CORRELATION OF THE PENNSYLVANIAN-LOWER CRETACEOUS SUCCESSION BETWEEN NORTHWEST ALASKA AND SOUTHWEST SVERDRUP BASIN: IMPLICATIONS FOR HANNA TROUGH STRATIGRAPHY

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ABSTRACT

Seismic stratigraphic studies of the Chukchi Sea region adjacent to northwest Alaska have demonstrated that the Pennsylvanian-lowermost Cretaceous succession of the area is much thicker than that of the adjacent North Slope. Thicknesses of 4 to 5 km are comparable with those of the southwestern Sverdrup Basin, an area which was interpreted to have been juxtaposed against the Chukchi Sea in pre-Hauterivian time. A comparison of sequence and lithologic development in wells from the southwestern Sverdrup Basin with that in a well in northwestern Alaska indicates that the southwestern Sverdrup Basin is indeed an excellent analog for the Hanna Trough Basin of the Chukchi Sea. Sandstones with reservoir potential probably are present within most sequences in the mid-Permian to Valanginian succession of the Hanna Trough, and reefs probably occur in the Pennsylvanian to Lower Permian succession. Source rocks are expected to be present in the Middle Triassic, Carnian, and Oxfordian-Kimmeridgian sequences and may possibly be present in the upper Paleozoic sequences.

INTRODUCTION

The Amerasia Basin of the Arctic Ocean is interpreted to have formed by the counterclockwise rotation of northern Alaska and adjacent northeast Russia away from the Canadian Arctic Islands in Early Cretaceous (Carey, 1958; Tailleur, 1973; Grantz and May, 1983; Embry, 1990). Using this plate tectonic model as a basic premise, a plate restoration and paleogeographic map for the Early Triassic of northern Alaska and the Canadian Arctic Islands area has been drawn (Fig.1). As shown on this reconstruction, a sinuous seaway transversed the area between the North America craton to the east and south and a smaller land area, Crockerland (Embry, 1993), to the north and west. Three major sedimentary basins contain the Pennsylvanian-Hauterivian deposits of this seaway, and they are the Arctic Alaska Basin of Northern Alaska, Hanna Trough Basin (Central Chukchi Basin) in the Chukchi Sea, and Sverdrup Basin in the Canadian Arctic Islands (Fig.1). The upper Paleozoic-Lower Cretaceous stratigraphy of the Arctic Alaska and Sverdrup basins is reasonably well known due to numerous outcrop studies in mountainous areas and subsurface studies that employ seismic and well data (Bird, 1991; Embry, 1991). On the other hand, the stratigraphy of the Hanna Trough Basin is known only from seismic studies (Thurston and Theiss, 1987; Grantz and May, 1987), although data from a few recently drilled wells are starting to become available.

As shown in Figure 1, the axis of the southwestern Sverdrup Basin lies on-strike with that of the Hanna Trough, and thicknesses of the Permian-lowermost Cretaceous successions in both areas are similar (3-4 km). The purpose of this paper is to correlate and compare the Pennsylvanian-Hauterivian succession in the Brock I-20 and Cape Norem A-80 wells, located in the axial portion of the southwestern Sverdrup Basin (Fig.1), with equivalent strata in the Tunalik 1 well, which is located on the eastern flank of the Hanna Trough (Fig.1). On the basis of the proposed correlations, interpretations are made as to the thicknesses and lithologies of the various stratigraphic sequences which comprise the Pennsylvanian-Hauterivian succession of the Hanna Trough.

METHODS

The stratigraphic subdivisions identified in the Brock I-20 (Pennsylvanian-Upper Triassic) and the Cape Norem A-80 (Lower Triassic-Barremian) wells are based on lithostratigraphic and biostratigraphic studies that are part of a regional basin analysis (Embry, 1991). The composite Pennsylvanian to mid-Hauterivian succession in these two wells is about 4,000 m. The succession has been subdivided into 13 second-order transgressive-regressive (T-R) sequences, each of which is bounded by regional sequence boundaries across which there are significant shifts in the depositional and tectonic styles of the basin. Biostratigraphic dating of each of the sequences has been accomplished mainly by palynological and micro-paleontological studies of the drill cuttings.

