GEOLOGICAL SURVEY OF CANADA
COMMISSION GEOLOGIQUE DU CANADA
OPEN FILE 1786

PALYNOSTRATIGRAPHY OF THE ESSO ET AL. ISSUNGNAK 0-61 WELL, BEAUFORT SEA, ARCTIC CANADA

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July 1988

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Open File Report No. 1786

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Abstract

This paper reports a palynological analysis of the Esso et al. Issungnak O-61 well in the Beaufort Sea, Arctic Canada (Figure 1) (Location N 70.01679°, W 134.31331°, G.S.C Locality 86839). The age at 160-180 m is likely no younger than Middle Pliocene. No age diagnostic palynomorphs occur at the base of the well (3583 m), but the presence of the foraminifer **Turrilina alsatica** at 2730 m indicates an Oligocene age. This indicates an Oligocene to Recent stratigraphic range for the pollen taxon **Symphoricarpos**, cf. **S. occidentalis**. A hardwood assemblage within the Mackenzie Bay sequence with range tops between 1505 and 1675 m includes several probable temperate arboreal taxa. This is interpreted to most likely represent a Middle Miocene temperature maximum and subsequent decline. However, the possibility that the assemblage is made up of reworked Paleogene taxa cannot be ruled out.

Method

Sixty-eight palynological samples were analysed from cuttings representing 20 m intervals, at 50 m increments, from 40-60 m to 3555-3575 m. Total well depth is 3583 m. Palynological slides were prepared from bit cuttings by standard procedures (HCl, HF, heavy liquid separation at sp. gr. 2.0, and Schulz solution). Palynological preparations are stored at the Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, Calgary.

In most slides palynomorphs were too sparse to yield a statistically useful sum, therefore the following routine was adopted to attempt to provide an equivalent level of effort for each sample. Slides of unscreened residue were scanned at 2 mm intervals under X200 or X500, with critical identifications made at X1250; the +20 micrometre and -20 micrometre fractions were scanned in a search for age diagnostic palynomorphs. The data have been plotted only by presence and absence (Figure 1).

Only palynomorphs which were reasonably well preserved and of similar, relatively low, thermal maturity were included in the tally. Palynomorphs which were badly eroded or were of questionable identity were ignored. Dinoflagellates were re-examined after the initial analysis. Dinoflagellates were rare and taxa were represented by one or few specimens. Taxa were often indistinctive, prohibiting reliable morphology.

Taxonomy of Late Tertiary floras can be based on a modern botanical nomenclature, or fossil morphological schemes, or some combination of the two. This report uses modern botanical nomenclature if a pollen type can be confidently related to a modern taxon. This usage is particularly appropriate for the Neogene. Identifications of modern pollen and Late Quaternary pollen are often limited to family or genus level, and this guides the level of precision expected in identifications of older palynomorphs.

Results and Interpretation

Figure 2 shows the stratigraphic distribution of selected taxa, arranged by highest appearance. The interpretation of these results considers three major questions: 1) the age at the top of the well; 2) the age at the bottom of the well, and; 3) the chronological significance of the range tops occurring predominantly between P2511-27 and P2511-32 (1505 to 1725 m).

Pliocene

Up to 5% **Tsuga** pollen, plus **Tsuga** macrofossils, occur in the Miocene-Pliocene Beaufort Formation on Banks Island (Matthews **et al.** 1986). **Tsuga** pollen is present as high as the Morgan Bluffs Formation on Banks Island, within which occurs the Matuyama/ Bruhnes boundary, at ca. 730 ka BP. However, above the Beaufort Formation, **Tsuga** pollen is rare and might be recycled, as recycled temperate hardwoods have been recognized in the Morgan Bluffs Formation (Matthew **et al.** 1986, Matthews 1987). **Tsuga** pollen is absent from the Late Pliocene/Early Pleistocene Gubik Formation of the north slope of Alaska (Nelson and Carter 1985). Wolfe (1972) indicates that **Tsuga** disappeared from western Alaska by Late Pliocene. Therefore, sample P2511-03 is likely not younger than Middle Pliocene. Taxa occurring above the **Tsuga** top in the Issungnak 0-61 well could occur in the Pleistocene, but are not limited to it.

