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THE SEDIMENTOLOGY AND STRATIGRAPHY OF THE HUSKY FORMATION IN THE SUBSURFACE, DISTRICT OF MACKENZIE, N.W.T.

D.R. BRAMAN

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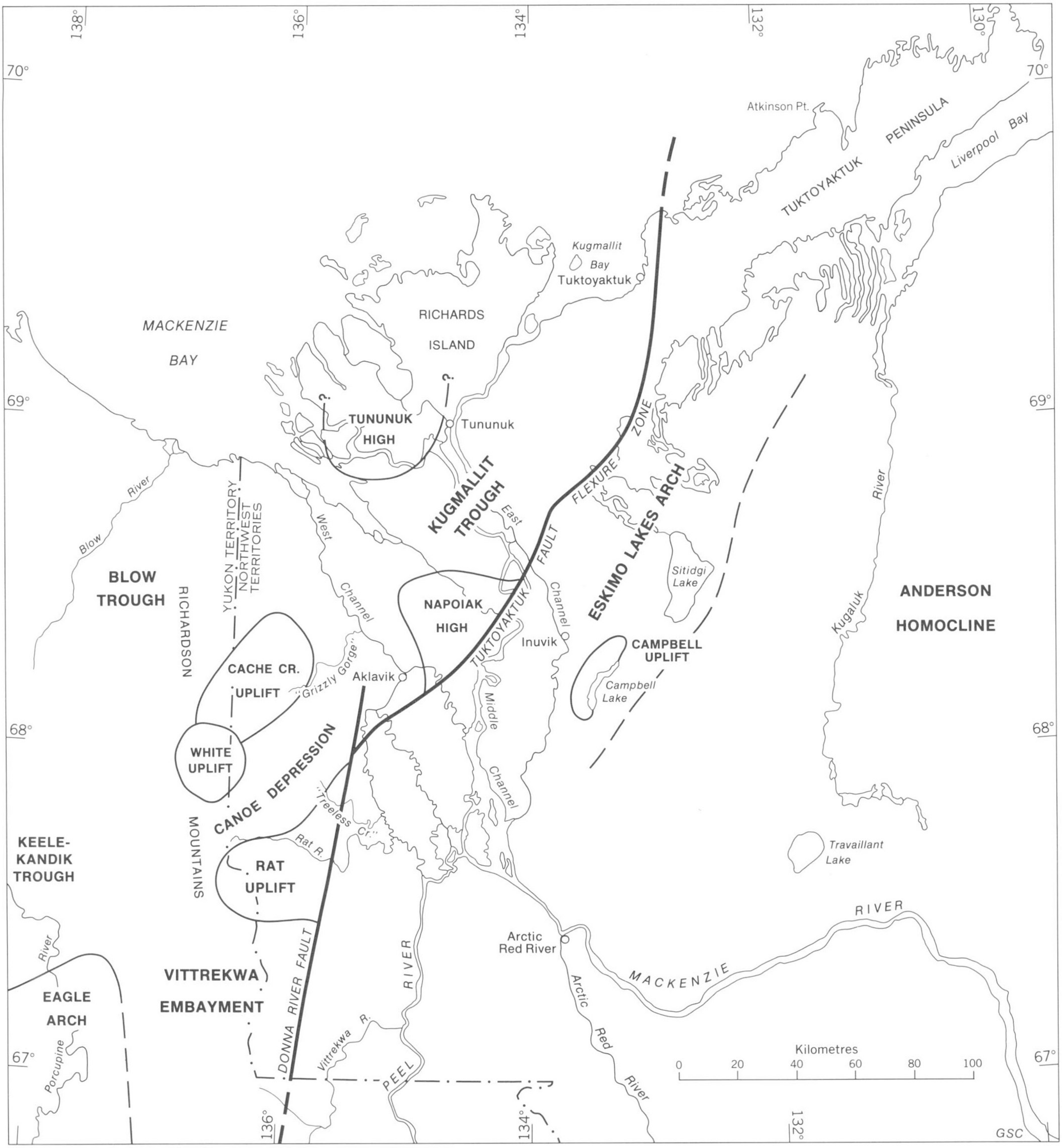

Figure 1. *Structural elements of northern Yukon Territory and Northwest Territories.*

THE SEDIMENTOLOGY AND STRATIGRAPHY OF THE HUSKY FORMATION IN THE SUBSURFACE, DISTRICT OF MACKENZIE, N.W.T.

Abstract

The Husky Formation is a shale unit with minor sandstone interbeds, and subcrops in the Mackenzie Delta and Tuktoyaktuk Peninsula areas. The fine grained sediments generally occur in coarsening-upward cycles. Within these cycles, three lithofacies are identified: a weakly bioturbated shale facies, a strongly bioturbated mixed shale-sandstone facies, and a weakly bioturbated sandstone facies. The three lithofacies probably represent a mud interbar or shoal facies, a bar or shoal margin facies, and a bar or shoal facies respectively. The environment of deposition was a shallow, siliciclastic, marine shelf, which had a northeast-southwest trend and which deepened to the north or northwest. The fine grained sandstone facies has a complex diagenetic history that includes cementing by silica overgrowths, etching of grains, partial filling of pore space with carbonate cement, and precipitation of a number of clay types as grain coatings and pore fillings between grain boundaries. Porosity is very poor and the reservoir potential of the sandstones is considered to be low.

Résumé

La formation d'Husky est constituée d'une unité de schiste argileux et d'un peu de grès interstratifié en sub-affleurement dans les régions du delta du Mackenzie et de la péninsule de Tuktoyatuk. Les sédiments à grains fins apparaissent généralement dans les cycles grossiers ascendants. A l'intérieur de ces cycles, on reconnaît trois lithofaciès: un faciès schiste argileux faiblement bioturbé, un faciès schiste argileux–grès fortement bioturbé et un dernier de grès peu bioturbé. Les trois faciès représentent respectivement un faciès à cordon intermédiaire de boue ou à haut-fond, un faciès à cordon ou à haut-fond de marge et un faciès à cordon ou à haut-fond. Le milieu de sédimentation fut celui d'une plate-forme siliciclastique d'eau peu profonde orientée nord-est–sud-ouest et s'enfonçant vers le nord ou le nord-ouest. Le faciès grès à grains fins a une évolution diagénétique complexe comprenant une cimentation par un afflux de silice, une corrosion des grains, un remplissage partiel des pores par un ciment carbonaté et la précipitation de différents types d'argiles recouvrant les grains et remplissant les espaces interstitiels. La porosité est très réduite et le potentiel de rétention des grès est peu élevé.

INTRODUCTION

The purpose of this study is to describe the Husky Formation, determine stratigraphic correlations within the formation, and interpret the diagenetic history and depositional environments over the area of its subsurface occurrence. These objectives are part of a much larger project on the Mesozoic stratigraphy of the Beaufort-Mackenzie Basin (Dixon, 1982) and more specifically an investigation of the organic geochemistry of the formation (Snowdon, pers. comm.). Figure 1 illustrates the structural elements that have been identified in the region (Dixon, 1982).

Acknowledgments

L.R. Snowdon, T.P. Poulton, A.F. Embry and D.H. McNeil provided valuable information to the author. J. Dixon also provided information as well as comments which contributed greatly to this report. J. Wong provided X-ray analysis results and G.P. Michael analyzed samples by SEM and took the pertinent photographs.

Previous Work

A number of early investigators explored and traversed the Husky Formation outcrop areas west of the Mackenzie River (McConnell, 1891; Camsell, 1906; O'Neill, 1924; Nauss, 1944; Richards, 1950; and Gabrielse, 1957). Through their efforts and observations, the presence of Upper Jurassic-Lower Cretaceous rocks was established in the region.

Jeletzky (1958, 1960, 1961a, 1961b, 1963, 1967, 1971a, 1971b, 1972, 1974, 1975, 1977, 1978 and 1980) has evaluated a number of aspects of the Husky Formation and set up a stratigraphic framework for the outcrop areas. Initially, Jeletzky (1958) identified the 'lower shale-siltstone division' in the Aklavik Range of the Richardson Mountains. An age of Early Kimmeridgian (possibly latest Oxfordian) to Berriasian was proposed for the division. It was subdivided into lower and upper members with a possible hiatus identified within the lower member. Jeletzky (1967) formally established the Husky Formation, including in it his previously informally described 'lower shale-siltstone division'. A type section was selected along the north side of Husky Creek at a point 5.6 km west of Husky Channel and 1.6 km southwest of the tip of Jurassic Butte (68°02'00"N; 135°25'00"W). Four members were defined, based on field relationships: lower member, arenaceous member, red-weathering shale member and upper member. In the same paper, Jeletzky described the age-equivalent, but arenaceous North Branch Formation, based on a type section exposed on the north branch of the Vittrekwa River in the first (lower) gorge (67°05'30"N; 135°44'00"W). This formation is considered to be the shoreline equivalent of the lower and middle Husky Formation (Jeletzky, 1967). Jeletzky (1977) also defined the arenaceous Porcupine Formation, which is partly equivalent to the Husky Formation, from the Dave Lord Ridge area, west of the Richardson Mountains (67°30'N, 137°45'W).

A summary of the geology and geological history of the Beaufort Sea area, including areas of the Mackenzie Delta where the Husky Formation subcrops, was provided by Lerand (1973). This was the first regional synthesis to include both subsurface and surface data. Young et al. (1976) discussed available data from wells drilled in the Beaufort-Mackenzie Basin and outcrop areas. This synthesis summarized the stratigraphy as then known and presented a paleogeographic interpretation for Husky time. Stratigraphic and sedimentologic data has been provided for an outcrop section by Fedoruk (1980), and Hedinger (1979) discussed the detailed foraminiferal biostratigraphy for a section in the Aklavik Range. Dixon (1982) described the subsurface Husky Formation in the Mackenzie Delta area.

GENERAL CHARACTERISTICS OF THE HUSKY FORMATION

Dark grey to brownish grey shale and siltstone with minor interbeds of coarser clastics characterize the Husky Formation. The coarser clastic portion consists of fine- to very fine-grained sandstones or silty sandstones, and, in the Richardson Mountains, medium- to coarse-grained, gritty sandstones or pebbly sandstones. Pebble conglomerates are locally preserved. Concretions, which weather rust to wine-red, are common in most parts of the sections. *Buchia* coquinas and carbonate concretions occur sporadically.

The four informal members from the northern Richardson Mountains were described by Jeletzky (1967) as having the following characteristics:

1. Lower member: the lower contact with the underlying Bug Creek Group is abrupt. The upper contact with the overlying member is conformable and gradational. The thickness of the member is 228 to 247 m (749 to 810 ft) and it is characterized by shale, silty shale and various siltstones that vary in color from black to brown or light grey when fresh surfaces are observed, but tend to weather brown, rust, or maroon. The shales and siltstones are soft to medium-hard and weather recessively. Resistant concretionary bands up to 0.9 m thick are numerous. These bands are brownish grey when fresh but weather rust, orange, or wine-red. Sandy siltstones and fine grained, mostly silty, sandstones are minor. They are poorly sorted, contain scattered coarse sand and grit clasts along with chert, quartz, and clay-ironstone pebbles. *Buchia* shell coquinas are mostly restricted to the coarser grained interbeds and occur in layers or nests within them.