The Pennsylvanian-Barremian stratigraphy of the Tunalik 1 well of northwestern Alaska is based on lithostratigraphic and biostratigraphic (palynology and micropaleontology) studies carried out by Mickey and Haga (unpublished) and on published descriptions and interpretations (Tetra Tech, 1982; Gryc, 1988). Only nine second-order sequences have been identified in

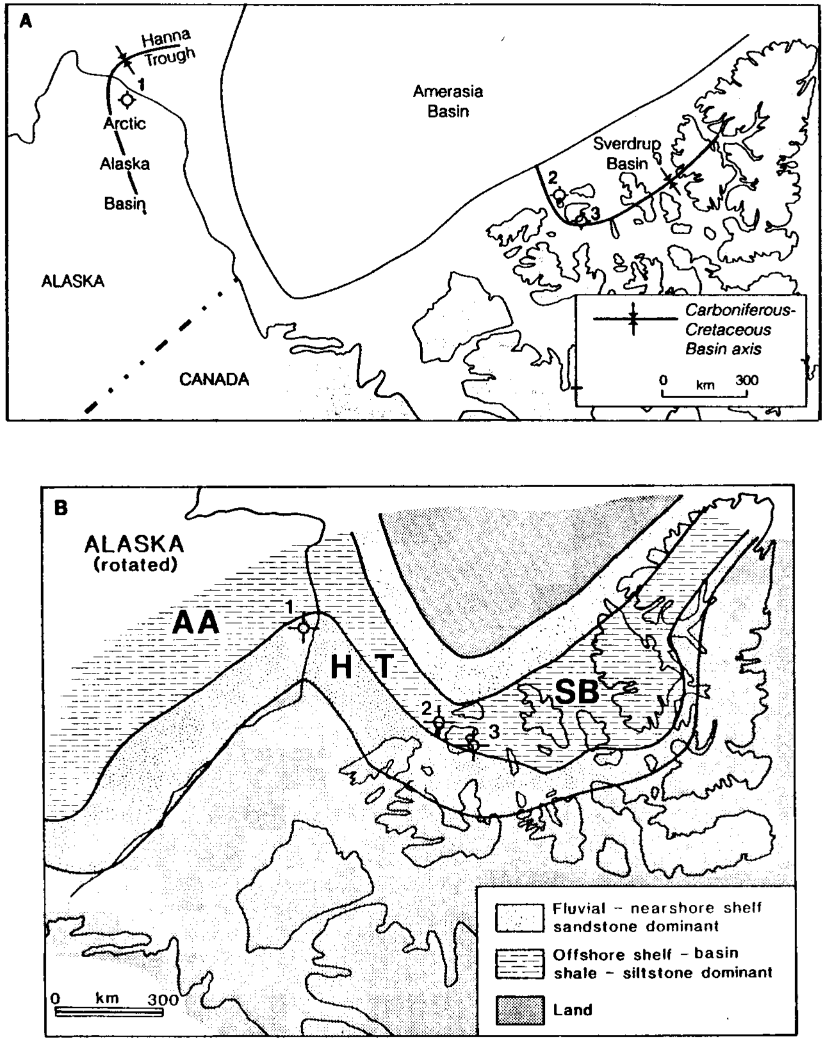

Fig.1. A. Location map showing the axes of the main Carboniferous to Cretaceous basins and the three wells used in this study. B. Early Triassic paleogeography of Arctic North America on pre-Cretaceous Arctic reconstruction. The Arctic Alaska Basin (AA), Hanna Trough Basin (HT), and Sverdrup Basin (SB) are linked along a continuous seaway. Note the close juxtaposition of the Hanna Trough and the southwestern Sverdrup Basin. Key to wells: (1) Tunalik 1, (2) Brock I-20, (3) Cape Norem A-80.