Oligocene

No age-diagnostic palynomorphs occur at the base of the Issungnak 0-61 well. McNeil (pers. comm. 1987) has identified the foraminifer **Turrilina alsatica** at 2730 m, which is an Oligocene indicator.

A distinctive pollen taxon **Symphoricarpos** cf. **S. occidentalis** occurs in samples P2511-49 and 64 (2605-2625 and 3355-3375 m, respectively), or to within 200 m of the base of the well. A Kremp File search indicates that this taxon has been identified only rarely. Leopold (1969) has reported it from the Middle Miocene in the Troublesome Formation, Colorado. Wolfe (1969) has reported one **Symphoricarpos** species for the Early and Middle Miocene flora of Alaska, and notes that **S. albus** is a taxon which may have entered America from Eurasia, via Alaska. Axelrod and Ting (1960) have reported **S. albus** from the Pliocene of California. Ioannides (1979) has also reported **S. occidentalis** in Assemblage B (2000 - 6840 ft) in the Netserk F-40 well, dating the assemblage as Oligocene to ?Pliocene.

It is unknown whether the stratigraphic range of **Symphoricarpos** cf. **S. occidentalis** in the Beaufort Sea is equivalent to that in Colorado. Wolfe's (1969) suggestion of migration of **S. albus** from Eurasia to America suggests that the genus may be earlier in the north than in the south. Considering the lack of a firmly defined basal age for **Symphoricarpos** from palynological and plant macrofossil evidence, and the occurrence of **Symphoricarpos** cf. **S. occidentalis** below **T. alsatica** in Issungnak O-61, an Oligocene age must be accepted for the taxon. **S. occidentalis** is an extant species, so this pollen type could appear in assemblages up to the Recent.

Middle Miocene

Figure 2 shows that between samples P2511-27 and 30 (1505 - 1675 m) there occur range tops in an assemblage of taxa. Ten of these pollen taxa probably represent arboreal, deciduous species. Taxa having range tops in this interval are **Carya** sp., Ericaceae, Liliaceae, **Pterocarya** sp., **Ulmus/Zelkova**, Aceraceae, **Castanea** sp., **Juglans** sp., **Liquidambar** sp., **Tilia** sp., unknown tricolporates (several taxa), **Erdtmanipollis** sp. (**Pachysandra/Sarcococca** sp.), **Ericipites compactipolliniatus** (Norris 1986), **Ilex** sp., and **Potamogeton** sp..

The top of this assemblage, as high as 1505 m, is about 75 m lower than the top of the Mackenzie Bay sequence based on seismic stratigraphy (Peach 1987). It is possible that the top is truncated by an erosional interval.

A relatively indistinctive dinoflagellate associated with the hardwood assemblage is cf. **Batiacasphera** sp., which has a range top at 1715 m and occurs intermittently down to 3365 m. Taxonomic uncertainty limits its stratigraphic value for this report, but further observation may prove it to be stratigraphically useful.

Two hypotheses can be entertained to explain the occurrence of the assemblage: 1) the pollen are recycled from Paleogene beds, or; 2) the occurrences represent real stratigraphic ranges of the taxa.

Supporting the first hypothesis (recycling) is the fact that several of the taxa may be found in Paleocene, Eocene and Oligocene beds in the Beaufort Sea region (Ioannides and McIntyre 1980, Norris 1986, Rouse 1977, Staplin et al. 1976). **Pistillipollenites macgregorii**, a Late Paleocene to Middle Eocene taxon (Rouse 1977, McIntyre 1985), occurs in P2511-34 at 1865 m. Although this is 200 to 300 m below the deciduous hardwood tops, its occurrence lends support to the hypothesis that much of the assemblage is reworked. However, for this hypothesis to be valid, a reason is required for cessation in the deposition of sediment containing recycled palynomorphs. No support can be found for this. J. Dixon (pers. comm. 1987) indicates that, for the sediments which the Issungnak O-61 well penetrates, there was no change in the source direction, which was to the southeast. However, there is no conclusive evidence for rejecting the recycling hypothesis.