2. Arenaceous member: consists of 12.2 to 36.6 m (40 to 120 ft) of fine- or (rarely) coarse-grained, silty and commonly gritty and pebbly sandstone, interbedded with sandy siltstone and some shale. Most of the rocks are drab grey. Minor interbeds of pebble conglomerate occur. A moderately to strongly glauconitic sandstone and siltstone form the top 0.3 to 1.8 m of the member. The upper contact appears to be conformable and gradational although fairly abrupt.

3. Red-weathering member: the maximum thickness is thought to be close to or slightly in excess of 30.5 m (100 ft). The upper contact is thought to be gradational with the sandy siltstones of the upper member. It is a light- to dark-grey or brownish grey shale, distinctly banded or laminated, and commonly calcareous. Numerous clay ironstone bands and concretions are present. Both shale and ironstone weather rust to orange and/or wine-red. It is generally fossiliferous.

4. Upper member: the thickness varies from 25.9 to 42.7 m (85 to 140 ft) and it consists of thin, alternating, dark grey to grey, sandy to very sandy siltstone with lesser amounts of lighter grey, fine- to very fine-grained grey to buff sandstone and dark grey to black shale. Concretions occur but these tend to be dark grey, hard shale or siltstone. The upper contact is gradational with the overlying Martin Creek Formation.

Dixon (1982) recognized the inapplicability of Jeletzky's four members in the subsurface, because to some extent they are defined on surface weathering characteristics. Dixon subdivided the formation into two informal members in the subsurface. The lower member correlates with Jeletzky's lower and arenaceous members. It consists of shale and mudstone with variable amounts of interbedded siltstone, fine grained sandstones and carbonate concretionary beds. The lower contact is abrupt with underlying units and the lower few tens of metres are commonly black shale or mudstone. The coarser grained interbeds commonly occur in coarsening-upward cycles. The uppermost beds within the member form a better developed coarsening-upward sandstone, which appears to be traceable over considerable distances. This sandstone is probably equivalent to Jeletzky's (1967) arenaceous member. The upper member abruptly overlies the lower member and consists of dark grey to black shale and mudstones. Coarser clastic beds are uncommon to rare in the lower part but increase in abundance upwards in the unit. There is a gradational contact with overlying sandstones of the Martin Creek Formation. It should be noted that the Martin Creek Formation is genetically related to the upper member of the Husky Formation and is the climax of a more massively developed coarsening-upward cycle similar to those observed in the lower member of the Husky Formation.

THICKNESS AND DISTRIBUTION

The Husky Formation has been reported from wells in the Tuktoyaktuk Peninsula north of Eskimo Lakes and the Campbell Lake uplift, and east of the Richardson Mountains in the Mackenzie Delta area. Outcrop data indicate that it is present in the Richardson Mountains, south Barn Range, Rock River area, and in the northern Ogilvie Range.

In the subsurface, the formation thins abruptly against the Tuktoyaktuk Fault Flexure Zone (Fig. 3). Northwest of this fault zone, the Husky Formation thickens (Fig. 3) and presumably reaches a maximum thickness beneath the Beaufort Sea, although wells have not penetrated the formation there as yet. There appears to be thinning of the formation on the north side of the Kugmallit Trough in the Mackenzie Delta, and on the west sides of the Blow and

Keele-Kandik troughs. The Cache Creek High may also have had an effect on the thickness of the Husky Formation although this has not been conclusively proven by drilling or outcrop evidence. The Husky Formation has a known maximum subsurface thickness of 558 m (1830 ft) (Kugpik O-13) and a maximum surface thickness of at least 792 m (2600 ft) (Blow Pass area, Jeletzky, 1971a).

The wells used in this study and the 'picks' for the Husky Formation are tabulated in Appendix I. Their locations are shown on Figure 2. The isopach map for the Husky Formation (Fig. 3) is based on all the wells in which the formation is encountered. Dixon (1982) indicated the possible presence of Husky Formation in the Tununuk K-10 well. Available paleontological data indicate that it is not present in this well. A few wells show an incomplete section, usually due to faulting. Generally, the overall pattern is of increasing thickness away from the Tuktoyaktuk Fault Flexure Zone. The position of this zone has been generalized from Young et al. (1976) and well data. As a rule, there is abrupt thinning (probably due to both depositional thinning as well as later erosive events) across this feature, as indicated by comparisons between Aklavik F-38 and Aklavik F-17 or East Reindeer A-01 and East Reindeer P-60. Evidence of thickening northwestward away from the fault is the basis for predicting a paleo-shoreline for the Husky Formation to the southeast of the Tuktoyaktuk Fault Flexure Zone. Mid-Cretaceous erosion has completely removed the formation over the Tununuk High. Evidence for this erosional event is the presence of the thick section of Husky Formation in the Kugpik O-13 well and its absence in the nearby Kugpik L-24 well. A number of embayments or troughs appear to exist, including one in the vicinity of Aklavik, another immediately east of East Channel and yet another in the Parsons Lake area. The embayment near Aklavik may be a reflection of the Canoe Depression and that near East Channel may reflect the Kugmallit Trough, although the south-southeast to north-northwest trend is not as shown for this feature in earlier work (Young et al., 1976). These are probably local 'troughs' within the larger Kugmallit Trough. The intervening areas between these embayments are local highs and the high to the east of the Aklavik embayment is the Napoiak High of Dixon (1982), which becomes a better developed structural entity later in the Cretaceous.

The overall aspect of the isopach map pattern for the lower member (Fig. 4) is very similar to that for the formation as a whole. For example, the positions of the embayments noted previously are all approximately the same, as is that of the Napoiak High. The dominant trend is a thickening of the lower member to the northwest away from the Tuktoyaktuk Fault Flexure Zone. The isopach map of the upper member (Fig. 5) indicates a filling of the Canoe Depression whereas the Kugmallit Trough still has some expression on the isopachs. Again, this member thickens northward from the Tuktoyaktuk Fault Flexure Zone and the rate of thickening increases with distance away from the fault.

The per cent sandstone was calculated from the gamma ray logs. The per cent sandstone map for the total Husky Formation (Fig. 6) provides a surprising result. One would anticipate a fining of the sediments offshore, and this is observed when all the data are considered. The interesting feature of the observed trend is that the area of maximum sand development is not nearshore, but in a position slightly offshore with finer grained sediments lying both shoreward and seaward from this maximum. The feature delineated by maximum sand development appears to be oriented parallel to the Tuktoyaktuk Fault Flexure Zone, which is in turn thought to be more or less parallel to the paleo-shoreline. The average grain size in the sediments of the Kugmallit Trough area is finer than that in laterally adjacent areas, probably reflecting deeper water conditions. The other embayments are weakly indicated if at all. The per cent sandstone map for the lower member (Fig. 7) generally parallels the trends seen in Figure 6. Again, there are indications that the maximum percentage of sand occurred at a point offshore. The per cent sandstone map for the upper member (Fig. 8) also indicates a coarsening offshore followed by a fining. The observed trends appear to be more uniform than for the lower member. This probably reflects a more regular shelf development during upper member deposition.

A sub-Husky Formation structural contour map (Fig. 9) was constructed in order to compare the observed patterns of formation thickness and sand trends with this surface. Although the surface may have been altered by post-Husky Formation tectonic events, many similarities exist between it and the features indicated on the isopach and per cent sandstone maps. The juxtaposition of the Kugmallit Trough sediments and a well defined structural trough (shown on the structural contour map) indicated on the mapped structural surface reflects features that existed prior to, or penecontemporaneously with, Husky deposition.

Two stratigraphic cross-sections were prepared for the Husky Formation utilizing gamma ray logs. The sections use a datum based on the boundary between the informal upper and lower members of the Husky Formation. Dixon (1982) identifies this contact as a hiatal surface. This surface is not easily picked in all cases, especially in wells that occupy a position in the presumably deeper water portions of the paleo-shelf. The section lines are shown on Figure 2.

Cross-section A-A' (Fig. 10) is drawn through five wells in a generally northwest-southeast line. This orientation is approximately perpendicular to the postulated strike of the paleo-shelf and paleo-shoreline. Therefore, it is probably going from 'deep' water in the northwest at Kugpik 0-13 to 'shallow' water at East Reindeer A-01. The deepening of the basin is physically expressed by a thickening of the formation along the line of section. The lower member thickens rapidly between East Reindeer A-01 and Ogruknang M-31 and then remains uniform, only thickening slightly between Ogruknang M-31 and Kugpik 0-13. The upper member in this cross-section shows a uniform thickening between East Reindeer A-01 and Kugpik 0-13. The observed, mainly coarsening-upward, sandstones are very localized and most are not continuous between laterally adjacent wells. This may be caused by sandstone trends on the shelf being approximately perpendicular to the line of section, resulting in apparent localization of the zones.

Cross-section B-B' (Fig. 11) runs from Aklavik F-38 to Pikiolik E-54 and includes the Napartok M-01, East Reindeer A-01, Parsons P-41, Parsons F-09, and Imnak J-29 wells. This cross-section parallels the strike of the postulated paleo-shoreline and probably passes through areas where the water depth was relatively uniform. The section thins toward the northeast. Some of the sandstones in the lower member are fairly persistent between adjacent wells, but others appear to be strictly localized. The upper sandstones of the lower member are particularly well developed and can be readily traced along the entire length of the section. Other sandstones are not as persistent, or not as obviously so.

