CORRELATION STUDY OF SELECTED EXPLORATION WELLS FROM THE NORTH SLOPE AND BEAUFORT SEA, ALASKA

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ABSTRACT

Using data from wells located in Federal Outer Continental Shelf (OCS) Beaufort Sea waters and coastal wells, this study extends the geologic correlations to the offshore Beaufort Sea. Geologic cross sections illustrate the stratigraphic correlations.

Four different tectonic sequences--basement complex, Ellesmerian, Beaufortian, and Brookian--constitute the stratigraphy of the North Slope and the adjacent Beaufort Sea shelf. A mid-Paleozoic orogeny metamorphosed the basement-complex rocks, Devonian in age and older, making them economic basement throughout the area. The Ellesmerian sequence includes the northerly derived clastic sediments and carbonates of Late Devonian to Triassic age deposited on the stable Arctic Platform. The Beaufortian sequence records the transition from a northern to southern sediment source during rifting of the continental margin from Early Jurassic to Middle Cretaceous time. The southerly derived sediments deposited from Early Cretaceous to the present make up the Brookian sequence.

INTRODUCTION

The study area covers a 270-km-long strip along the coast of the North Slope, Alaska, from longitude 146°00' W. to 153°00' W. (Plate 1). Various correlation studies exist for the onshore and nearshore areas of the North Slope (Molenaar et al., 1986; Bird and Molenaar, 1987; and the Alaska Geological Society, 1971 and 1973). We correlate data from selected wells used in these previous publications with publicly released State of Alaska and Federal well data. The borehole logs are from wells drilled in the State of Alaska's waters and the Federal OCS. The nine OCS wells represent locations drilled in the Beaufort Federal waters prior to January 1987. Plate 1 shows the location of the wells.

BASIN DEVELOPMENT

The Ellesmerian orogeny of Late Silurian to Early Mississippian time deformed and mildly metamorphosed the Precambrian and early Paleozoic sedimentary rocks that compose the present-day basement complex (Grantz et al., 1990). Carbonates and northerly derived clastics were deposited during Early Mississippian through Triassic time across a southward-sloping stable shelf, known today as the Arctic Platform. These shelf sediments lie unconformably on the basement complex rocks.

During Jurassic time, two major tectonic events occurred that affect North Slope geology. First, rifting of the northern part of the Arctic Platform began in Early Jurassic time (Grantz and May, 1983). Second, uplift and deformation during Late Jurassic time in the region of the present central southern Brooks Range occurred as a result of the initial stages of subduction of the North American plate beneath the intraoceanic Koyukuk arc (Box and Patton, 1987).

The present continental margin of northern Alaska formed as an extensional feature similar to an Atlantic-type, or passive, margin (Grantz and May, 1983). Extensional structures resembling those generally associated with Atlantic-type margins occur beneath the Alaskan Beaufort shelf.

STRATIGRAPHY

The basement complex is an informal and simplistic term used for all subsurface rocks older than the Endicott Group (Bird, 1988). The basement complex ranges in age from Precambrian to Devonian (Fig.1). Lithologies vary from granite, schist, or slightly metamorphosed sedimentary rocks (west of 148° W. longitude) to interbedded, metamorphosed carbonate and clastic rocks (east of 148° W. longitude). The basement-complex rocks represent the acoustic and economic basement throughout the North Slope.

Hubbard, Edrich, and Rattey (1987) separate the sediments above the basement complex of northern Alaska into three tectonic sequences--Ellesmerian, Beaufortian, and Brookian. Each sequence represents a complete cycle of basin development. This study uses a slightly modified version of their classification.

The base of the Endicott Group and the disconformity at the top of the Sag River Formation define the bottom and top of the Ellesmerian sequence, respectively (Fig.1). This sequence includes the carbonates and clastics deposited on the southward-sloping, stable Arctic Platform prior to the onset of rifting in the Early Jurassic.

