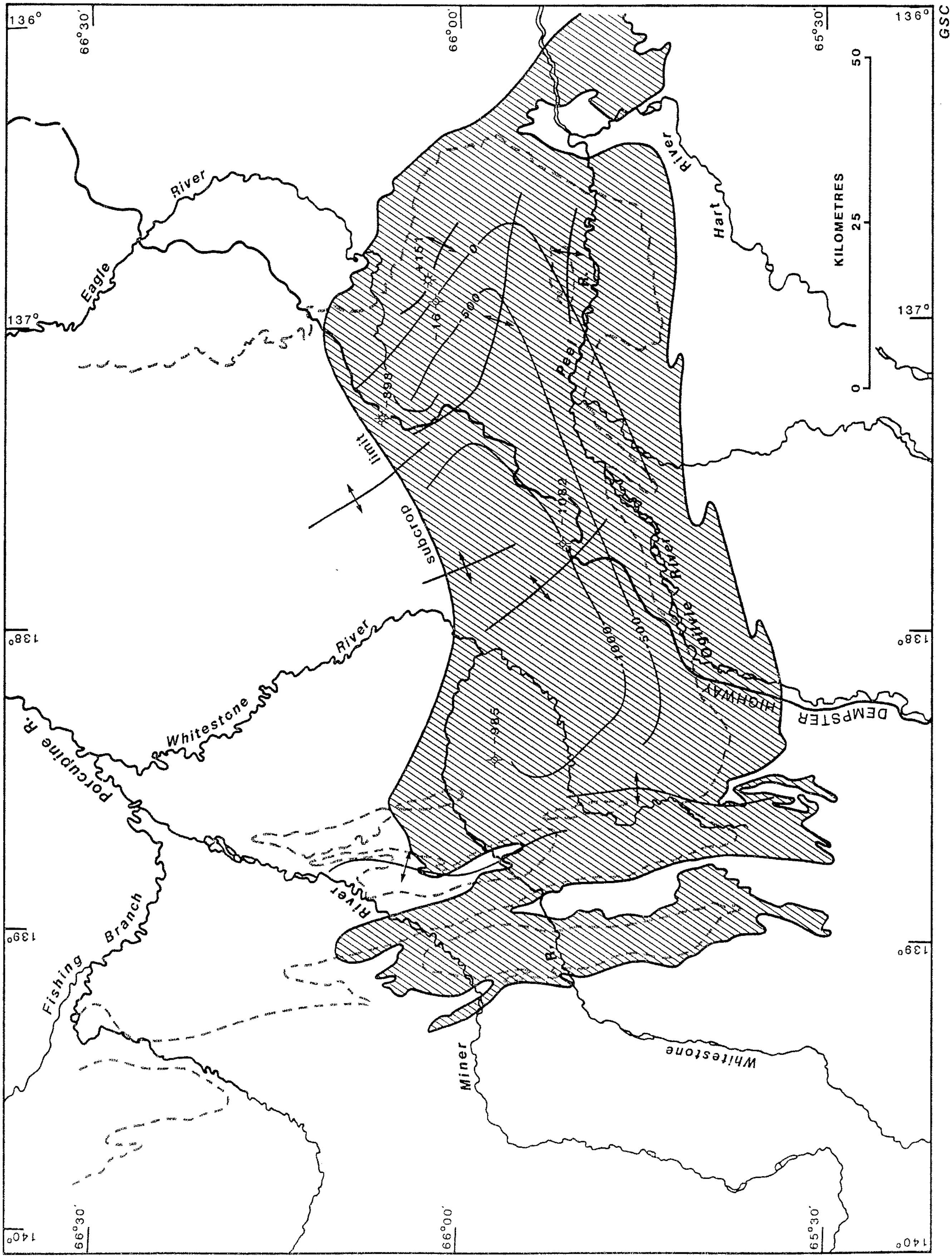