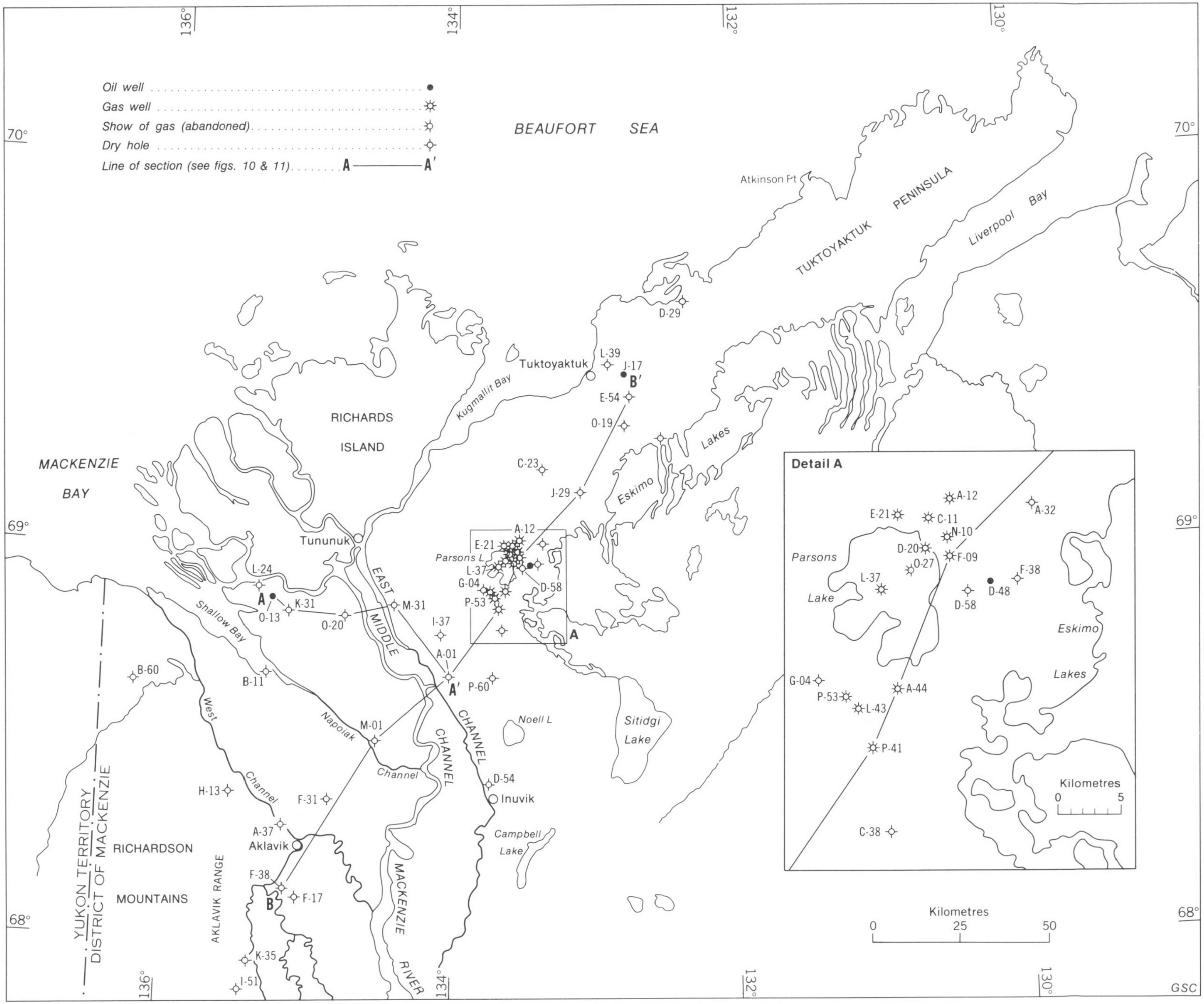

Figure 2. *Well locations and lines of cross-section A-A′ and B-B′.*

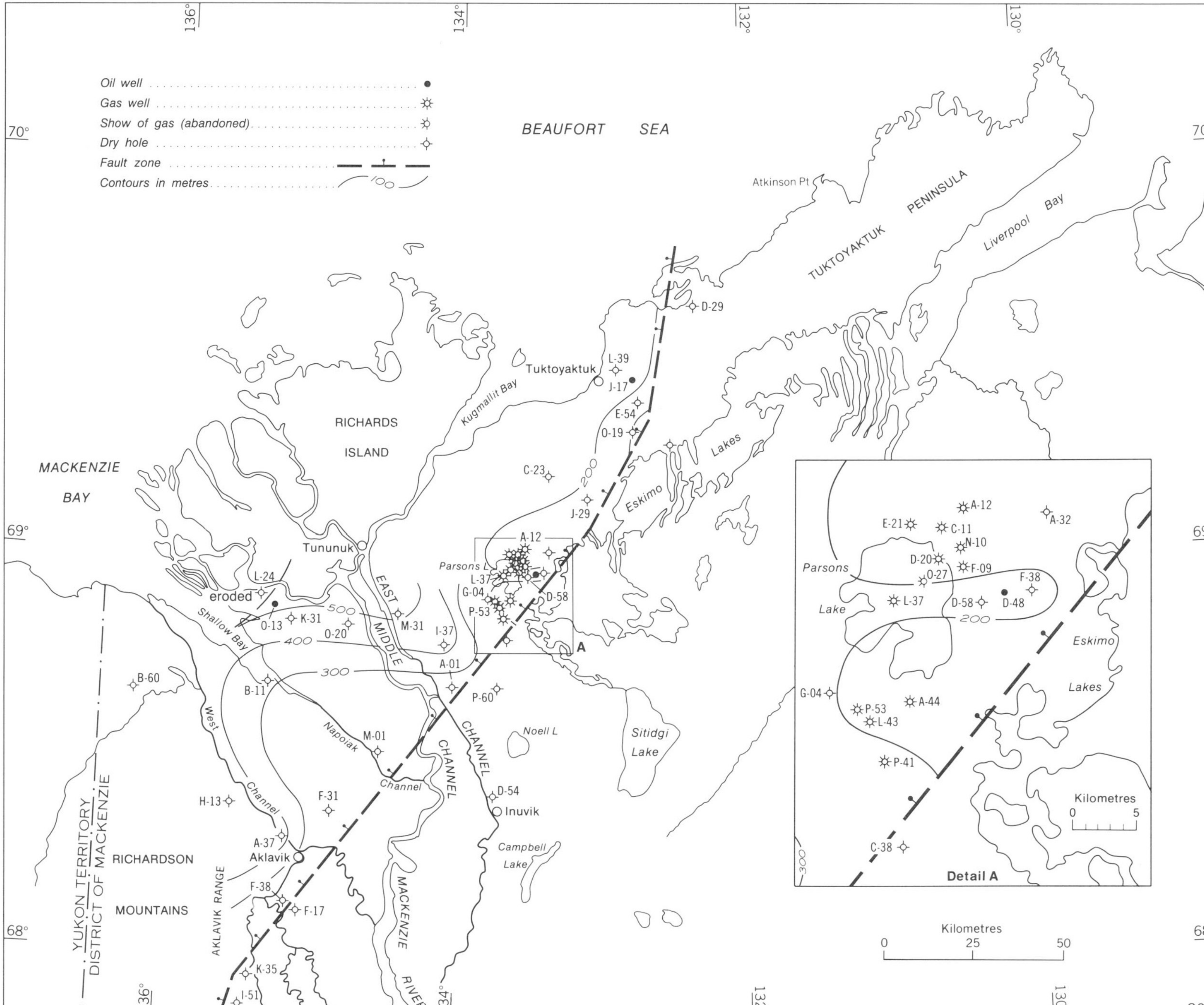

Figure 3. *Total isopach map for the subsurface Husky Formation.*

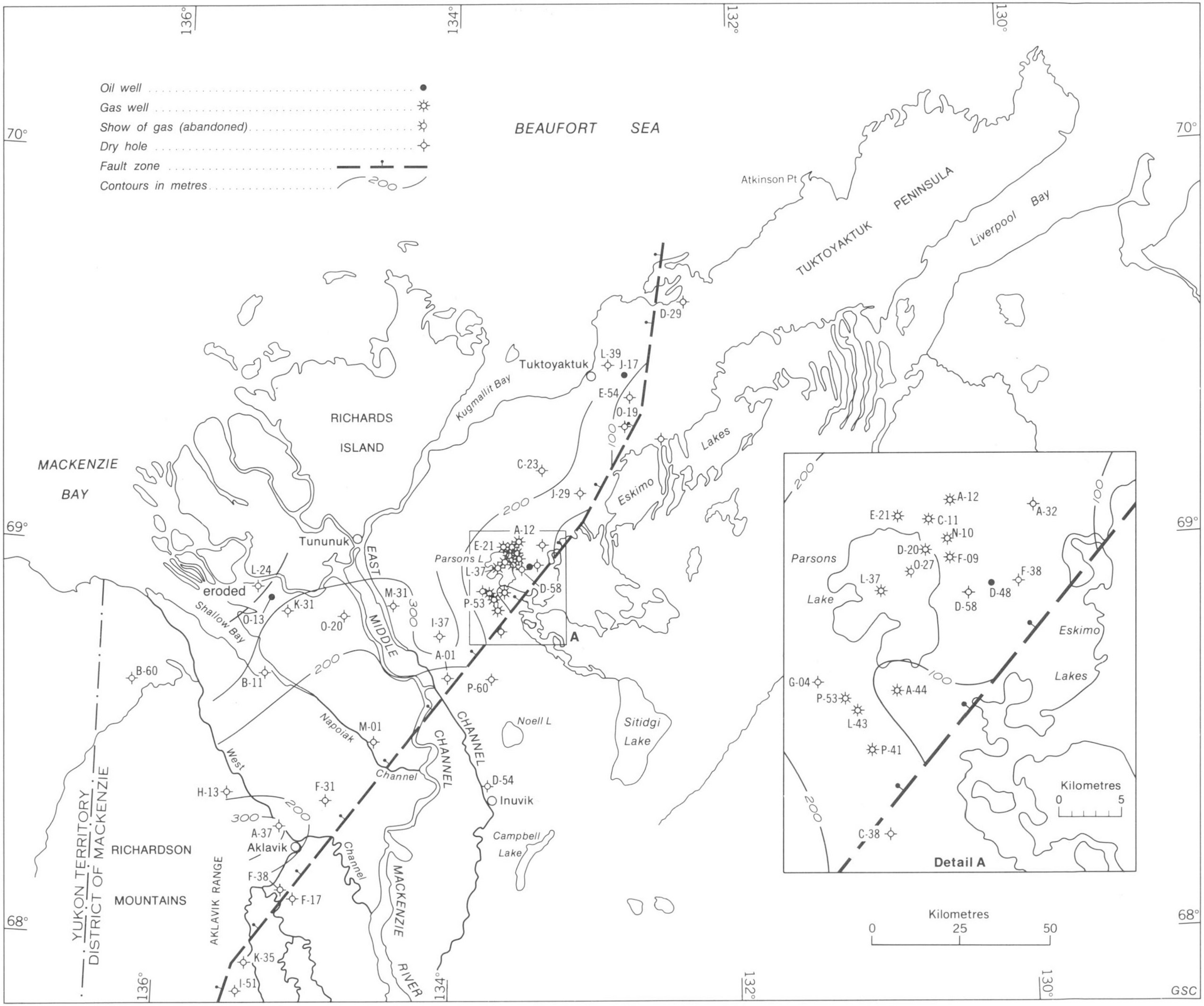

Figure 4. *Isopach map for the lower member of the Husky Formation.*