External Comparisons

The alternative hypothesis is that the taxa represent an in situ occurrence of Miocene or Pliocene flora. In this case, the data should iterate patterns found in other Beaufort Sea wells containing Mackenzie Bay Sequence sediment (Young and McNeil 1984). However, variable well-reporting formats, differing taxonomic systems, and the difficulty of implementing a formal system of comparison makes this an imprecise procedure. Regardless, the following brief comparisons have been made, in so far as it is practical.

The palynological assemblage that tops at 1505 m compares with the Adgo F-28 Zone 3 (AD3), of Austin and Cumming (1977), in the occurrence of **Tilia**, **Ulmus**, **Ilex**, **Castanea**, and **Pistillipollenites macgregorii**, although Norris considers the latter two to be reworked. AD3 is also the top of **Tsuga**, which occurs much higher in Issungnak O-61. AD3 was considered to be Oligocene (Norris, in Austin and Cumming 1977).

A reasonably good comparison of the Issungnak O-61 assemblage with the top at 1505 m can be made with Pullen E-17 Zone 3, which is considered to be Miocene - Upper Pliocene (Austin and Cumming 1979a). Pullen Zone 3 includes the top of Chenopodiaceae (periporate 3), but also the top of **Tsuga**, unlike the Issungnak O-61 well. Zone 3 includes species of **Carya**, **Pterocarya**, and **Tilia**.

In Ivik K-54 the **Tsuga** mudstone unit is considered to be Miocene (Austin and Cumming 1979b), and below the **Tsuga** mudstone unit occur the taxa **Tilia**, **Ulmus**, **Pterocarya**, and Chenopodiaceae (periporate 3). This pattern of tops is more similar to the Issungnak O-61 well than the pattern of the Adgo F-28 and Pullen E-17 wells, but no palynological assemblage unit seems correlative with that of the mid-Issungnak O-61 well.

The Netserk B-44 well bears similarities to the Issungnak O-61 well, with **Tsuga** appearing highest, and with **Ulmus**, **Castanea**, and **Tilia**, and Chenopodiaceae (periporate 3) below. This all occurs within the **Tsuga** mudstone unit considered to be Miocene (Austin and Cumming 1979c).

In Pelly B-35 (Austin and Cumming 1979d) **Tsuga** occurs with or above **Ulmus**, **Pterocarya**, and **Tilia** within the Miocene **Tsuga** mudstone unit. **Castanea** and **Ilex** occur far below. This pattern is not closely similar to the Issungnak O-61 well.

The distributions of tops within the Mackenzie Bay and Nuktak sequences of the Nuktak C-22 well (Norris 1986) do not show patterns which compare closely with the Issungnak O-61 well. **Tsuga**, and **Ulmus** occur together in the Mackenzie Bay sequence, while **Pterocarya (Polyatriopollenites stellatus)** occurs just below. Chenopodiaceae species occur in the Nuktak sequence, higher than **Tsuga**. Other temperate hardwood types are lacking.

North Issungnak L-86 is about 10km north-northwest of Issungnak O-61, and a more detailed comparison of their stratigraphy is merited. Seismic stratigraphy and foraminiferal zonation shows that the Akpak/Mackenzie Bay sequence boundary is present, and that the Akpak sequence is much thicker in L-86 than in O-61, possibly due to lack of erosion of the sequence in L-86 (McNeil. pers. comm. 1987). In L-86 the top of the Mackenzie Bay sequence is at 2392 m depth (Peach 1987). This coincides with a boundary between the **Pentadinium laticinctum** and **Systematophora ancyrea** subzones within the **Tsuga igniculus** zone, which is interpreted to mark a chronological boundary between Early Miocene and Middle to Late Miocene (Bujak Davies Group 1987). If it is an Early to Middle Miocene boundary, it fits well with the chronological interpretation of the top of the Mackenzie Bay sequence of the O-61 well (this report). However, though the age interpretations may coincide, the details of the palynomorph assemblage are significantly different in O-61 and L-86 wells.