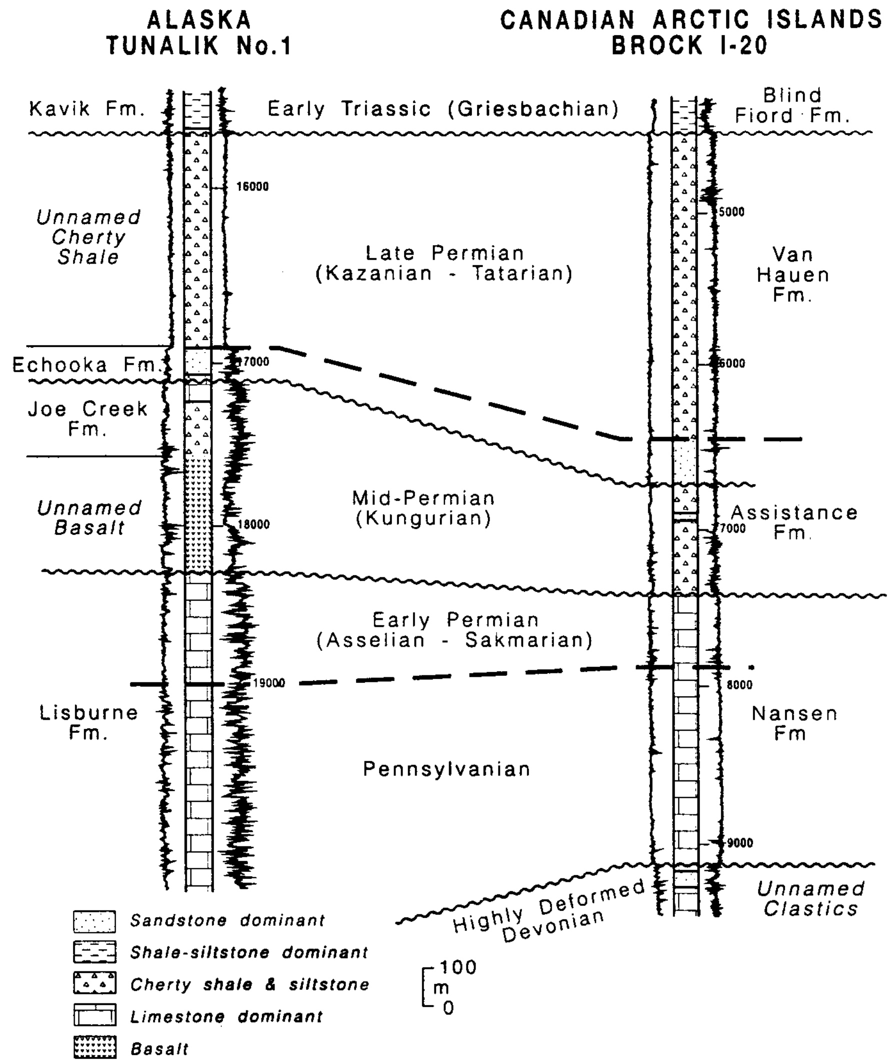

Fig.2. Correlation of Pennsylvanian-Permian sequences between Tunalik 1 of northwestern Alaska and Brock I-20 of the southwestern Sverdrup Basin. See Figure 1 for well locations.

the Pennsylvanian-mid-Hauterivian succession in this well.

CORRELATIONS

Pennsylvanian-Permian

Our correlations for the Pennsylvanian-Permian succession between Brock I-20 and Tunalik 1 are illustrated in Figure 2. The thickness of the succession is about 1,500 m in both wells and three second-order sequences--Pennsylvanian-Lower Permian, mid-Permian, and Upper Permian--can be correlated between the wells.