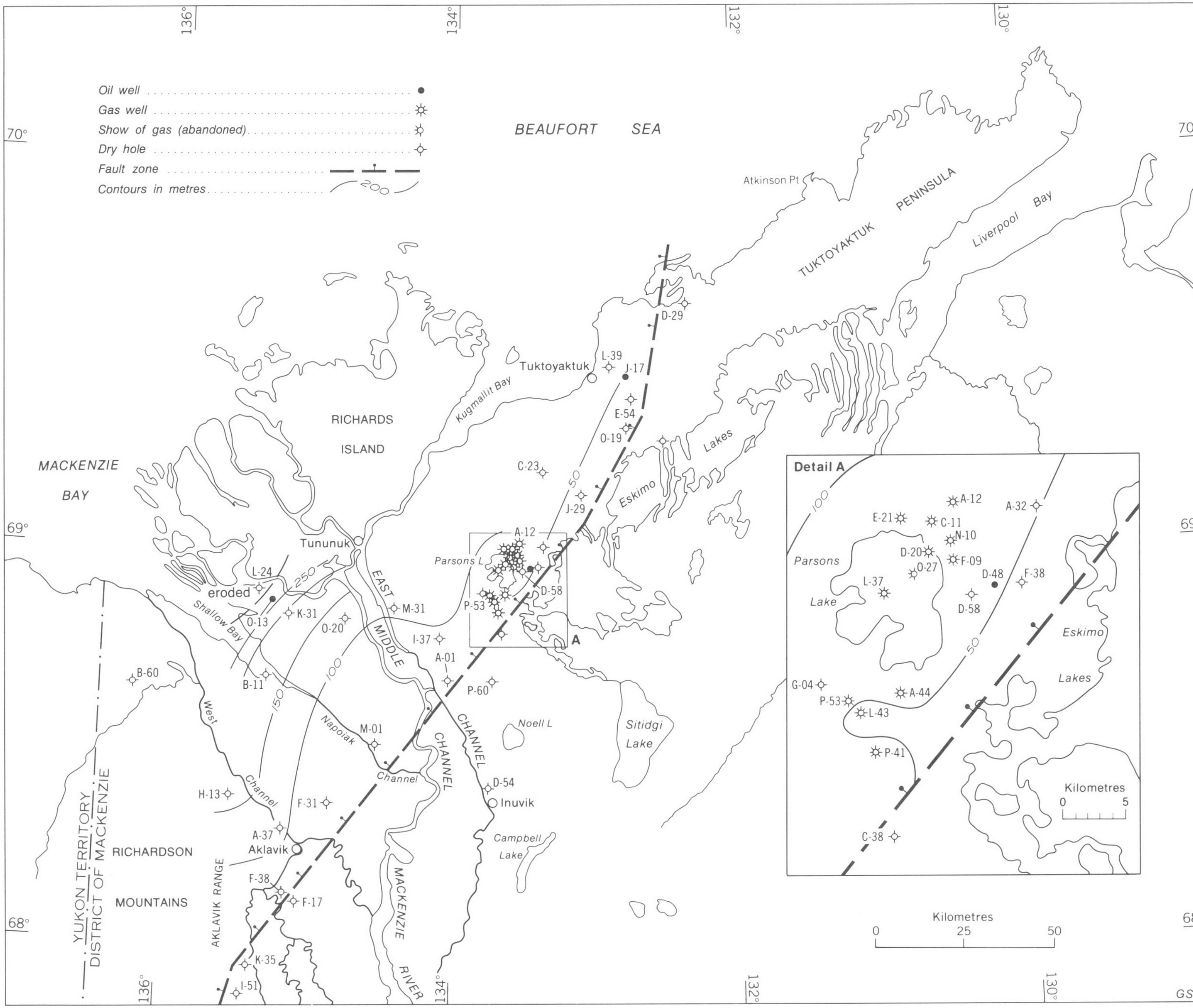

Figure 5. Isopach map for the upper member of the Husky Formation.

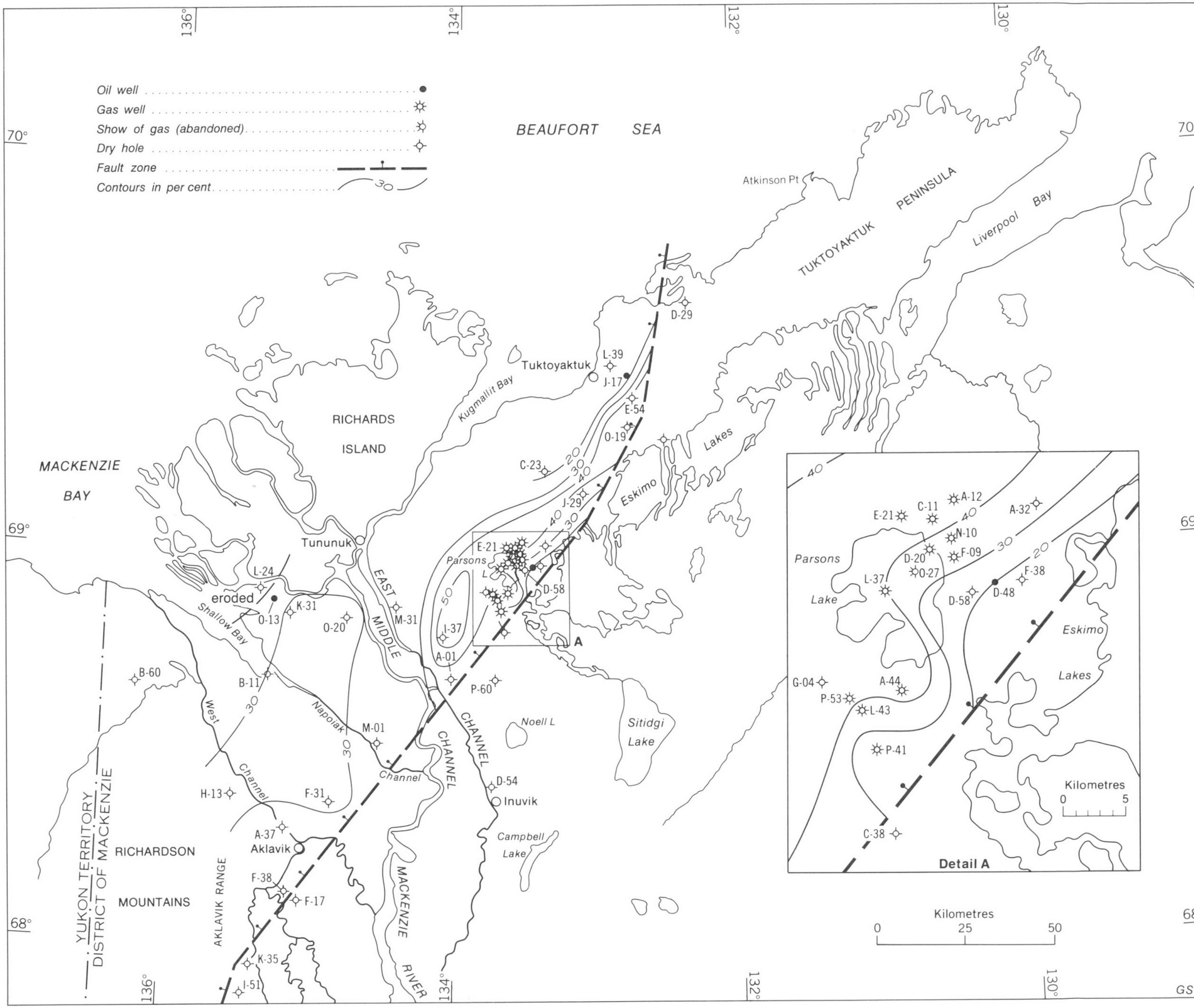

Figure 6. *Per cent sandstone map for the total Husky Formation.*

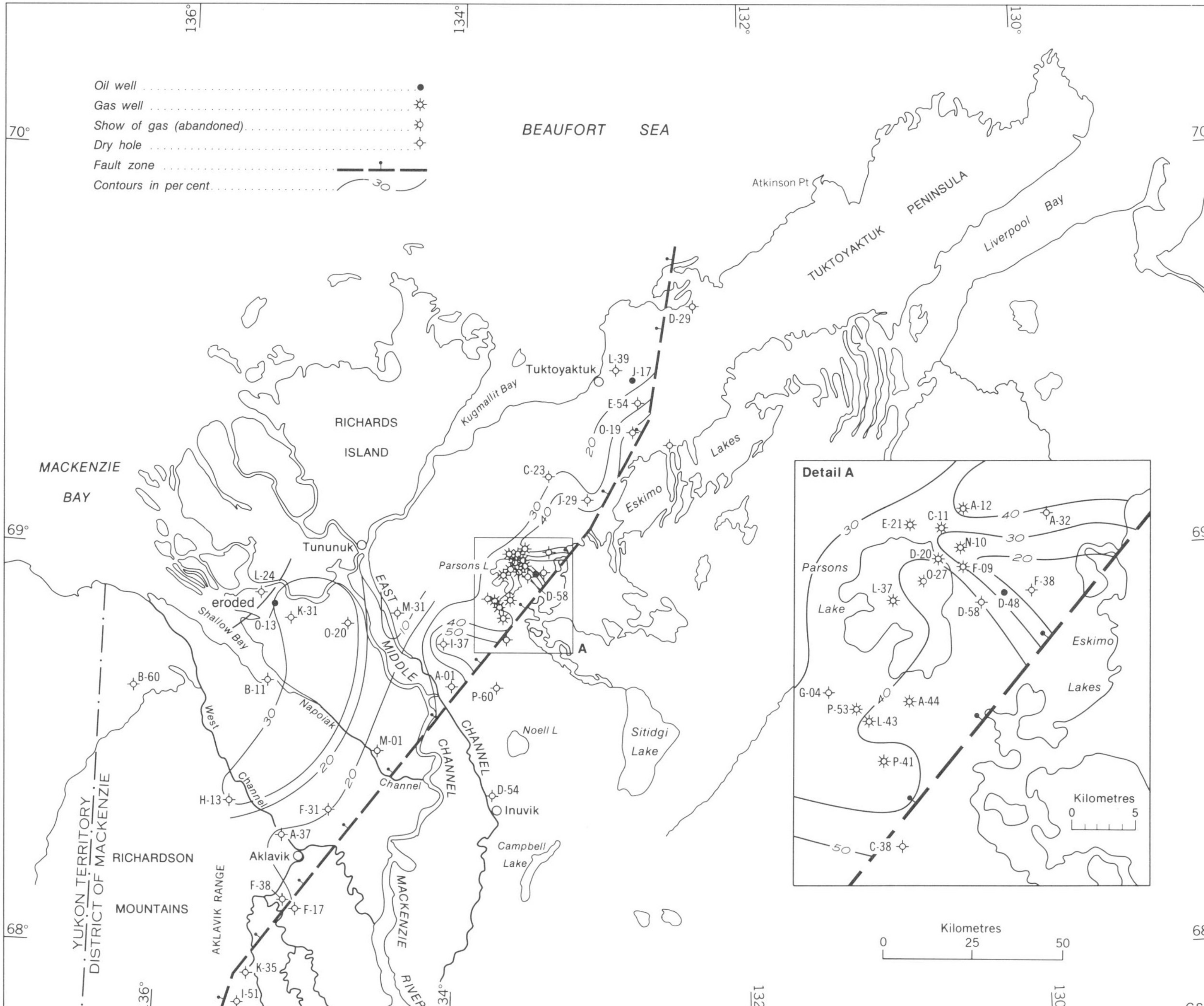

Figure 7. Per cent sandstone map for the lower member of the Husky Formation.