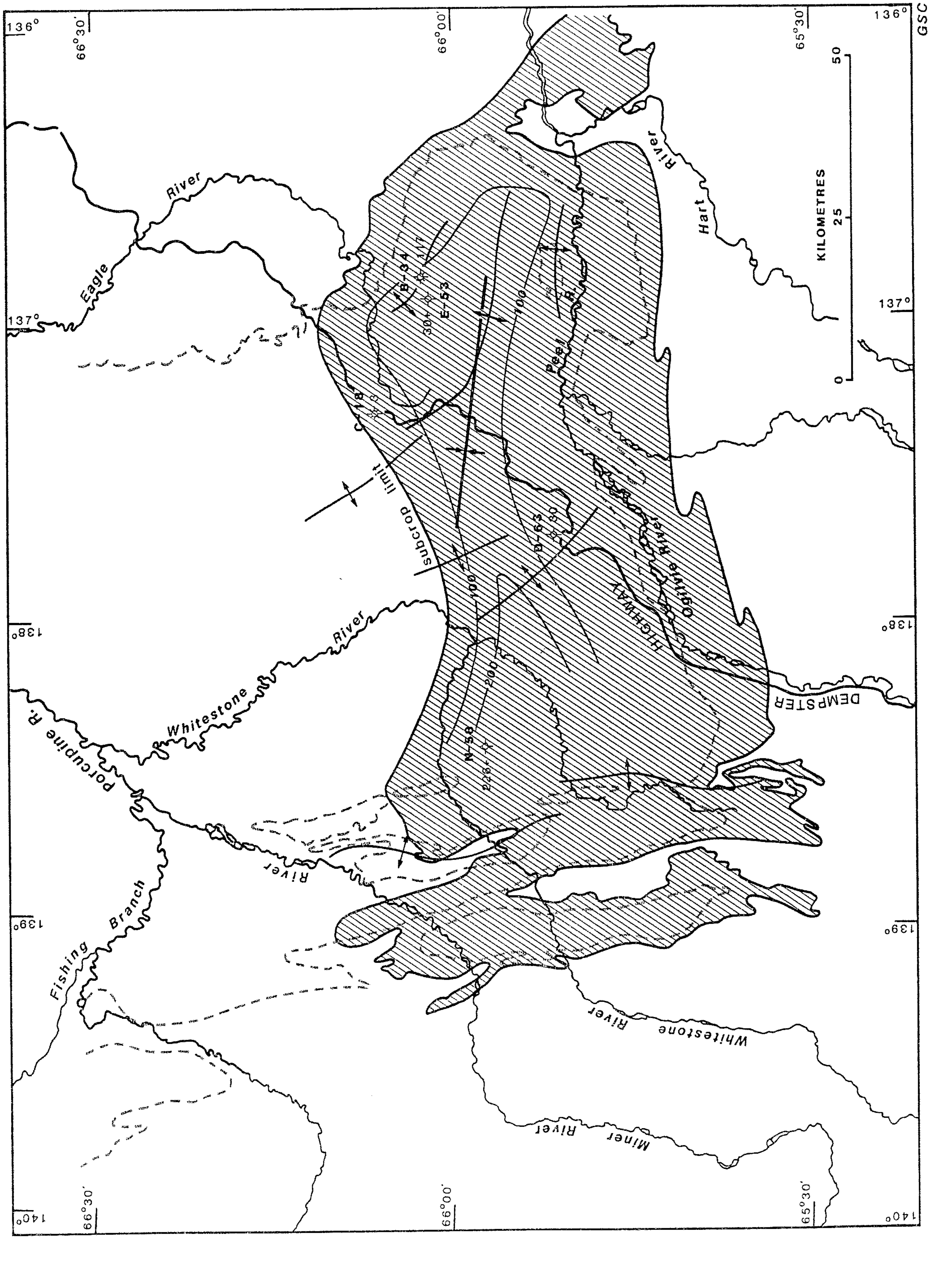