The lower boundary of the first sequence (Pennsylvanian-Lower Permian) is a subaerial unconformity on deformed lower Paleozoic strata in Brock I-20, but this boundary was not reached in Tunalik 1. The upper boundary of the sequence is a subaerial unconformity. Strata below the unconformity were subject to rifting, whereas those above formed during thermal subsidence in the Sverdrup Basin (Stephenson et al., 1987). This upper boundary corresponds with the basal-Echooka unconformity, which is a very widespread, significant boundary in the northern Alaska-Chukchi Sea region and was used by Thurston and Theiss (1987) as the lower boundary of their upper Ellesmerian megasequence. In both the Brock I-20 and Tunalik 1 wells, the strata of the Pennsylvanian to Lower Permian sequence comprise mainly shallow-water carbonates. In the Sverdrup Basin, large carbonate reefs are developed at various horizons within the shelfal carbonates of this sequence (Beauchamp, 1993). Such reefs are likely to be present in this sequence in the Hanna Trough.

In the Tunalik well, the mid-Permian (Kungurian) sequence consists of glauconitic siltstone and sandstone with thin limestones and a thick basalt unit. A thick, widespread basalt unit (Esayoo Formation) also occurs at the base of this sequence in the northeastern Sverdrup Basin. Coarse-grained, shallow-marine, and delta-plain sandstones (Sabine Bay Formation) occur on the Sverdrup Basin margin and might be present on the flanks of the Hanna Trough.

In both wells, the Upper Permian sequence is bounded by widespread subaerial unconformities and comprises mainly cherty shale and siltstone of deep-water origin. Shallow-water limestone (Degerbols Formation) and sandstones (Trold Fiord Formation) make up the sequence on the margins of the Sverdrup Basin, and such lithologies are quite possibly present in the Hanna Trough.

Triassic

The composite Triassic succession in the Brock I-20 and Cape Norem A-80 wells is 1,800 m thick and contains four second-order sequences--Lower Triassic, Middle Triassic, Carnian, and Norian. Embry (1988, 1991) described the regional development of these four sequences in the Sverdrup Basin. In the Tunalik 1 well, Triassic strata are only 300 m thick and comprise only two second-order sequences (Lower Triassic, Norian) (Fig.3).

The Lower Triassic sequence in the Brock I-20 well is about 900 m thick and comprises mainly shale, siltstone, and very fine-grained sandstone of offshore shelf to slope origin. Such lithologies typify much of the Lower Triassic of the Sverdrup Basin, although thick, fluvial to shallow-marine sandstones (Bjorne Formation) occur on the basin flanks. The thin, argillaceous Lower Triassic strata in the Tunalik well probably do not typify the development of the sequence in the Hanna Trough. In that area, the Lower Triassic sequence may be considerably thicker (1,000 m?) and contain substantial sandstone intervals (similar to the Ivishak Formation of northern Alaska) on both the eastern and western basin margins (Fig.1).

The Middle Triassic and Carnian sequences are 750 m thick in the Cape Norem A-80 well and contain substantial thicknesses of shallow-marine sandstones, with lesser amounts of siltstone, shale, and limestone. Farther basinward, these lithologies change facies to deeper water, organic-rich shales that are excellent petroleum source rocks (Brooks et al., 1992). Although the two sequences are interpreted to be absent in the Tunalik well, they are likely to be present in the thicker, more complete succession preserved in the Hanna Trough. Reservoir and source rocks similar to those of the Sverdrup Basin may be present in the Hanna Trough.

The Norian sequence is present in both the Tunalik and Cape Norem wells and is bounded by subaerial unconformities. The Norian strata in Tunalik are mainly dark-grey to black shales with interbeds of limestone and siltstone. In Cape Norem, the strata are mainly medium- to dark-grey shale and siltstone with interbeds of very fine-grained glauconitic sandstone. Thick sandstones are developed in the sequence in the eastern Sverdrup Basin but, in the southwest, the sequence consists mainly of offshore shale and siltstone with thin shoreface sandstones at the top. Lithologies similar to those found in the southwestern Sverdrup Basin may be expected in the Hanna Trough.