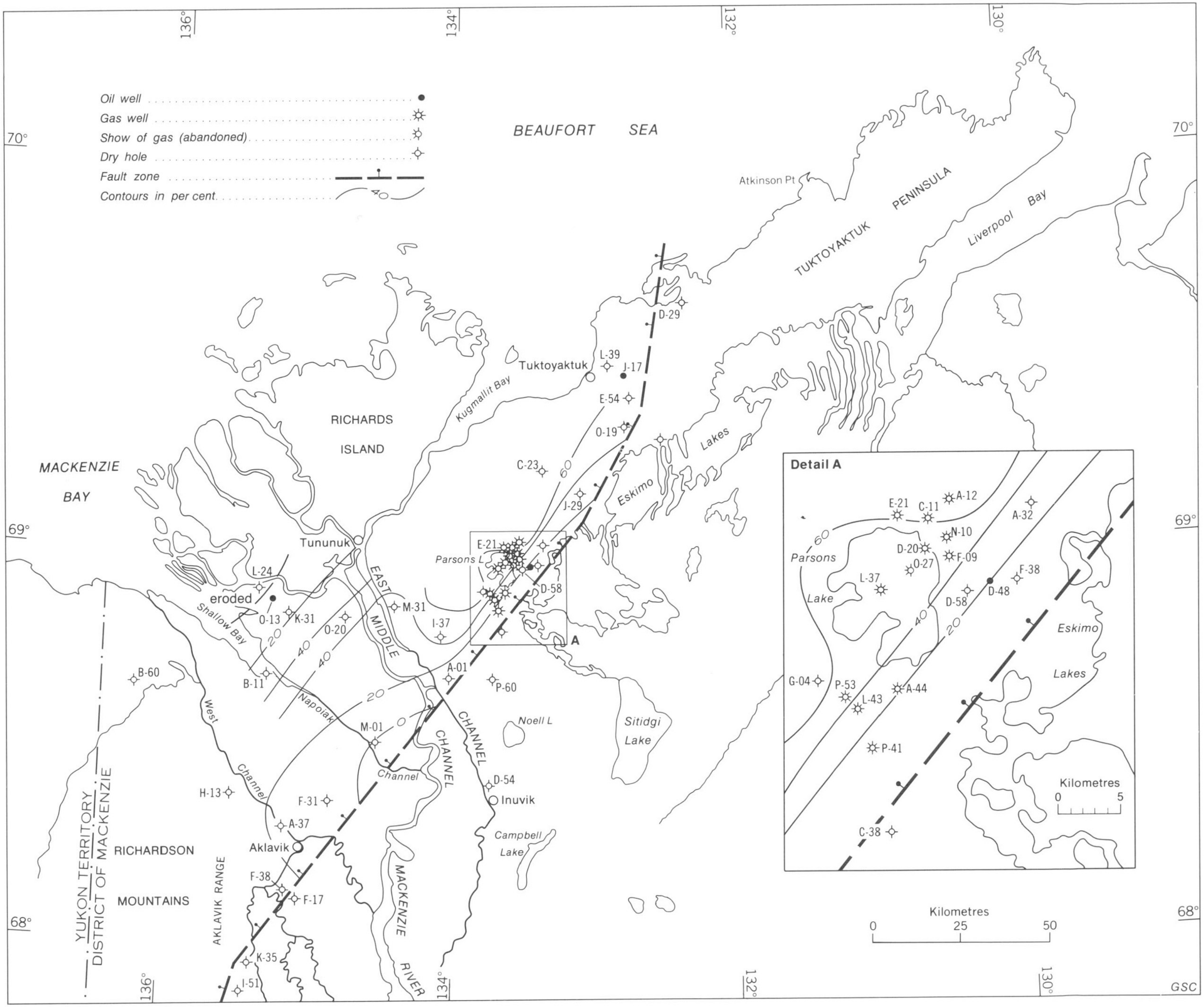

Figure 8. Per cent sandstone map for the upper member of the Husky Formation.

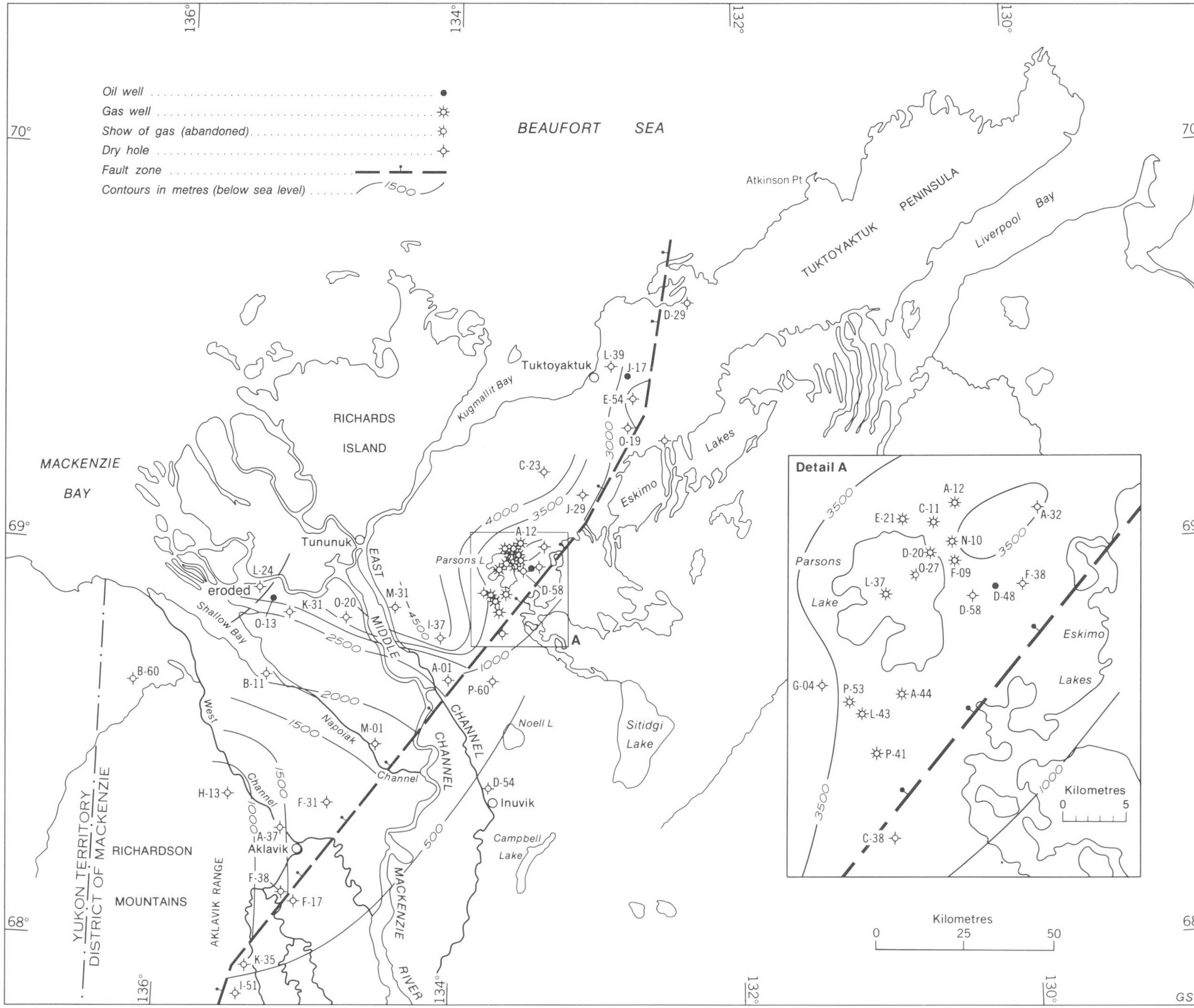

Figure 9. *Sub-Husky Formation structural contour map.*

RELATIONSHIP TO OTHER UNITS

The Husky Formation abruptly overlies strata of the Bug Creek Group in the northern Richardson Mountains. Jeletzky (1967) commented on the uneven nature of this contact, with the surface lows of the Bug Creek Group filled in by fissile, sulphur-stained shale of the Husky Formation. Jeletzky did not see any coarser detrital particles or basal conglomerate at this horizon. The upper unit of the Bug Creek Group is the Aklavik Formation (Poulton et al., 1982), which is dominantly a massive sandstone. Eastwards and northeastwards, the Husky overlaps the Bug Creek Group and rests directly on Paleozoic units. In the subsurface, this contact is always abrupt and locally is characterized by a thin pebble conglomerate in the cores that span it.

The upper contact with the Martin Creek Formation (Dixon, 1982) of the Parsons Group is a gradational one. In fact, it appears that the characteristic coarsening-upward cycles seen throughout the Husky Formation are continued into the Martin Creek Formation, with the cycles in the latter formation being more massively developed and persistent units than those observed within the Husky Formation.

The Husky Formation is laterally equivalent to parts, or all, of the North Branch (Jeletzky, 1967), Porcupine River (Jeletzky, 1977) and Kingak formations (Young et al., 1976). The Porcupine River and North Branch represent nearshore and beach coarse clastics. The interbedded fine clastics and shale of the Husky Formation represent a marine shelf; the upper part of the predominantly shale Kingak Formation to the west and north represents a deeper marine environment.

Equivalent marine strata from part of the Gilmore Lake Member of the Langton Bay Formation have been described from the Anderson Basin (Brideaux and Fisher, 1976; Yorath and Cook, 1981) and contain similar lithofacies to the Husky Formation. Northward, on Banks Island, Miall (1979) has described coeval marine strata, which he identified as Mould Bay Formation, but which are in a mainly shale facies as opposed to the general sandstone facies of the typical Mould Bay Formation (Tozer and Thorsteinsson, 1964).

AGE DETERMINATIONS

In the previously mentioned papers by Jeletzky, a biostratigraphic sequence based on pelecypods was established and utilized for subdivision, correlation and age determination. These faunas indicate that the Husky Formation ranges in age from Late Oxfordian/Early Kimmeridgian to Early Berriasian. The sequence used includes in ascending order: a lower unzoned portion, *Buchia concentrica* Zone, *Buchia mosquensis* Zone, *Buchia piochi* Zone, *Buchia fischeriana* Zone, *Buchia terebratuloides* Zone, *Buchia okensis* Zone, and *Buchia* n. sp. aff. *volgensis* Zone (Jeletzky, 1980). A number of other types of fossils are at least partly useful in the biozonation of the formation, including foraminifera, dinoflagellates and ammonites (Hedinger, 1979; Brideaux, 1977; Brideaux and Fisher, 1976). The entire formation has not been studied in detail using these last three fossil types.

Jeletzky (1958, 1967) has indicated the ages of the four recognized members in outcrop. The lower member spans the short, unzoned portion and the *Buchia concentrica*, *B. mosquensis*, *B. piochi* and *B. fischeriana* zones, indicating an age span of Late Oxfordian through Kimmeridgian and Portlandian into Tithonian. The arenaceous member was correlated with the *Buchia fischeriana* and *B. terebratuloides* zones, indicating a Late Tithonian age. The red-weathering member is characterized by the *Buchia okensis* fauna, which indicates an Early Berriasian age. The upper member belongs to the *Buchia* n. sp. aff. *volgensis* Zone, indicating a Berriasian age.

In the subsurface, ages based on microfossils have been provided from a number of wells. The lower member has been dated as Late Oxfordian-Early Kimmeridgian to Late Volgian (Jeletzky and Chamney, in Brideaux et al., 1975; Brideaux, Chamney and Jeletzky, in Brideaux et al., 1976; Chamney, in Barnes et al., 1974). The upper member has been dated as Berriasian (Jeletzky, in Brideaux et al., 1975).

SEDIMENTOLOGY

Rock samples and gamma ray logs from wells penetrating the Husky Formation indicate a fine grained sequence with a few sandstone units that commonly coarsen upwards. As a rule, the sandstones have gradational bases but a few have abrupt bases. They have abrupt upper contacts although a few grade into overlying shale-rich zones. The sandstone cycles do not appear to form any consistent areal pattern and are variable in number and spacing between wells. One sandstone within the sequence is commonly well developed, especially in the Parsons Lake area. The number of cycles varies between one and seven, and sections with the greatest number of cycles appear to correlate with the greatest thickness of Husky Formation.

Very few cores are available for study from the Husky Formation (Appendix II). The strata in these cores are similar in a number of respects. Generally, they are argillaceous with some thin sandstone beds. Bioturbation is common and pervasive. Grain size of the sandstones is very fine to fine. Where the lower contact of the formation is cored (Kimik D-29 and Mayogiak J-17), a thin, pebble zone is present.

From observations of the available core, the cycles recognized contain three successive lithofacies (Fig. 12):

1. Shale facies: consists of dark grey to black shale, weakly fissile to blocky with scattered floating pebbles and sand grains, minor siderite nodules and a few pelecypod fossils. Yellow-brown mudstone layers (1-8 cm thick) are present, but not common, within dark shale sequences. The shale has 15 to 35 per cent very fine- to fine-grained sand grains, floating or with point contacts, within the clay matrix. Organic material is present and a single sample analyzed yielded 0.8 per cent organic carbon in the total sample. Glauconite is locally present. The boundary between the shale facies and the overlying mixed facies is gradational. Bioturbation is not prevalent in the shale facies.