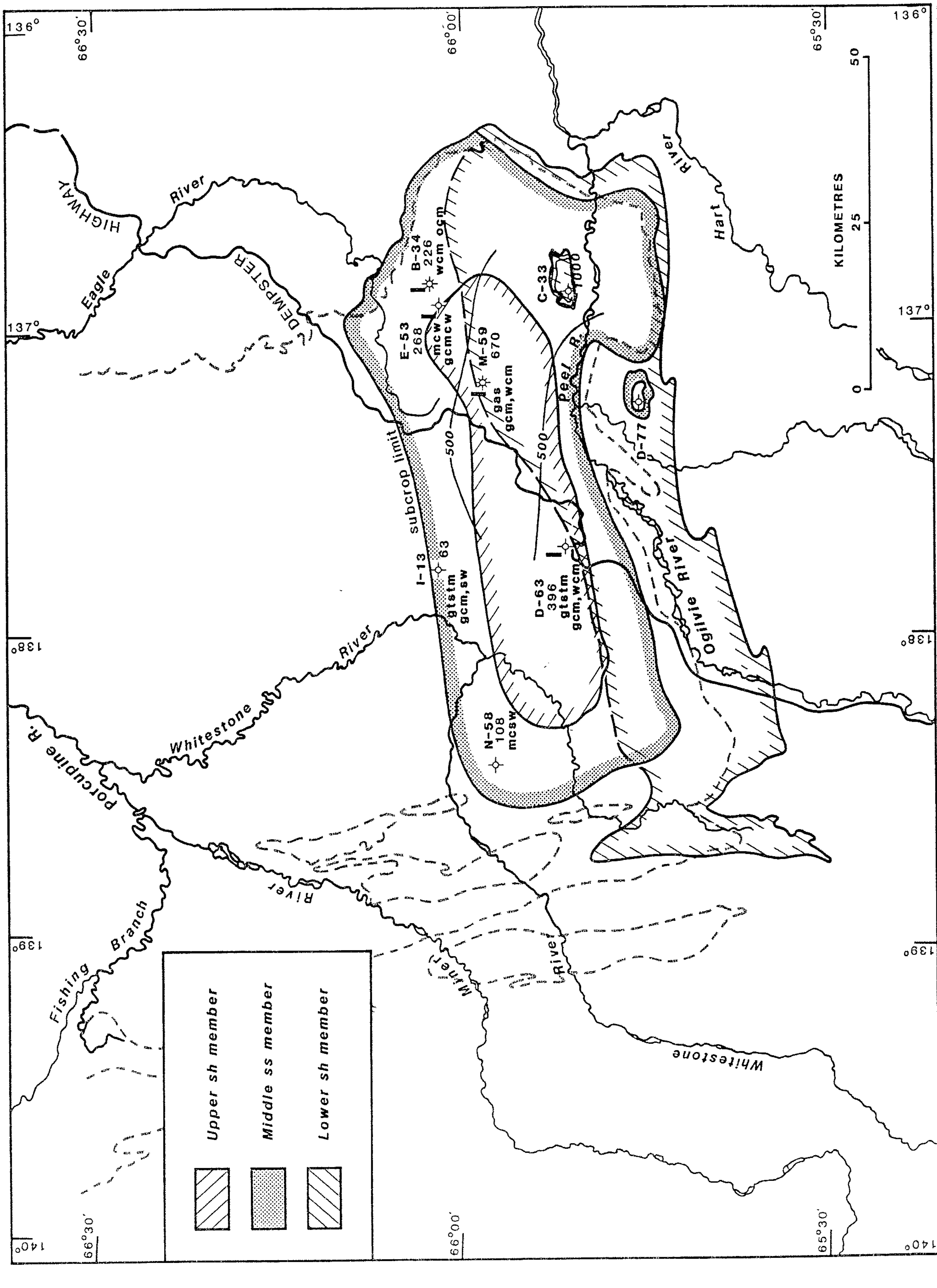