Uppermost Triassic-Lowermost Cretaceous

In the Cape Norem well, the uppermost Triassic to lowermost Cretaceous succession is bounded by two widespread unconformities which are of early Rhaetian age at the base and mid-Hauterivian age at the top (Fig.4). Between these two major boundaries, the succession is 1,400 m thick and consists mainly of

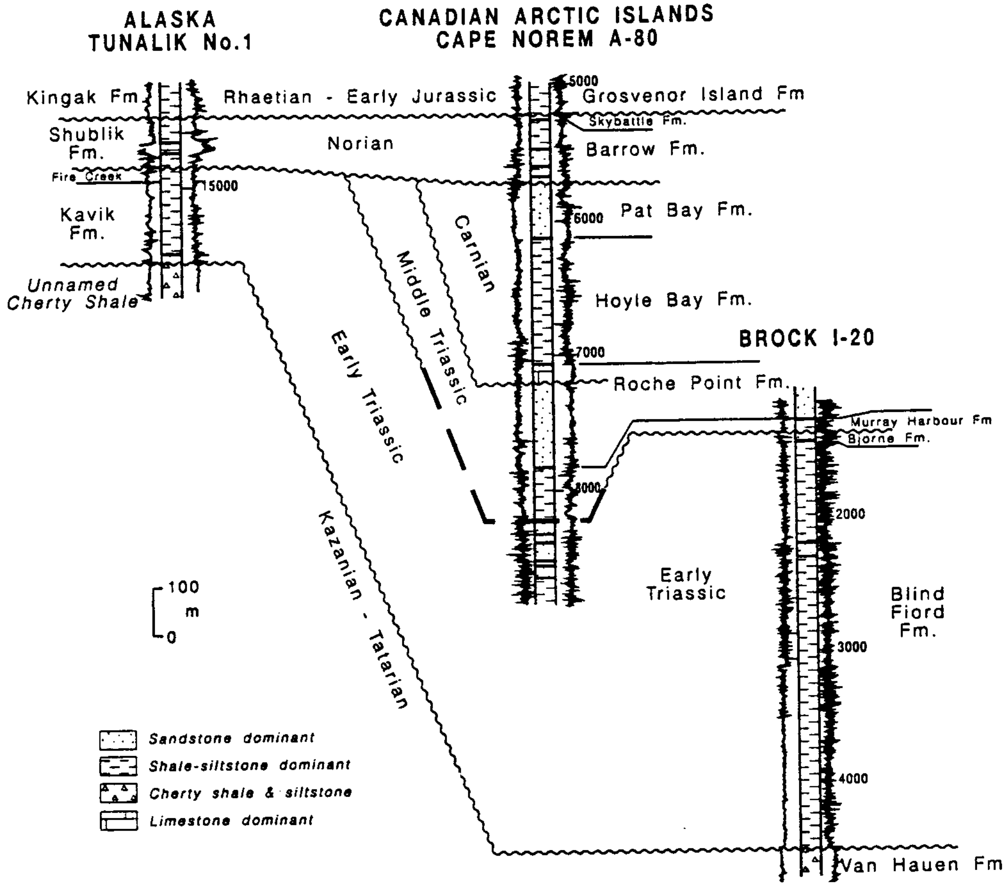

Fig.3. Correlation of Triassic sequences between Tunalik 1 of northwestern Alaska and Brock I-20 and Cape Norem A-80 of the southwestern Sverdrup Basin. See Figure 1 for well locations.