In L-86 the Mackenzie Bay, Akpak, and Iperk sequences are interpreted from seismic stratigraphy (Dixon and Dietrich 1985), and by foraminifers (McNeil pers. comm. 1987). Palynological analysis of the well (Bujak Davies Group 1987) shows that at the top of the Mackenzie Bay sequence there is no equivalent to the set of range tops found in the O-61 well at this boundary, nor is there the diversity of hardwood pollen taxa found in the Mackenzie Bay sequence in the O-61 well. Under either hypothesis for the source of the Mackenzie Bay flora in O-61, recycling or autocthonous occurrence, one would expect greater similarity in the flora of the two wells. Tops in L-86 in taxa which are equivalent to taxa found in the O-61 well, i.e. **Polyatriopollenites stellatus** (**Pterocarya** sp.), **Juglanspollenites** sp. A (**Juglans** sp.), **Ilexpollenites marginatus** (**Ilex** sp.), **Ericipites compactipolliniatus** (same), **Quercoidites microhenrica** (**Quercus** sp.), **Caryapollenites simplex** (**Carya** sp.). range from 2580 m up to 1460 m, or up through the Akpak and into the Iperk sequences. While erosion or slower deposition of the Mackenzie Bay sequence in O-61 could explain stratigraphic compression of the tops, the same diversity of taxa was not observed within the Mackenzie Bay sequence in L-86 as in O-61.

Normal faulting has resulted in significant topographic gradients. The top of the Mackenzie Bay sequence is approximately 800 m higher in the O-61 well than that in the L-86 well, though they are but 10 km distant horizontally. The distribution of hardwoods up into the Akpak sequence in the L-86 well could result from erosion of material from the Mackenzie Bay sequence to the south, penetrated by the O-61 well. Local redeposition of sediment across faults may be far more significant than recycling from more distant sources. However. the difference in palynostratigraphic resolution in the two wells remains problematic.

The closest comparison to the assemblage which tops in the Mackenzie Bay sequence in Issungnak O-61 is found in the assemblage immediately below the disconformity in Ukalerk C-50 (McNeil et al. 1982). The palynomorphs **Pterocaryapollenites** sp. (**Pterocarya** sp.), **Ulmipollenites undulosus** (**Ulmus** sp.), **Ilexpollenites** sp. (**Ilex** sp.), **Caryapollenites** spp. (**Carya** sp.), **Juglanspollenites** sp. (**Juglans** sp.), and **Tiliapollenites - Bombacacidites** complex (**Tilia** sp.) occur just below the disconformity. McNeil et al. (1982) consider the top of this assemblage to mark the onset of cooler conditions in the Late Miocene or Early Pliocene.

There is some concordance in the pattern of range tops in the Issungnak O-61 well and the other wells considered. It is possible that hypothesis two is correct, i.e., that most of the taxa are in situ although the range tops may be truncated. However, the lack of a clear, consistent pattern amongst wells is disquieting. The interpretations of the composition of this assemblage and its age must therefore be considered tentative. It is worth considering whether there is any evidence, external to palynology, which would favour either the recycling, or the in situ hypothesis.

Macrofossil evidence from south and central Alaska may be significant in interpreting Beaufort Sea palynomorphs. A distinct transition occurs between Seldovian and Homerian floral assemblages (Middle to Late Miocene). Wolfe (1972) describes the Seldovian (Early to Middle Miocene) assemblages as the richest post-Eocene floral assemblages in Alaska, with greatest taxonomic diversity in the Salicaceae, Betulaceae, Juglandaceae, Fagaceae, Ulmaceae, and Aceraceae, and with distinct Asian affinities. The Seward Peninsula assemblage contains **Carya**, **Pterocarya**, **Ulmus/Zelkova**, and **Ilex**, along with the dominant Pinaceae. In contrast to the Seldovian, the Homerian Age macroflora from southern Alaska is missing **Liquidambar**, **Nyssa**, and **Juglans**, and has poor representation of Juglandaceae and Ulmaceae. Conifers, especially Pinaceae, dominate Late Miocene Alaskan vegetation (Wolfe 1972). This transition seems closely related to the 1505 m range top event in the Issungnak well. Taxa such as **Ericipites** spp., **Liliacidites**, Aceraceae, **Castanea** sp., **Tilia** sp., **Erdtmanipollis** sp., **Potamogeton** sp., **Quercus** sp. are not specifically mentioned by Wolfe (1972), but the climatic changes causing the local extinction of temperate hardwoods must have affected taxa not observed in the macrofossil record.