136°
66°30'
66°00'
65°30'
136°
GSC
137°
137°
138°
138°
139°
139°
140°
66°30'
66°00'
65°30'
140°
KILOMETRES
0
25
50
Eagle
River
Hart
River
Peel
R.
subcrop
limit
Ogilvie
River
DEMPSTER
HIGHWAY
Whitestone
River
Porcupine R.
Fishing
Branch
River
Miner
R.
Whitestone
+151
-16
0
-500
-998
-1082
-1000
-500
-985

FIGURE 21.



136°
66°30'
66°00'
65°30'
137°
138°
139°
140°
GSC
KILOMETRES
0
25
50
Eagle
River
Hart
River
Peel
R.
Whitestone
River
Porcupine R.
Fishing
Branch
River
Ogilvie
River
DEMPSTER
HIGHWAY
Whitestone
River
Miner
River
subcrop
limit
B-34
E-53
D-63
N-58
100
200

FIGURE 22.



136°
66°30'
66°00'
65°30'
137°
138°
139°
140°
GSC
KILOMETRES
0
25
50
DEMPSTER
HIGHWAY
Eagle
River
Peel R.
Hart
River
Ogilvie
River
Whitestone
River
Porcupine R.
Fishing
Branch
River
Miner
River
Whitestone
subcrop limit
500
500
B-34
226
wcm ocm
E-53
268
mcw
gcmcw
M-59
670
gas
gcm,wcm
C-33
1000
D-77
I-13
63
gtstm
gcm,sw
D-63
396
gtstm
gcm,wcm
N-58
108
mcsw
Upper sh member
Middle ss member
Lower sh member

FIGURE 23.