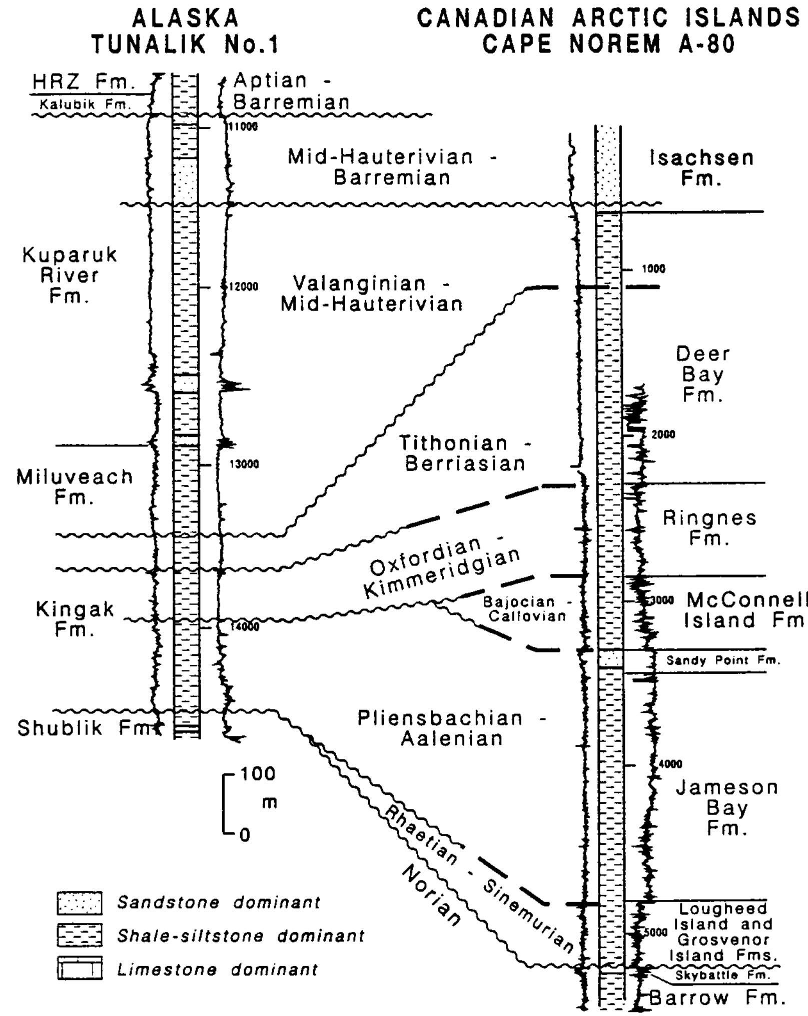

Fig.4. Correlation of uppermost Triassic-lowermost Cretaceous sequences between Tunalik 1 of northwestern Alaska and Cape Norem A-80 of the southwestern Sverdrup Basin. See Figure 1 for well locations.

offshore marine shale and siltstone with minor, very fine- to fine-grained sandstone. Six second-order sequences are present and are of Rhaetian-Sinemurian, Pliensbachian-Aalenian, Bajocian-Callovian, Oxfordian-Kimmeridgian, Tithonian-Berriasian, and Valanginian age. These sequences are bounded mainly by conformable transgressive surfaces, although modified subaerial unconformities may form some boundaries. All of the boundaries become significant unconformities on the Sverdrup Basin margins, where the sequences contain thick sandstone units.

The uppermost Triassic to lowermost Cretaceous succession in Tunalik is 900 m thick and, like the strata at Cape Norem, it consists almost entirely of offshore shale and siltstone with minor sandstone. Four sequences have been identified in the succession, and these are bounded by unconformities.

The Rhaetian-Sinemurian sequence in the southwestern Sverdrup Basin consists of mainly offshore shale and siltstone, with shoreface sandstone present only on the basin edge. The sequence appears to be absent in Tunalik, although it may exist at the base of the Kingak Formation. In the Hanna Trough, a thin succession of shale and siltstone would be expected, with the possibility of sandstone development only on the basin edge.

The Pliensbachian-Aalenian sequence also consists of mainly shale and siltstone in the southwestern Sverdrup Basin with glauconitic sandstones commonly present in the uppermost portion. Similar argillaceous lithologies typify the correlative Kingak Formation in northwest Alaska and may dominate in the Hanna Trough.