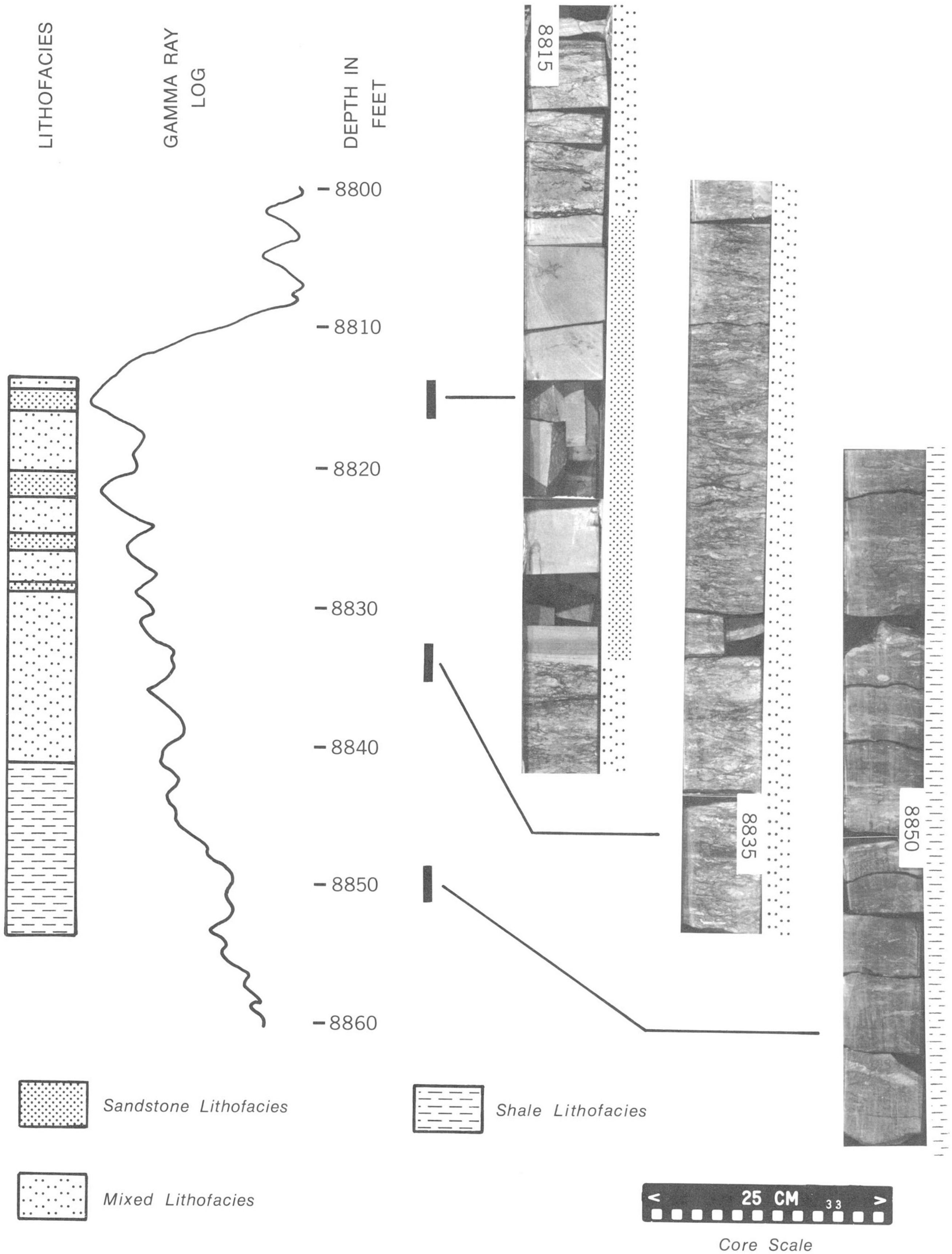

Figure 12. *Lithofacies in a coarsening-upward cycle from Mayogiak J-17 well, Core No. 7.*

2. Mixed facies: this facies generally shows an increase in the amount of siltstone and very fine- to fine-grained sandstone. The rock has a mottled appearance, with dark areas consisting predominantly of shale, and light brown or tan areas with a high percentage of sandstone and siltstone. Commonly, no relict bedding or sedimentary structures are present. Where they are, it is usually in the form of laminae preserved in sandstone fragments. Bioturbation is the cause of the mottling and sandstone fragments. Burrows may be present and are visible as vertical tubes (escape tubes), white-walled tubes, or horizontal tubes. In some cases, bioturbation is so intense that the sediment is homogeneous in appearance. The sandstone component generally makes up 35 to 65 per cent of the total facies. Organic material is present, with 1.9 and 0.76 per cent total carbon determined from two samples. Glauconite is locally present. The change to the overlying sandstone facies is usually abrupt.

3. Sandstone facies: consists of very fine- to fine-grained sandstones that are massive, ripple-laminated, or crossbedded (low angle). The sandstones have an abrupt base that is uneven or irregular, and an abrupt upper boundary that is commonly burrowed. There does not appear to be a preferred or common internal vertical sequence of sedimentary structures within the sandstones. In places, the parallel and ripple laminae are interbedded, indicating possible oscillatory depositional conditions. The sandstones are made up of more than 65 per cent quartz. Organic material is present, but does not appear to be as abundant as in the mottled facies. Glauconite is common to abundant. The sandstone that marks the boundary between the upper and lower members has not been cored, but well cuttings show that there is a glauconite-rich zone near the top of it.

The three facies most commonly occur in a vertical coarsening-upward sequence, with the mixed facies occurring between an underlying shale facies and an overlying sandstone facies. In places, the sandstone facies occur stacked, separated by a mixed facies.

TABLE 1

Lithology of thin sections

SAMPLE			CONSTITUENTS (in percentage)						
Well	Footage (ft)	(m)	Quartz	Clay	Rock Fragments	Feldspar	Glauconite	Calcite	Mica
Mayogiak J-17	8819.4	(2688.1)	81	18	-	1	-	-	-
	8821.4	(2688.8)	54	46	-	-	-	-	-
	8822.8	(2689.2)	57	43	-	-	-	-	-
	8824.6	(2689.7)	69	30	-	-	1	-	-
	8836.8	(2693.5)	52	48	-	-	-	-	-
	8960.2	(2731.1)	72	10	-	-	6	12	-
	8967.0	(2733.1)	63	35	-	-	1	-	1
	8972.0	(2734.6)	83	9	-	-	3	5	-
	8974.6	(2735.3)	33	65	-	-	-	1	1
	8982.4	(2737.7)	56	44	-	-	-	-	-
	9011.1	(2746.6)	15	84	-	-	-	-	1
	9027.0	(2751.4)	30	70	-	-	-	-	-
	9375.4	(2857.6)	26	58	16	-	-	-	-
Kugpik O-13	9641.4	(2938.6)	48	52	-	-	-	-	-
	9646.9	(2940.4)	40	58	-	2	-	-	-
	9652.9	(2942.2)	79	20	-	1	-	-	-
	9657.5	(2943.6)	83	17	-	-	-	-	-
	9677.1	(2949.6)	72	28	-	-	-	-	-
	9679.8	(2950.4)	31	68	-	-	-	-	1

- if present less than 1 per cent

PETROLOGY AND CLAY MINERALOGY

Nineteen core samples and five cutting samples were thin sectioned, thirteen cutting samples were submitted for clay analysis, and three core samples were submitted for SEM study. Three of the core samples were also submitted for whole rock X-ray analysis and per cent organic carbon determination. Figures 13 and 14 illustrate some of the minerals and fabrics observed during SEM analysis. Table 1 shows the observed composition of the nineteen thin sections taken from cores. The feldspars are poorly represented in this table owing to limited recognition of feldspar in thin section, because staining techniques were not employed. The feldspar recognized in the counts consisted mostly of fresh-appearing plagioclase. Potassium feldspars were generally not recognized although they were identified during SEM analysis. The X-ray analysis on the well cuttings indicated that the feldspars make up to 3 per cent in the whole rock analysis, whereas feldspar content in the three core samples ranged from 4 to 8 per cent. Fedoruk (1980) reported 22 to 33 per cent feldspars in four samples from the Husky Formation along Cache Creek. The varying percentages obtained from different areas may be indicative of multiple sources for the sediment or a variable distance from the source.

Rock fragments also are probably underestimated in the counts. Observed rock fragments consisted predominantly of polycrystalline quartz, of about the same composition as the enclosing rock. Therefore, their recognition is very difficult. Fedoruk (1980) estimated between 3 and 7 per cent in the four samples he studied. His estimate may be more accurate than the less than one per cent actually observed in this study.

Most of the quartz grains have euhedral overgrowths. Many of the grains have been subsequently etched, possibly prior to or during later calcite cement precipitation. Many of the grains have large amounts of clay minerals coating the surfaces, indicating that the clay is authigenic and formed after the precipitation of the overgrowth. The quartz grains are generally without inclusions and fairly clear in appearance. The pre-overgrowth condition of the grains is well rounded. Grain-to-grain contacts include point contacts, concavo-convex, straight, and welded ones.

Both calcite and dolomite cements were noted and they completely fill some pores.