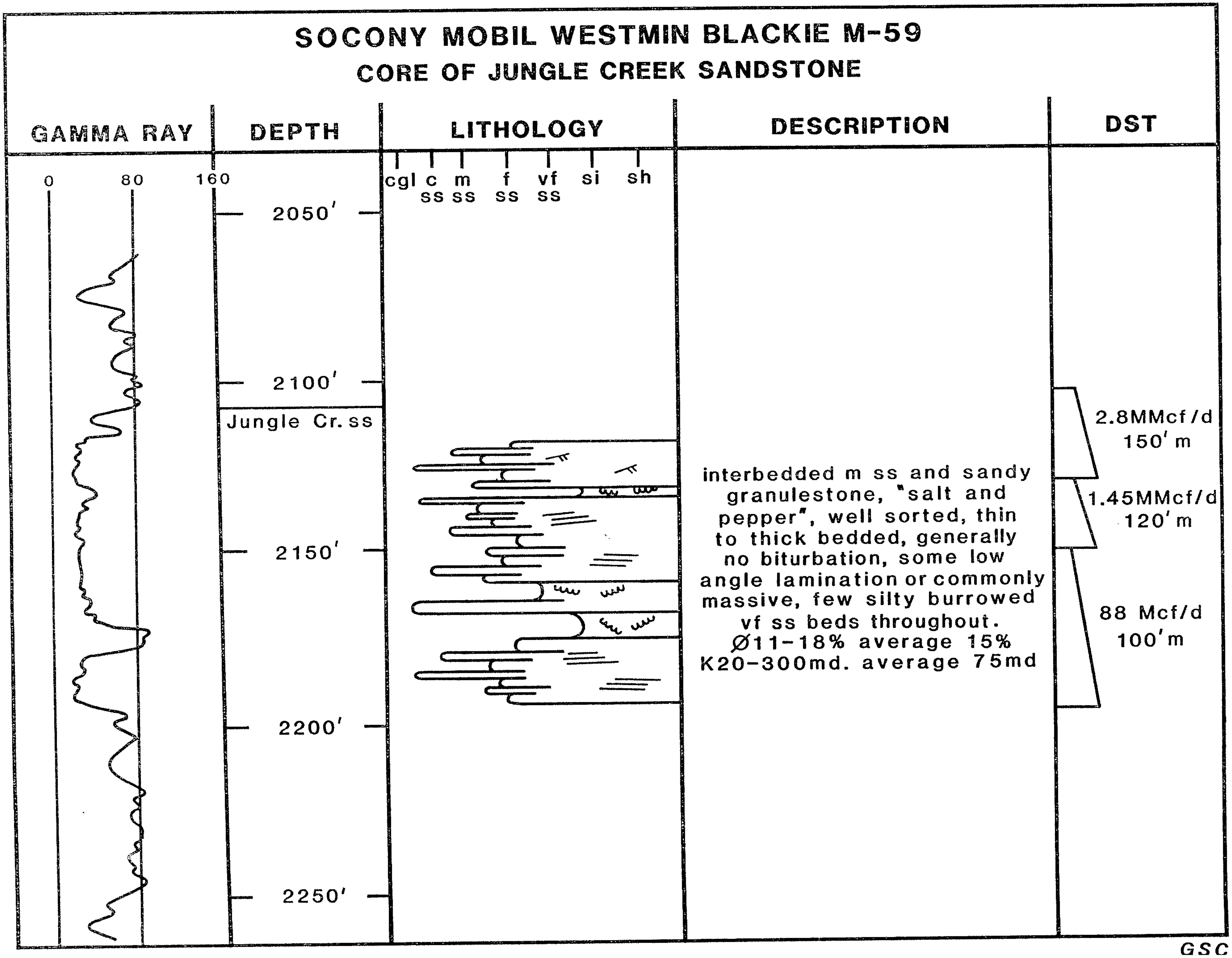
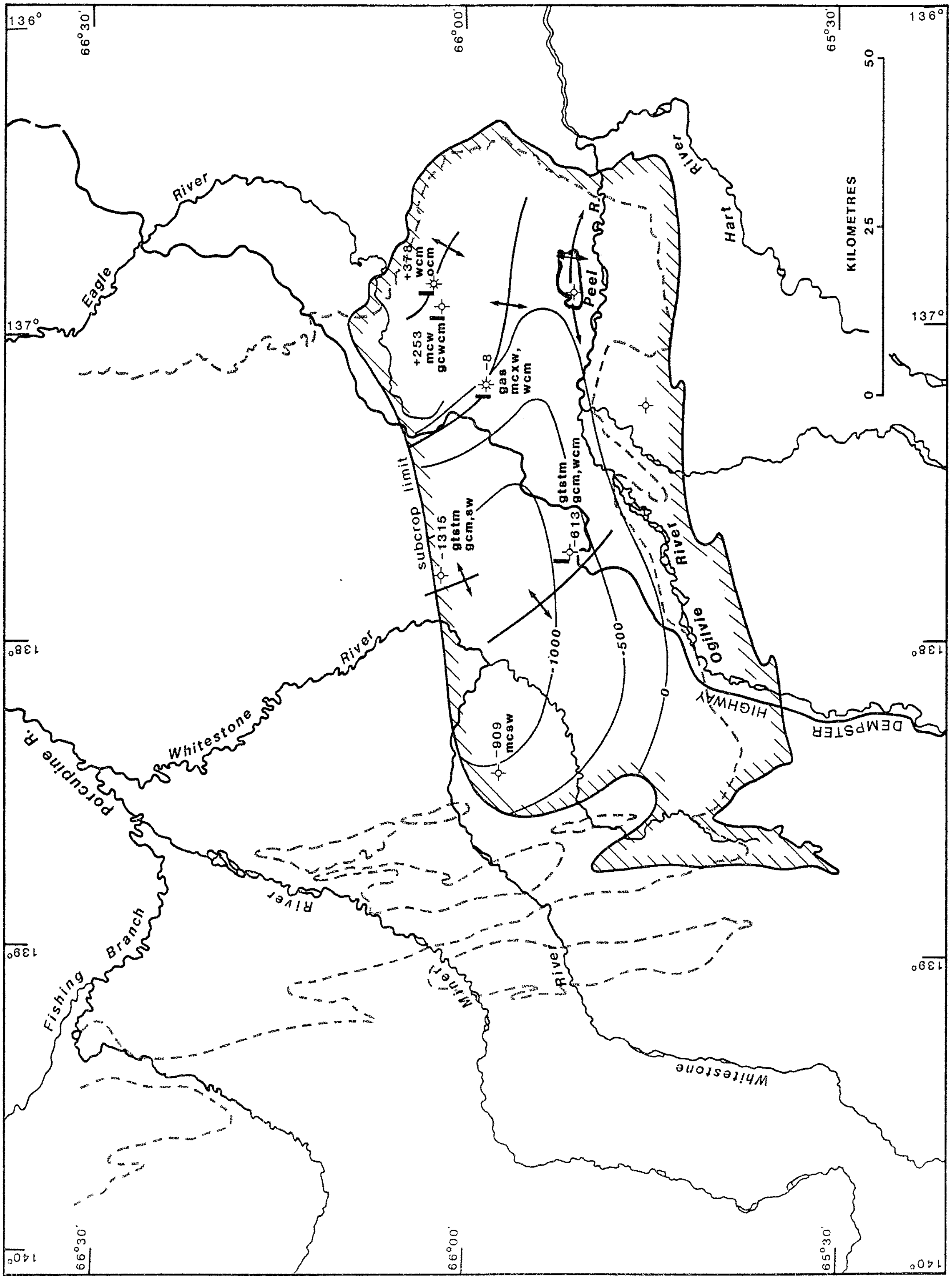