The Bajocian-Callovian sequence in the southwestern Sverdrup Basin usually consists of a thin succession of shale and siltstone with abundant concretions. Sandstones are locally developed on the basin margin. The sequence appears to be missing in Tunalik, but a very thin, starved representative of the sequence possibly is present in the well. This sequence may be thin and very argillaceous over most of the Hanna Trough.

The Oxfordian to Kimmeridgian sequence in the southwestern Sverdrup Basin consists of dark-grey to black shale and siltstone and has source-rock potential at some localities (Stewart et al., 1992). Sandstones are present on the basin margin, and the sequence is capped by an unconformity, leading to the possibility of down-dip sandstone development. The sequence has a similar thickness and lithologic development in the Kingak Formation in Tunalik, and similar strata may extend over much of Hanna Trough. The sequence may contain important source rocks in Hanna Trough like it does in Sverdrup Basin and northern Alaska, and sandstones possibly could be developed at the top of the sequence in basinal localities.

The Tithonian-Berriasian sequence consists of medium-grey shale and siltstones in the southwestern Sverdrup Basin, with sandstones present along the basin edge. Also, a subaerial unconformity caps the sequence along the basin margins, allowing for the possibility of down-dip sandstone development. This sequence is only 60 m thick in Tunalik but may well be thicker in the Hanna Trough. Sandstones may be present in this sequence in the Hanna Trough in both marginal and more central locations.

The uppermost sequence, the Valanginian-mid Hauterivian, occurs in both the Cape Norem and Tunalik wells and, unlike the underlying Triassic-Jurassic sequences, it is thicker in Tunalik. In both wells, the succession consists of offshore marine, dark-grey shale and siltstone, and similar lithologies are expected over much of the Hanna Trough. Sandstones may develop in the uppermost portion of the sequence in basin-central localities, where the capping unconformity becomes a conformity.

Mid-Hauterivian-Aptian

The unconformity at the base of the mid-Hauterivian-Barremian sequence is interpreted to be the Amerasia Basin breakup unconformity (Grantz and May, 1983; Embry and Dixon, this volume) and, not surprisingly, postmid-Hauterivian strata of the Sverdrup Basin have little in common with equivalent strata in northern Alaska. As shown on Figure 4, the mid-Hauterivian to Aptian strata of the Cape Norem well consist of arenaceous, fluvial to shallow-marine strata, in contrast to the more argillaceous, offshore-marine strata in the Tunalik well. For the post-mid-Hauterivian succession, Sverdrup Basin stratigraphy has little to offer in the way of predicting the lithologic developments in the Hanna Trough.

CONCLUSIONS

In premid-Hauterivian, the southwestern Sverdrup Basin was juxtaposed against Hanna Trough, and the established Pennsylvanian to Valanginian sequence stratigraphy of the southwestern Sverdrup Basin can be used to help predict the lithostratigraphic succession in Hanna Trough. Reservoir and source-rock development vary greatly from sequence to sequence. Carbonate reefs of Pennsylvanian to Early Permian age and shallow-water sandstones of middle to Late Permian age are the best reservoir possibilities for the upper Paleozoic strata. For the 10 Triassic to Valanginian sequences, sandstones may be present in most of the sequences, with the Lower Triassic and Carnian sequences probably having the most widespread sandstone units. Source rocks may occur in the Middle Triassic, Carnian, Pliensbachian-Aalenian, and Oxfordian-Kimmeridgian sequences.

ACKNOWLEDGMENTS

The authors would like to thank the Geological Survey of Canada for permission to publish this paper. J. Dixon, K. Sherwood, D. Stone, and A. Grantz critically read the paper and contributed to its improvement. The efforts of Billie Chiang, who processed the manuscript, and Peter Neelands, who drafted the figures, are greatly appreciated. Geological Survey of Canada Contribution No. 44393.

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