The Beaufortian sequence (Fig.1) encompasses all the locally and northerly derived sediments deposited during rifting of the continental margin. The base of this sequence is the Triassic disconformity at the top of the Ellesmerian sequence. In most places, the Lower Cretaceous Unconformity (LCU) defines the break between the Beaufortian and Brookian sequences. When locally derived sandstones, such as the Point Thomson Sandstone, Put River Sandstones, and their equivalents, lie on top of the LCU, we interpret the top of the Beaufortian sequence to be at the top of these sandstones (Fig.1).

Rifting strongly controlled the deposition of the upper Beaufortian sequence. Erosion of Ellesmerian and basement complex rocks along the rift-margin uplift produced coarse-grained sediments. These sediments accumulated in nearby topographic lows, forming the marine Kuparuk Sandstone and the fluvial Put River and Point Thomson Sandstones (Hubbard et al., 1987).

The Brookian sequence includes the series of southerly derived, deltaic sediments deposited from Early Cretaceous to the present time. The main deltaic depocenter shifted from west to east through time. Consequently, the age of the Brookian decreases from the west to the east (Scherr et al., 1991, Plates 3, 4, and 5).

The formalized Brookian terminology, developed mainly from outcrop data (Lerand, 1973), does not apply well to the offshore Brookian strata. The onshore Brookian strata are mostly nonmarine to shallow-marine facies in the southern and western North Slope. Along the coast and offshore, distal delta facies make up a greater proportion of the Brookian strata in the subsurface. Thus, existing stratigraphic nomenclature needs to be redefined for the offshore strata.

Usage of the term Pebble Shale is the first of two terminology problems encountered in the study. Previous reports refer to part or all of this informally named unit as follows: the Hue Shale (Bird and Molenaar, 1987), the Highly Radioactive Zone (HRZ) (Hubbard et al., 1987), the Gamma-Ray Zone (Bird, 1982); and the Pebble Shale (Molenaar et al., 1987). Definitions for these various unit names seem to depend on the area studied and the authors' view of the lithology and the source of sedimentation.

We choose to use the term HRZ because consistent correlations can thereby be made in the wells examined. The definition of the HRZ as used in this study is the first prominent increase in gamma-ray log values above the LCU. The HRZ consists of relatively thin beds of organic-rich, radioactive shales that range in age from Hauterivian to early Coniacian. These shales represent a series of condensed-section, distal facies that accumulated during different cycles of deposition (Hubbard et al., 1987).

Another terminology problem is delineating the different prodelta shales. The Torok Formation is lithologically recognizable only west of the Colville River delta where it lies between the HRZ and the sands of the Nanushuk. When the Nanushuk sands lap out near the Colville River delta, the Torok Formation can no longer be lithologically distinguished from the shale of the Colville Group or the Canning Formation. Paleontological age data (Scherr et al., 1991, Plate 3) show the age difference between the older Torok Formation shales (Barremian to Aptian) in the Y-0302 No.1 well and the middle Cretaceous (Turonian to Albian) prodelta shales in the Y-0334 No.1 well. The absence of prodelta shales older than Albian time in the Y-0334 No.1 well marks the approximate boundary between two Brookian deltaic sequences and their associated prodelta shales--the Torok Formation and the Canning Formation.

For the younger prodelta shales, we propose a stratigraphic cutoff, following guidelines proposed by Krumbein and Sloss (1963, p. 350), at the Nanushuk Group pinch-out (Fig.1 and Plate 1). At the cutoff, the shale of the Colville Group changes to the Canning Formation. We extend the stratigraphic cutoff to the surface because no clear lithologic break separates sands of the Colville Group and the Sagavanirktok Formation in many of the wells. West of the cutoff is the undifferentiated Sagavanirktok Formation and Colville Group; east of the cutoff is the Sagavanirktok Formation and the Canning Formation (Fig.1 and Plate 1).

The Gubik Formation, a deposit of unconsolidated sediments only a few hundred feet thick (Bird, 1982), is the surface formation along most of the coast. However, it cannot be distinguished on the borehole logs. Therefore, we combine the Gubik Formation with the Sagavanirktok Formation. We define the top of the Sagavanirktok Formation as either the ground level or the seafloor on borehole logs.