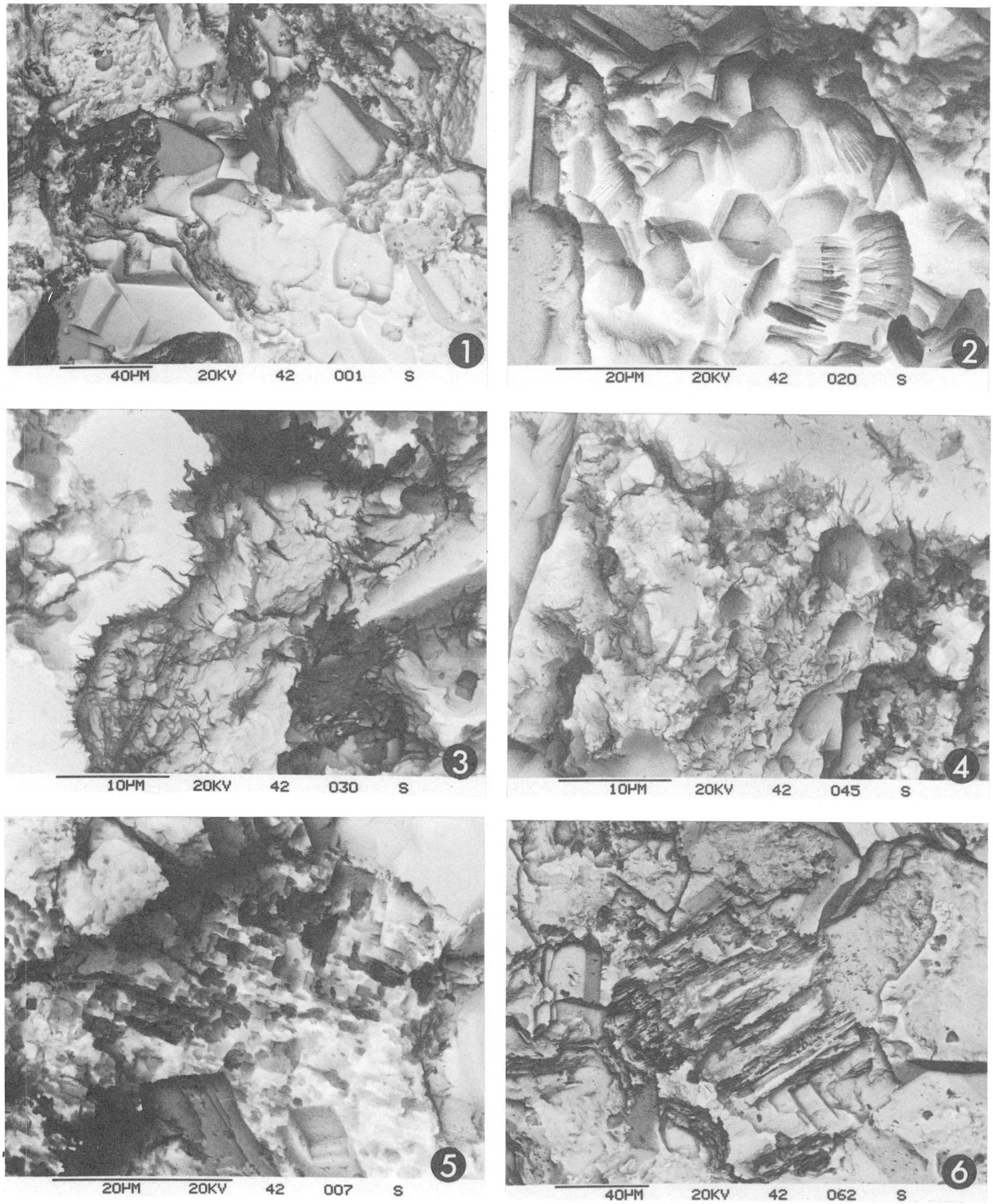

Figure 13. *SEM views of mineralogy and fabric of core samples.*

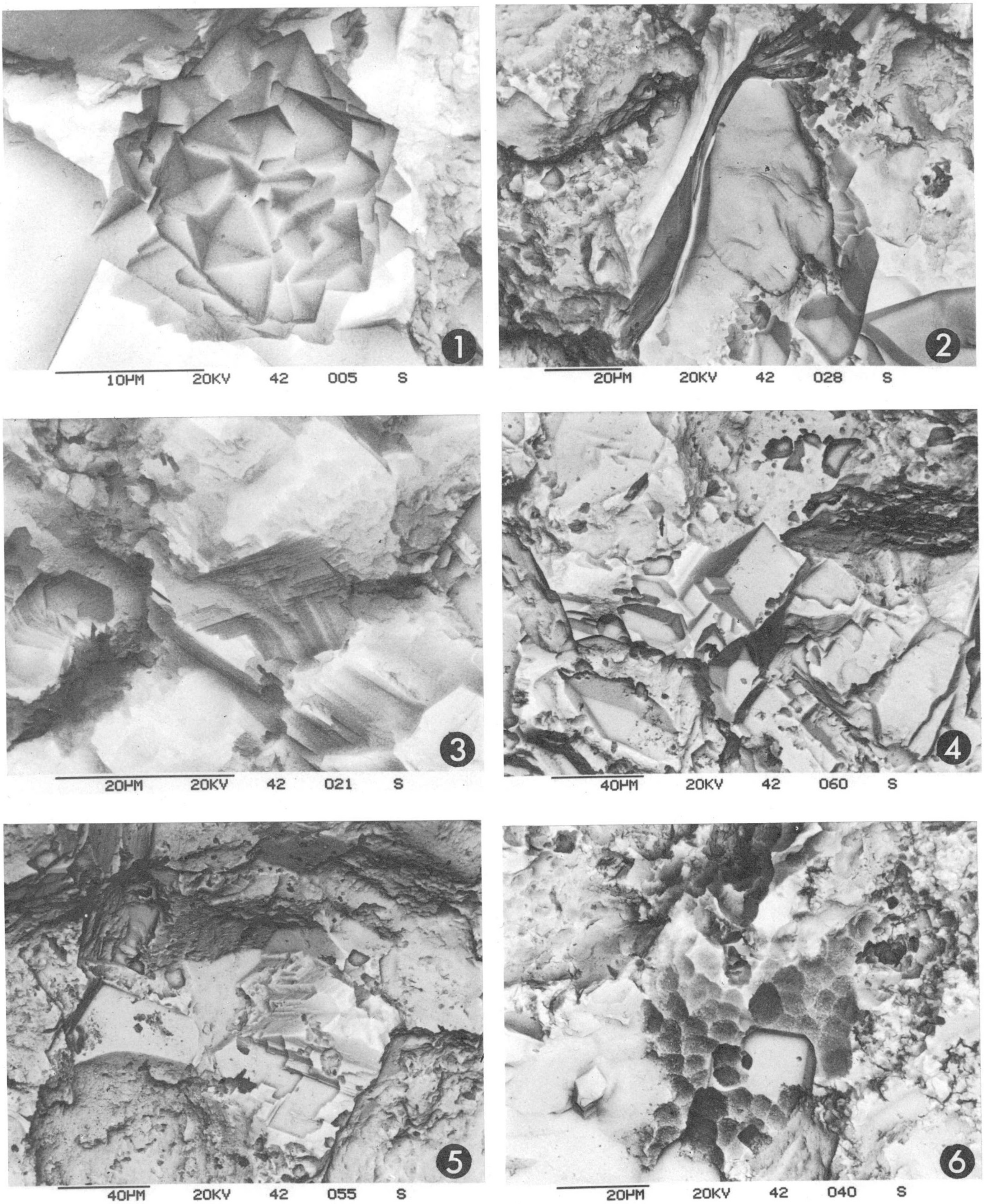

Figure 14. *SEM views of mineralogy and fabric of core samples.*

Clays are abundant and diverse. Kaolinite, mixed-layer clays, illite/smectite, and chlorites are common. The clays occur as grain replacements of some feldspars, coatings on euhedral quartz grains, and as pore-filling material. The results from semi-quantitative whole rock X-ray diffraction determinations are tabulated in Table 2. The samples included thirteen from well cuttings and three from core samples. The well cuttings were selected to obtain a suite of samples from varying stratigraphic depths, in order to evaluate diagenetic changes with depth. Several generalizations may be made from the results. Quartz content ranges from 64 to 84 per cent. Feldspar generally ranges from 2 to 8 per cent. Of the clays, the mixed-layer types are the most common, constituting between 5 and 12 per cent. Illite and kaolinite/chlorite each make up 2 to 5 per cent of the rock. Calcite and/or dolomite content varies between 0 and 5 per cent. A semi-quantitative X-ray analysis was also completed on the less than 2 μm clay fraction for the well cutting samples (Table 3). Quartz makes up 20 to 48 per cent of this fraction and mixed-layer clays 23 to 47 per cent. Illite ranges from 12 to 20 per cent and kaolinite/chlorite 11 to 26 per cent of the fraction. The mixed-layer clays are composed of illite, chlorite, montmorillonite, and 2:1 layer silicates in varying proportions. Kaolinite is more abundant than chlorite, although there are exceptions to this generalization.

Accessory minerals are in some cases common within the samples. Glauconite is present in most samples and, although it usually makes up less than one per cent of the total mineral assemblage, in some samples it becomes abundant, comprising 6 per cent of the total. It is most commonly observed in the sandstone facies. Pyrite is often present and occurs as scattered spherules, replacement of fossil fragments, and elongate rods. Calcium phosphate minerals were noted in samples during SEM study. Ankerite and siderite are also present in minor amounts. Muscovite is present and generally makes up less than one per cent of the mineral assemblage. Some heavy minerals are present, including zircon.

For the most part, porosity is low, but locally may be as high as 20 per cent.

ENVIRONMENTS OF DEPOSITION

Fossils indicate that the Husky Formation was deposited in a marine environment (Jeletzky, 1958, 1967, 1975). The Husky Formation conforms well to the shallow marine shelf model. Deposition in a shallow marine shelf environment is influenced by such factors as basin energy (in the form of tides, currents and storms), tectonics, sediment supply, sedimentation rate, and biological activity. The deposits formed in such an environment vary, depending on the intensity and interrelationships of these factors, but commonly show the following characteristics, which were compiled from observations made during the present study, as well as a number of published reports (Anderton, 1976; Baird, 1981; Boyles and Scott, 1982; Brenner and Davies, 1974; Burst, 1958; Byers, 1974; Campbell, 1971; Caston, 1972; Evans, 1970; Exum and Harms, 1968; Goldring, 1971; Goldring and Bridges, 1973; Goldring and Langenstrassen, 1979; Hamblin and Walker, 1979; Houboult, 1968; Hough, 1932; Johnson, 1977, 1978; Kenyon, 1970; Kenyon and Stride, 1970; Michaelis and Nixon, 1969; Nio, 1976; Off, 1963; Porter, 1976; Reineck and Singh, 1972; Simpson, 1975; Spearing, 1975; Sutton et al., 1970; Swift, 1976; Swift and Field, 1981; Weimer, 1976; and Wright and Walker, 1981):

1. They are generally characterized by fine grained sediments; clays, silts, or fine sands dominate.
2. Sedimentation occurs in cycles which may be abrupt or gradational at top and bottom.
3. The cycles usually coarsen upwards with increasing numbers and thickness of sandstone beds near the top of the cycles.
4. Three environmental facies are recognized within these cycles:
   a. Central bar or shoal facies: generally fine grained sand with parallel- or cross-laminae; some low-angle crossbeds. A few shale partings may be present. Bioturbation or burrowing is minimal.
   b. Bar or shoal margin facies: extensively bioturbated with a mottled texture. Sandstones show similarities to central bar or shoal facies but bioturbation has altered the original sedimentary structures. The percentage of clays is greater than in the central bar or shoal facies.
   c. Interbar or shoal facies: predominantly clay with minor amounts of sand, but not as extensively bioturbated as bar or shoal margin facies. Sedimentary structures are difficult to recognize because of fine grain size.
5. The sand areas are small compared to total shelf area, and isolated from one another. Sizes may be up to 160 km long (usually less than 20 km), 2 to 60 km wide, with a maximum thickness of about 30 m.
6. Coarser grained sediments such as sands and conglomerates may occur as isolated clasts or in thin beds of limited areal extent.
7. Fossils may be abundant locally but as a rule are uncommon within the sediments. Bioturbation is very common and in many cases pervasive. Where shelly fossils are abundant they may occur as lenses or layers and are commonly associated with a coarse grained unit.
8. Few sedimentary structures show evidence of high energy.
9. The bars or shoals are commonly aligned in space and time.
10. Visible carbonaceous material is rare or uncommon, and consists of broken plant fragments or partial stems. Disseminated organic debris may be abundant, making the sediments potential source rocks.
11. Unconformities or hiatal surfaces may be present within a sequence and these need not be associated with a lithological break.
12. The bars or shoals migrated laterally through time and not all have symmetrical profiles.
13. The bar or shoal may be a potential reservoir rock.
14. Glauconite may be present and it may be abundant near the tops of the bar or shoal facies.