Independent isotopic paleoenvironmental data are scarce for the northern latitudes in the Pacific. Interpretation of high latitude temperatures relies on the positive correlation between temperatures at high latitudes, where cold water sinks, and the temperature of benthic waters at low latitudes. The data have been summarized and interpreted by Savin (1977) and subsequent workers. A sharp temperature drop is indicated for the Middle Miocene by O^{18}/O^{16} ratios of benthic foraminifera (Savin 1977). These same data also show a small temperature rise from Middle Oligocene to Late Oligocene, and then a temperature plateau across the Oligocene/Miocene boundary, with a small rise from Early to Middle Miocene. Subsequent research has allowed the recognition of several minor Middle and Late Miocene cooling events (Kennett 1985, Elstrom and Kennett 1985). If one accepts the premise that high latitude temperature change is a prime cause of variation seen in the palynological record, certain interpretations result. The assemblage that tops at 1505 m probably reflects a relatively warm Early-Middle Miocene climate. Discounting the effects of erosional truncation, the top of the assemblage probably results from the Middle Miocene high latitude temperature drop, which probably also correlates with the Seldovian/Homerian boundary of Wolfe (1972). Furthermore, the temperature plateau across the Oligocene/Miocene and Miocene/Pliocene boundaries make those boundaries intrinsically difficult to define by the analysis of palynological or macrofossil assemblages. This fact may be reflected in the Issungnak O-61 well by the lack of clear palynological separation within the lower Mackenzie Bay sequence, or between it and the underlying Kugmallit sequence.

Both the Alaskan macrofossil data and the $^{18}O/^{16}O$ data suggest that one might expect a distinct floral transition in the Beaufort Sea palynology in the Middle Miocene. Factors which can distort a climatic signal observed through the palynological record, and vitiate correlation, are many; i.e., differential response of species to climatic change, differential representation of species in the pollen rain, probabilities associated with the occurrence of taxa in sparse samples, sorting of pollen during primary deposition, recycling of palynomorphs, caving of sediment during drilling, and mud contamination of cuttings. It is entirely conceivable that the noise can overwhelm the palynological signal. Although it is not certain that a dominant Middle Miocene climatic signal has been observed in the Issungnak O-61 well, there seems to be a reasonable probability that it is so.

Thermal Maturity Observations

Thermal Alteration Index observations were made on P2511-26 (1455-1475 m), P2511-30 (1655-1675 m), P2511-49 (2605-2625 m), and P2511-59 (3105-3125 m). Observations were made on relatively thin-walled triporate, periporate, and trilete palynomorphs, and failing those, on exinous fragments. The interval of observations was limited by the difficulty of obtaining useful palynomorphs from kerogen slides of samples with low palynomorph concentration. The colour observation standard was that of Pearson (1984). Values obtained were 2 or 2-, with few palynomorphs in the 2+ range. These correspond to medium to high immature values, approximately correlative with a vitrinite reflectances of 0.5% and below (Pearson 1984). No trend in thermal maturation was observed throughout the well.

Acknowledgements

The advice and editorial assistance of D. H. McNeil, the taxonomic advice of D.J. McIntyre, and discussions with A.R. Sweet, J. Utting and J.K. Lentin during the course of this study are gratefully acknowledged.