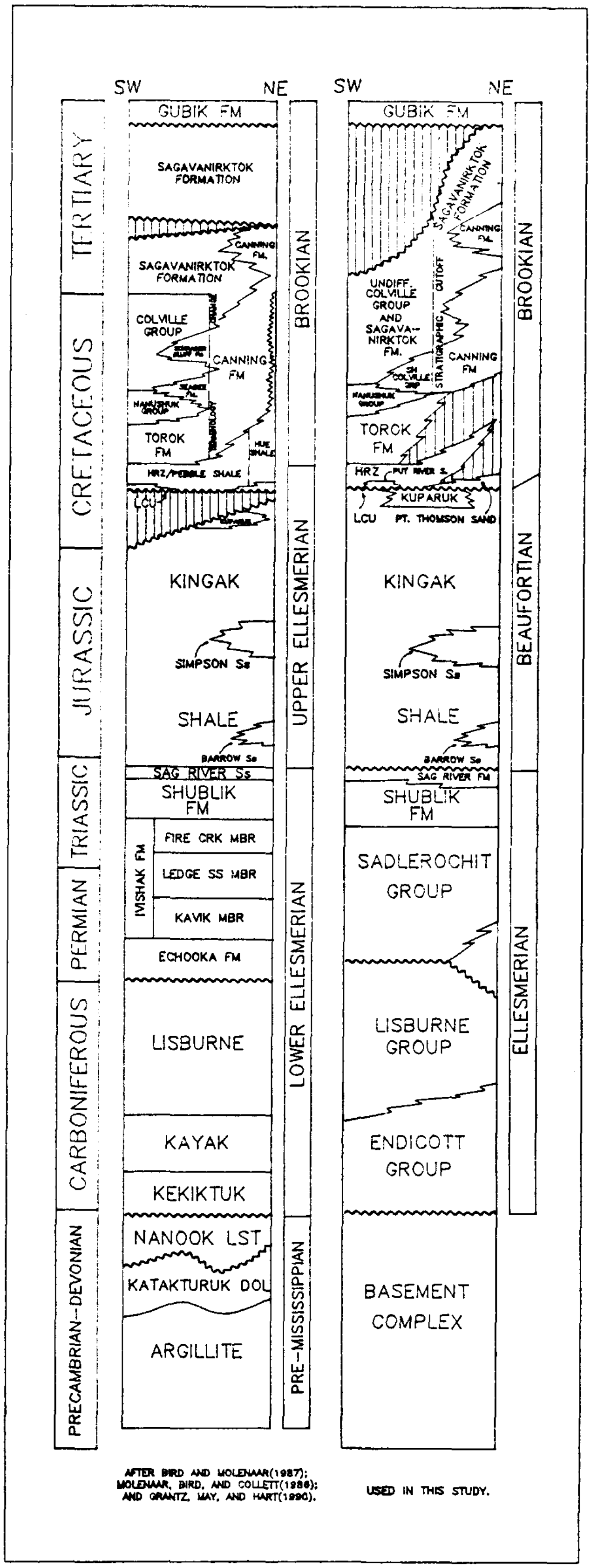
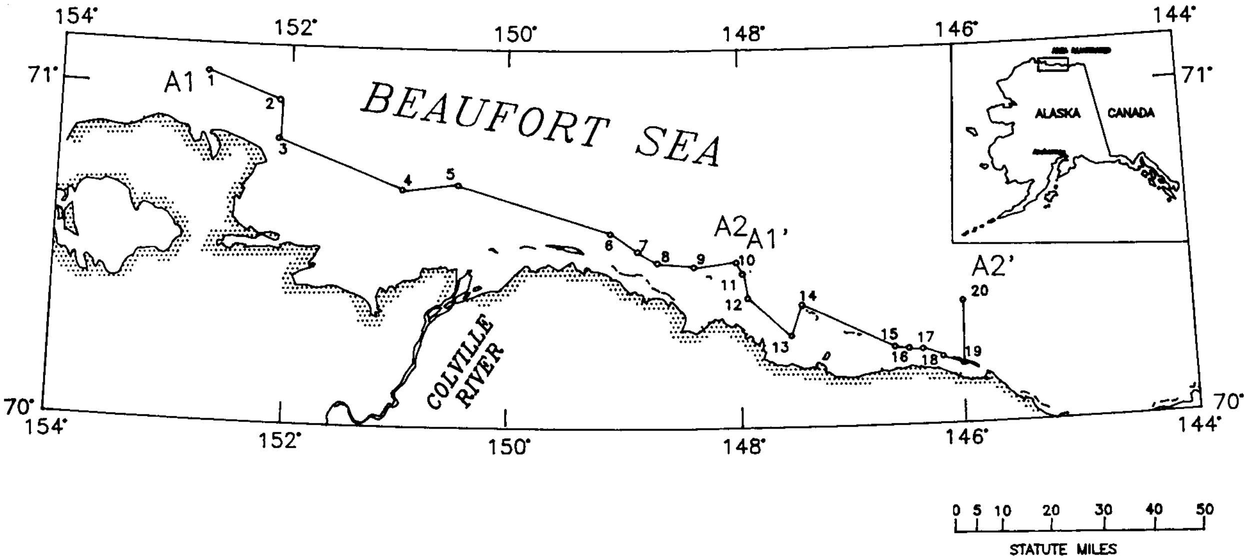