TABLE 2

Semi-quantitative results of whole rock X-ray analysis (in percentage)

Sample Number	Mixed Layer	Illite	Kaolinite/ Chlorite	Quartz	Feldspars	Calcite/ Dolomite
Treeless Creek I-51 1010 ft (307.9 m)	6	2	3	79	3	2
Beaverhouse Creek H-13 2000 ft (609.6 m)	8	4	4	77	2	tr
East Reindeer P-60 3100 ft (944.9 m)	6	4	5	75	3	-
Aklavik F-38 4200 ft (1280.2 m)	8	-	3	82	2	-
Aklavik A-37 4900 ft (1493.5 m)	6	4	5	77	-	5
Unak B-11 6000 ft (1828.8 m)	5	3	3	76	tr	3
Unak B-11 6900 ft (2103.1 m)	8	4	4	77	3	-
Kugpik O-13 8310 ft (2532.9 m)	7	4	2	82	3	-
Kugpik O-13 9000 ft (2743.2 m)	8	tr	tr	64	2	2
Kugpik O-13 10 000 ft (3048.0 m)	12	tr	5	65	-	-
Kipnik O-20 11 000 ft (3352.8 m)	6	3	3	79	2	-
Ikhil I-37 14 100 ft (4297.7 m)	10	-	3	84	2	-
Ikhil I-37 15 030 ft (4581.1 m)	12	-	3	75	2	-
Mayogiak J-17 8822.8 ft (core) (2689.2 m)	9	6	3	73	8	-
Mayogiak J-17 8836.8 ft (core) (2693.5 m)	7	5	6	74	5	-
Mayogiak J-17 9027.0 ft (core) (2751.4 m)	10	5	4	69	4	5

TABLE 3

Semi-quantitative results of less than two micron size clay fraction (in percentage)

Sample Number	Illite	Kaolinite/ Chlorite	Quartz	Mixed Layer and/or Expandable Layer
Treeless Creek I-51 1010 ft (307.9 m)	12	23	34	31
Beaverhouse Creek H-13 2000 ft (609.6 m)	15	17	20	48
East Reindeer P-60 3100 ft (944.9 m)	21	26	25	28
Aklavik F-38 4200 ft (1280.2 m)	14	22	32	32
Aklavik A-37 4900 ft (1493.5 m)	14	24	26	36
Unak B-11 6000 ft (1828.8 m)	13	25	39	23
Unak B-11 6900 ft (2103.1 m)	20	13	27	40
Kugpik O-13 8310 ft (2532.9 m)	16	11	43	30
Kugpik O-13 9000 ft (2743.2 m)	16	11	41	32
Kugpik O-20 10 000 ft (3048.0 m)	16	13	37	34
Kipnik O-20 11 000 ft (3352.8 m)	14	10	47	29
Ikhil I-37 14 100 ft (4297.7 m)	18	16	30	36
Ikhil I-37 15 030 ft (4581.1 m)	17	9	27	47

A modified model might be applied to the noted observations. Nittrouer and Sternberg (1981) described modern sediments on a shelf in close proximity to the source. Their observations demonstrated that on the nearshore portion of the shelf studied, sediments were mainly sands that were laminated and generally lacked bioturbation, whereas the offshore sediments were mud and silt that were homogeneous and mottled because of bioturbation. This pattern was observed perpendicular to a linear shelf. This model does not appear applicable to the Husky Formation because the sand bodies are situated offshore to some extent, and they are not restricted to certain portions of the shelf but occur along its entire length. There is a general fining offshore (northeastward), probably due to deepening water, lower depositional energies, and a greater distance from the source.

It is concluded that the sandstone-capped cycles in the Husky Formation represent bars or sand shoals on a clay- or silt-dominated, shallow, marine shelf. Bar or shoal linearity cannot be resolved at present because of the wide well spacing from which interpretations must be made. The recognized textural facies of shale, mixed sandstone and shale, and sandstone, correlate well with the environmental facies of interbar or intershoal, bar-or-shoal margin, and central bar or shoal facies. Although, from stratigraphic relationships, a shoreline (source) to the southeast is postulated, the sediments give no indication of its proximity or presence.

The sediments do not show evidence of high energy within the depositional environment. Isolated pebbles and other such materials could have been emplaced by a number of mechanisms, including ice rafting, tree rafting, and as a result of being employed as gastric aids in large marine animals and birds. Tree rafting is probably the most likely mechanism in an environment such as that postulated for the Husky Formation. A second possible mechanism is the reworking of pre-existing pebble layers by organisms.

SUMMARY AND CONCLUSIONS

In the subsurface, the Husky Formation has a characteristic lithology of shale interbedded with very fine grained sandstones. Three lithofacies can be recognized: a shale facies with little bioturbation, a very fine grained sandstone facies with little bioturbation, and a mixed facies which is characteristically mottled and heavily bioturbated. These three lithofacies commonly occur in coarsening-upward sequences of shale, mixed sandstone and shale, and sandstone.

The depositional environment was a shallow marine shelf dominated by siliciclastic, fine grained sediment. The major component on this shelf was clay, but fine grained sandstone was concentrated in bars or shoals. These bars or shoals were active features, may have been deposited relatively rapidly, and formed offshore. The margins of the bars or shoals were biologically active, with organisms reworking the layered sands and clays. Areas between the bars or shoals, probably with lower energies, were the sites of mainly clay deposition with relatively little bioturbation. The shelf was a fairly low energy environment.

Deeper water embayments occurred at places along the shelf and these were sites of thicker Husky Formation accumulations. By late Husky time, these features had been partially filled and the shelf was fairly uniform in slope and profile. The shelf parallels a fault system termed the Tuktoyaktuk Fault Flexure Zone; this was probably active during the time of deposition and to some extent controlled the sediment distribution patterns. The Husky Formation thickens to the northwest away from this fault zone, reflecting deeper water. None of the wells in the Beaufort Sea area and Richards Island area of the Mackenzie Delta have penetrated equivalent strata, but the possibility exists for a facies change to the northwest with deposition of fine grained sediment by turbidity currents in a basinal setting.

Porosity is generally very poor throughout the Husky Formation sandstones, indicating that they are very poor reservoirs. The formation probably is a potential source rock, although this has not been fully evaluated (Langhus, 1980).

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APPENDIX I

Wells and tops utilized in study

Well	Formation Top (m)	Formation Top (ft)	Formation Bottom (m)	Formation Bottom (ft)	Lower Member Top (m)	Lower Member Top (ft)	Remarks
Shell Aklavik A-37	1097	(3600)	1513	(4964)	1211	(3974)	
Union Aklavik F-17	731	(2398)	764	(2505)			
Union Aklavik F-38	1279	(4195)	1510	(4954)	1343	(4406)	
Shell Beaverhouse Creek H-13	503	(1650)	768	(2519)			Incomplete/faulted
Gulf Mobil East Reindeer A-01	2568	(8425)	2822	(9260)	2640	(8660)	
Gulf East Reindeer C-38	1170	(3840)	1280	(4200)			
Gulf East Reindeer C-04	3369	(11 054)	3592	(11 784)	3459	(11 349)	
Gulf East Reindeer P-60	920	(3020)	970	(3182)			
Chevron et al. Fish River B-60							No tops picked/faulted
Gulf Mobil Ikhil I-37	4267	(13 998)	4707	(15 432)	4414	(14 480)	incomplete
Dome IMP Imnak J-29	3131	(10 272)	3304	(10 840)			
Amoco Ulster Scurry Inuvik D-54							No tops picked
Gulf Mobil Kamik D-48	3018	(9900)	3213	(10 540)			
Gulf Mobil Kamik D-58	3161	(10 370)	3191	(10 468)			Incomplete
Gulf Mobil Kamik F-38	3339	(10 955)	3566	(11 700)	3375	(11 075)	
IMP IOE Kimik D-29	2509	(8232)	2582	(8470)			
Shell Kipnik 0-20	3308	(10 852)	3556	(11 667)	3341	(10 960)	Incomplete
Shell Kugpik 0-13	2533	(8310)	3091	(10 140)	2678	(8785)	
IOE Mayogiak J-17	2633	(8640)	2856	(9370)			
IMP Mayogiak L-38							Uncertain if Husky present
Esso Mayogiak M-16	2608.5	(8558)	2871.0	(9419)			
Esso Pex Napartok M-01	1549	(5082)	1798	(5899)			
Shell Napoiak F-31	930	(3050)	1158	(3800)	997	(3270)	
IMP Nuna A-32							E logs did not reach bottom
Gulf Mobil Ogruknang M-31	4068	(13 348)	4429	(14 532)			incomplete
Gulf Mobil Parsons A-44	3281	(10 765)	3450	(11 320)	3356	(11 012)	
Gulf Mobil Parsons D-20	3064	(10 054)	3251	(10 668)	3150	(10 335)	
Gulf Mobil Parsons F-09	3082	(10 110)	3313	(10 870)	3139	(10 300)	
Gulf Mobil Parsons L-37	3146	(10 320)	3377	(11 079)	3219	(10 560)	Bottom estimated
Gulf Mobil Parsons L-43	3129	(10 266)	3280	(10 760)	3168	(10 395)	
Gulf Mobil Parsons N-10	2893	(9491)	3076	(10 095)	2947	(9668)	
Gulf Mobil Parsons O-27	3057	(10 028)	3222	(10 570)			
Gulf Mobil Parsons P-41	3320	(10 892)	3542	(11 622)	3399	(11 150)	
Gulf Mobil Parsons P-53	3066	(10 060)	3185	(10 450)			Fault contact
IMP IOE Pikiolik E-54	2618	(8590)	2739	(8985)	2647	(8685)	
Banff Aquit Arco Rat Pass K-35	539	(1770)	576	(1890)			
Gulf Mobil Siku A-12	3066	(10 060)	3235	(10 612)	3109	(10 200)	
Gulf Mobil Siku C-11	3072	(10 080)	3182	(10 440)			Fault contact
Gulf Mobil Siku E-21	3228	(10 590)	3394	(11 135)	3309	(10 855)	
Banff Aquit Arco Treeless Creek I-51	305	(1000)	326	(1070)			
IOE Tuktu 0-19	2102	(6895)	2199	(7216)	2141	(7024)	
Shell Tullugak K-31	2067	(6780)	2562	(8406)	2120	(6935)	
Shell Unak B-11	1820	(5970)	2123	(6965)			Faulted section
IMP Delta 5 Wagnark C-23	3915	(12 845)	4179	(13 710)			

APPENDIX II

Cores taken from the Husky Formation

Well		Core (ft)	Core (m)	Recovered (ft)	Recovered (m)
Gulf East Reindeer C-38	Core #1	3922-3951	(1195-1204)	29	(8.8)
IMP IOE Kimik D-29	Core #4	8463-8482	(2580-2585)	14	(4.3)
Shell Kugpik O-13	Core #4	9640-9702	(2938-2957)	62	(18.9)
IOE Mayogiak J-17	Core #7	8818-8858	(2688-2700)	39.5	(12.0)
	Core #8	8960-8995	(2731-2742)	35	(10.7)
	Core #9	8995-9021	(2742-2750)	21	(6.4)
	Core #10	9021-9034	(2750-2754)	14	(4.3)
	Core #11	9034-9055	(2754-2760)	21	(6.4)
	Core #12	9366-9383	(2836-2841)	17	(5.1)
Gulf Mobil Parsons N-10	Core #11	9480-9512	(2890-2899)	32	(9.8)
IMP IOE Pikiolik E-54	Core #6	8812-8872	(2686-2704)	60	(18.3)
IOE Tuktu O-19	Core #2	6883-6913	(2037-2107)	30	(9.1)