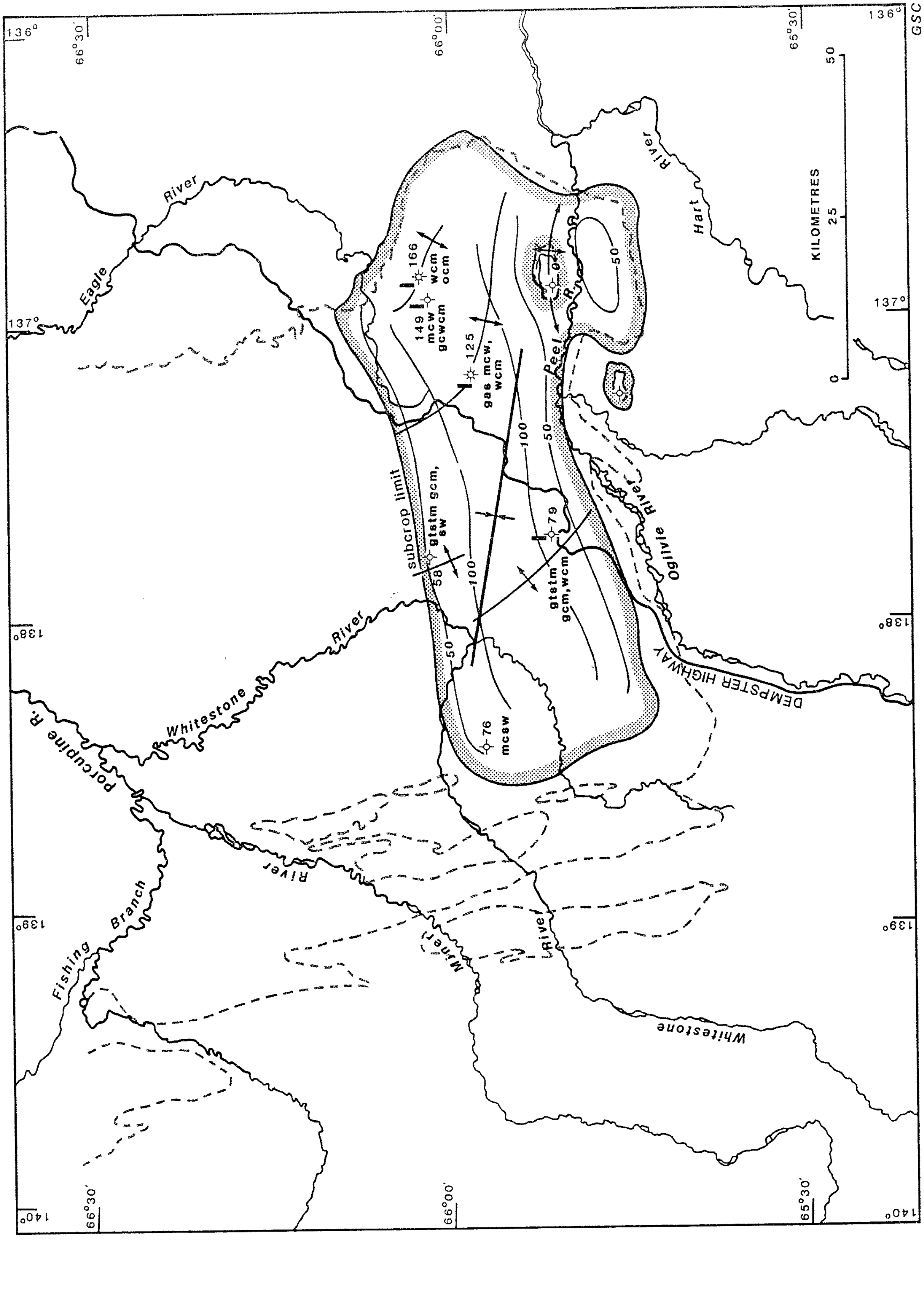