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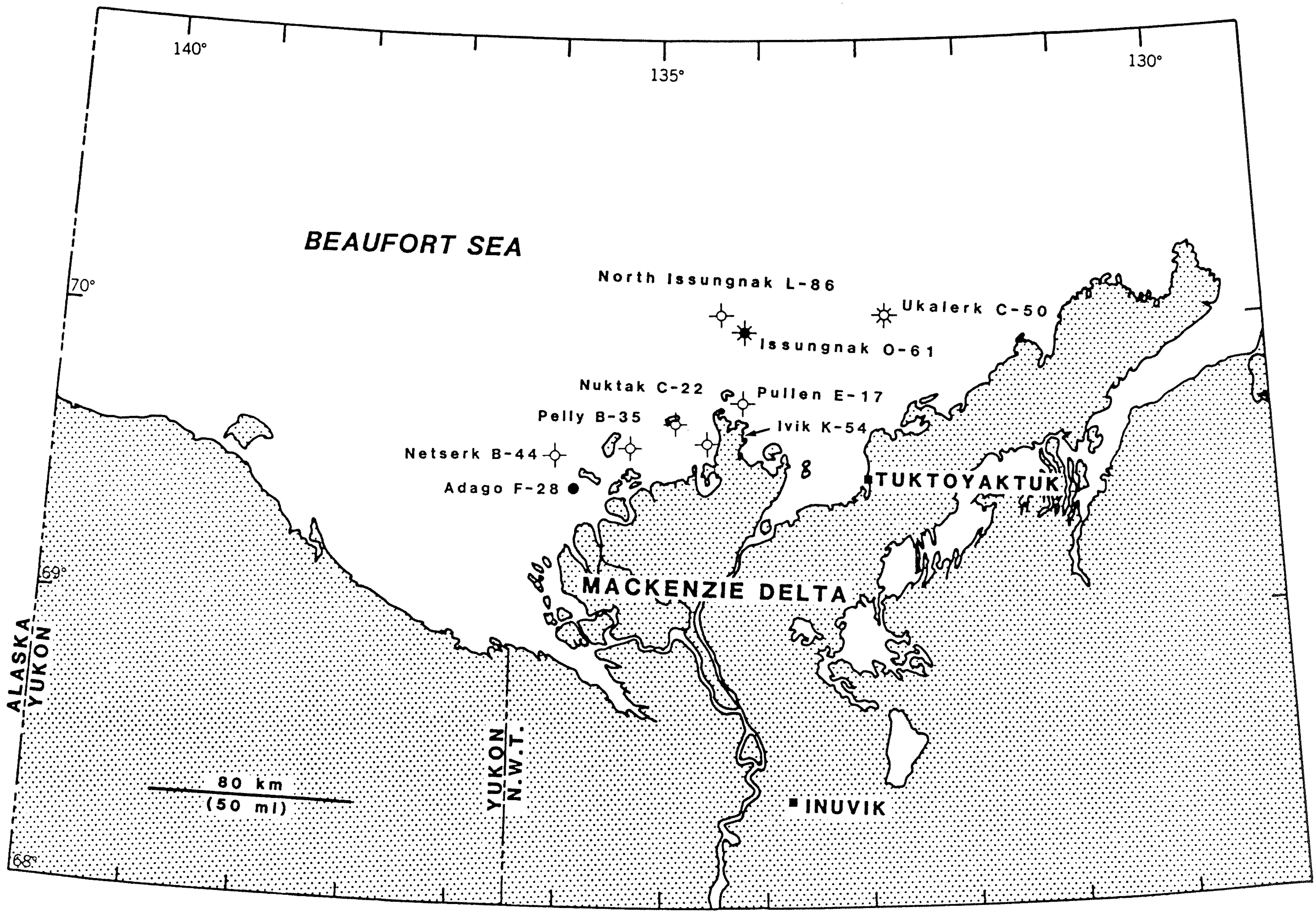
140°
135°
130°
70°
69°
68°
BEAUFORT SEA
North Issungnak L-86
Ukalerk C-50
Issungnak O-61
Nuktak C-22
Pullen E-17
Pelly B-35
Ivik K-54
Netserk B-44
Adago F-28
TUKTOYAKTUK
MACKENZIE DELTA
INUVIK
ALASKA
YUKON
YUKON
N.W.T.
80 km
(50 mi)

FIGURE 1

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