Fig.1. Stratigraphic Chart

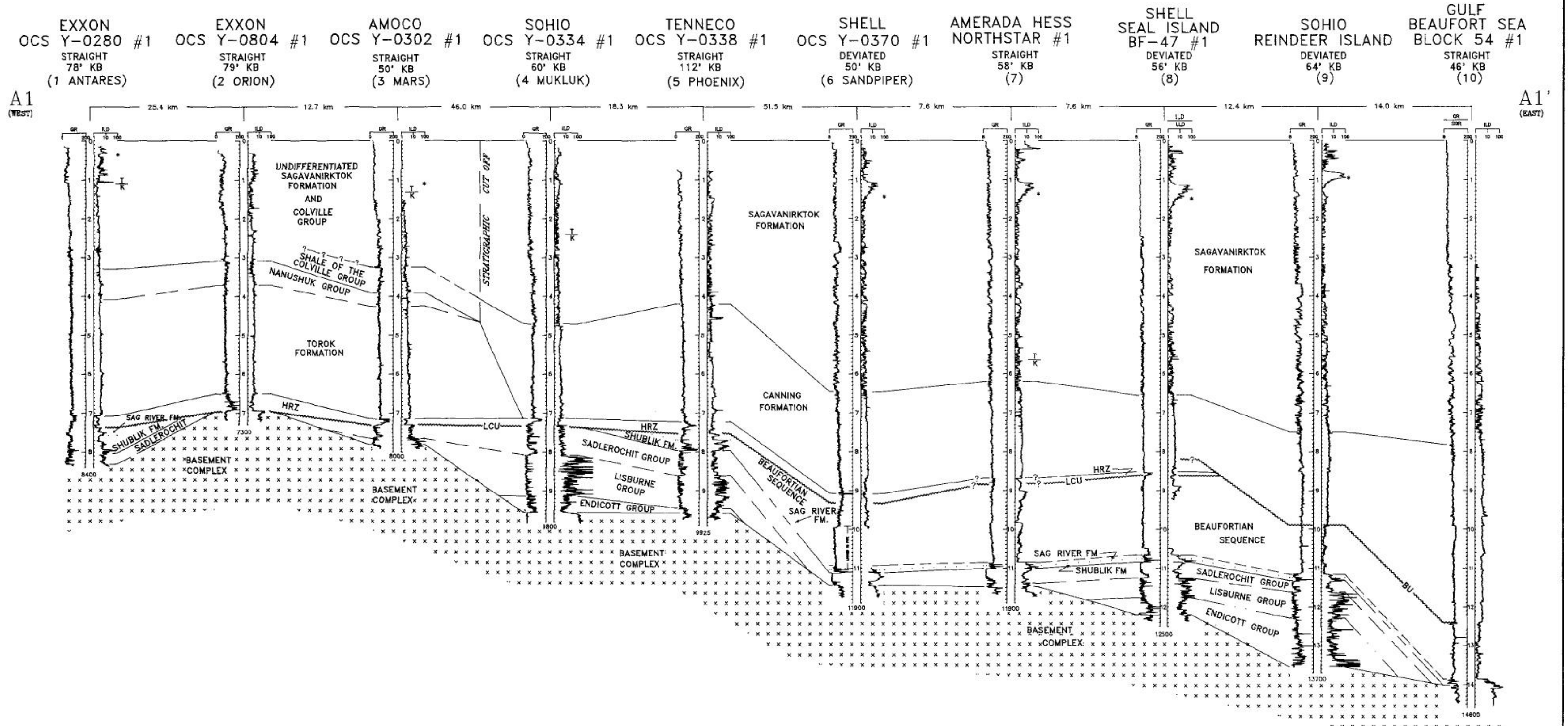
Plate 1. Cross Sections A1–A1' and A2–A2' (overleaf) across the Beaufort Sea, Alaska. (Modified from Scherr, et al., 1991, plates 3, 4, and 5.)