SOCONY MOBIL WESTMIN BLACKIE M-59
CORE OF JUNGLE CREEK SANDSTONE
GAMMA RAY
DEPTH
LITHOLOGY
DESCRIPTION
DST
0
80
160
2050'
2100'
2150'
2200'
2250'
Jungle Cr. ss
cgl
c ss
m ss
f ss
vf ss
si
sh
interbedded m ss and sandy granulestone, "salt and pepper", well sorted, thin to thick bedded, generally no biturbation, some low angle lamination or commonly massive, few silty burrowed vf ss beds throughout.
Ø11-18% average 15%
K20-300md. average 75md
2.8MMcf/d
150'm
1.45MMcf/d
120'm
88 Mcf/d
100'm
GSC

FIGURE 24.



136°
66°30'
66°00'
65°30'
137°
138°
139°
140°
KILOMETRES
0
25
50
Eagle River
Hart River
Peel R.
Ogilvie River
DEMPSTER HIGHWAY
Whitestone River
Porcupine R.
Fishing Branch
Miner River
Whitestone
subcrop limit
+378
wcm
ocm
+253
mcw
gcwcm
-8
gas
mcxw,
wcm
gtstm
gcm,wcm
-613
-1315
gtstm
gcm,sw
-909
mcsw
-1000
-500
0
GSC

FIGURE 25.


136°
66°30'
66°00'
65°30'
136°
GSC
KILOMETRES
0
25
50
137°
137°
138°
138°
139°
139°
140°
140°
Eagle
River
Hart
River
Peel
R.
Ogilvie
River
DEMPSTER HIGHWAY
Whitestone
River
Porcupine R.
Fishing
Branch
River
Miner
River
Whitestone
subcrop limit
166
wcm
ocm
149
mcw
gcwcm
125
gas mcw,
wcm
79
gtstm
gcm,wcm
gtstm gcm,
sw
58
76
mcsw
100
50
0

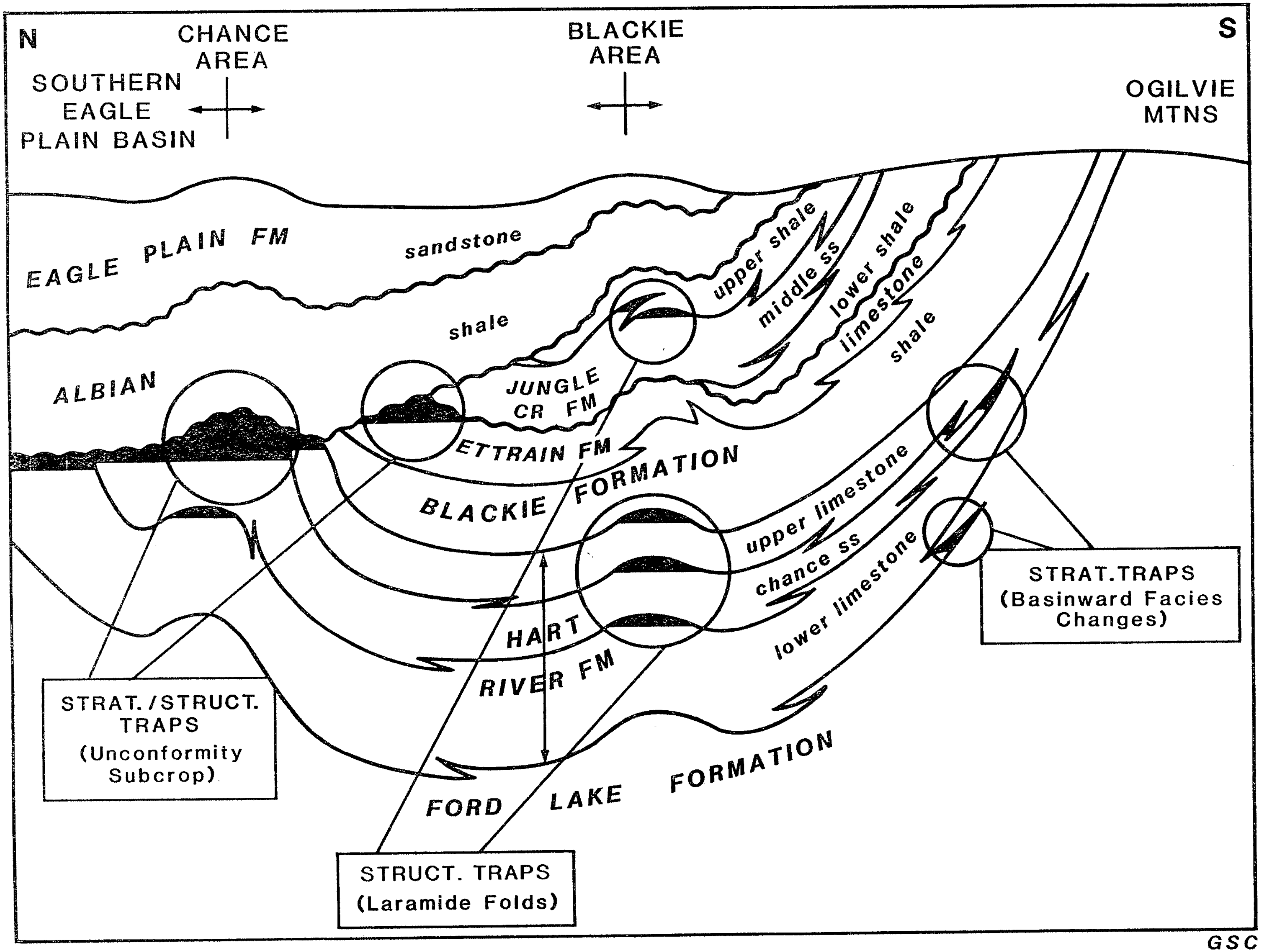

N
S
CHANCE AREA
BLACKIE AREA
SOUTHERN EAGLE PLAIN BASIN
OGILVIE MTNS
EAGLE PLAIN FM
sandstone
shale
ALBIAN
upper shale
middle ss
lower shale
limestone
shale
JUNGLE CR FM
ETTRAIN FM
BLACKIE FORMATION
upper limestone
chance ss
lower limestone
HART RIVER FM
FORD LAKE FORMATION
STRAT./STRUCT. TRAPS (Unconformity Subcrop)
STRUCT. TRAPS (Laramide Folds)
STRAT.TRAPS (Basinward Facies Changes)
GSC

FIGURE 26.