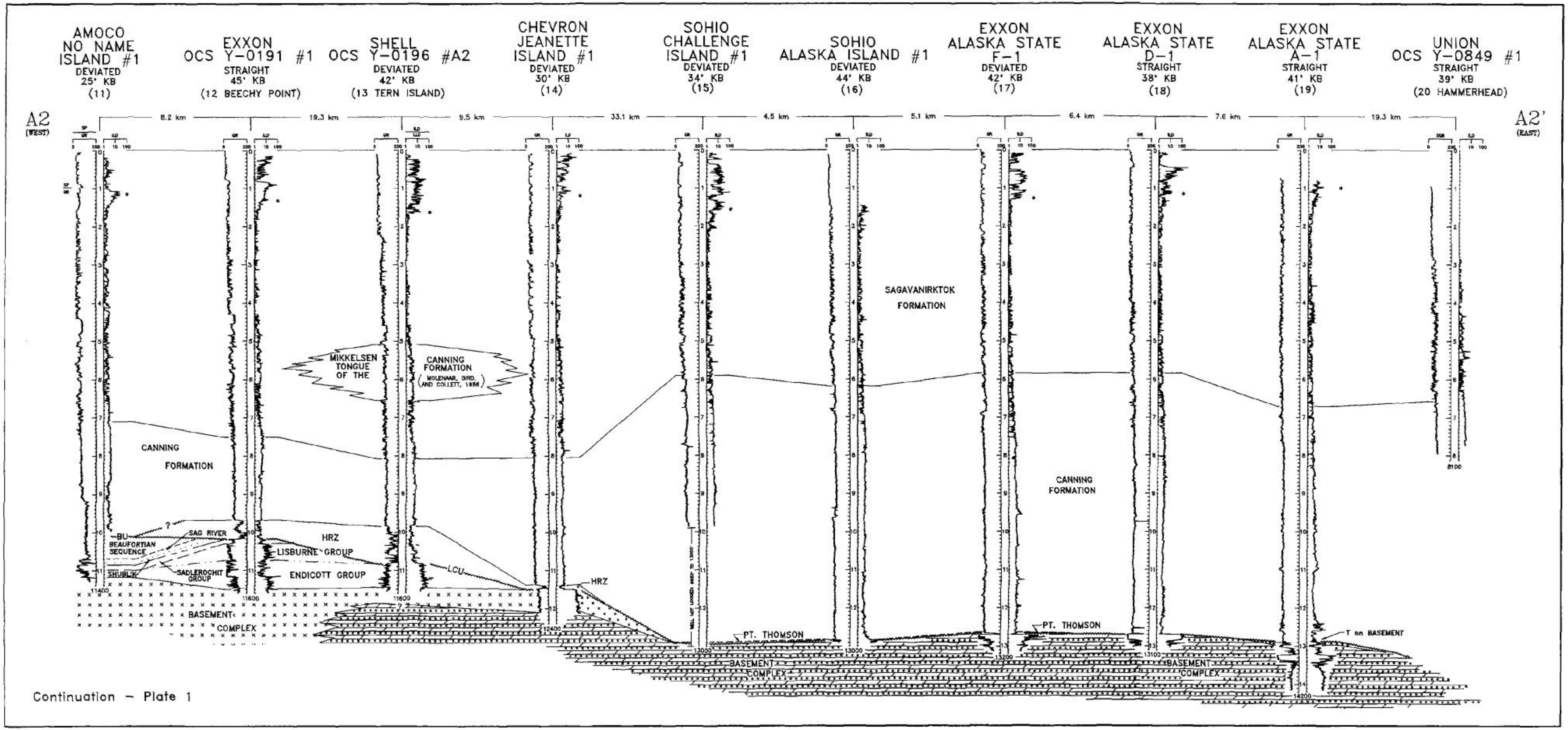
EXPLANATION

DEPTH IN 1000 FEET
* BASE OF PERMAFROST
SP SPONTANEOUS POTENTIAL
GR GAMMA RAY(IN API UNITS)
SGR SPECTROSCOPY GAMMA RAY(IN API UNITS)
ILD INDUCTION – DEEP(IN OHM-METERS)
LLD LATEROLOG – DEEP(IN OHM-METERS)
SP/GR POINT WHERE LOG CHANGES
50' KB HEIGHT OF KELLY BUSHING ABOVE DATUM IN FEET
(1 ANTARES) REFERENCE NUMBER FROM INDEX MAP, INCLUDES PROSPECT NAME FOR OCS WELLS

DATUM IS MEAN SEA LEVEL
~BU~ BROOKIAN UNCONFORMITY
~LCU~ LOWER CRETACEOUS UNCONFORMITY
METAMORPHOSED SEDIMENTARY ROCKS
INTERBEDDED METAMORPHOSED CARBONATE AND CLASTIC SEDIMENTARY ROCKS
T/K TERTIARY/CRETACEOUS BOUNDARY FROM BUJAK DAVIES GROUP



Continuation – Plate 1



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SUMMARY

Our interpretation depicts four major tectonic sequences in northern Alaska--the metamorphosed basement complex, the south-sloping trailing-margin Ellesmerian, the rift-associated Beaufortian, and the northerly prograding deltaic Brookian. Each sequence represents different, internally complex cycles of basin development and depositional geometries.

Several correlation problems exist in the Brookian sequence between the onshore and offshore stratigraphy. The onshore Brookian sequence, where the formal stratigraphic nomenclature was developed, consists mostly of nonmarine to shallow-marine facies, interbedded with marine facies. This nomenclature does not apply well to the shale-dominated distal delta facies found along the coast and offshore.

One problem encountered in the study area is the delineation of the basal Brookian shales using well logs, a problem compounded by the existing nomenclature based on outcrop and lithologic data. A consistent correlation can be made in the wells by picking the top of the Pebble Shale/HRZ unit at the first prominent increase in gamma-ray log values above the LCU. We refer to this unit as the HRZ.

The main correlation problem is the identification or separation of the different prodelta shales. Paleontological age data are used to define the termination of the Torok Formation near the Colville River delta. However, we must use a stratigraphic cutoff, based on the pinch-out of the Nanushuk Group, to differentiate between the shale of the Colville Group and the Canning Formation. The cutoff also is extended up section to represent the transition from the sandy Sagavanirktok Formation to the undifferentiated sands and shales of the Colville Group and Sagavanirktok Formation. We hope this study provides a basic framework for future studies that will further clarify the stratigraphy of the North Slope and the adjacent Beaufort Sea.

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