EARLY TERTIARY WRENCH FAULTING IN THE NORTH CHUKCHI BASIN, CHUKCHI SEA, ALASKA

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ABSTRACT

Seismic-reflection mapping reveals that the southeastern portion of the North Chukchi Basin was wrench faulted during the Early Tertiary. The wrench faults are distributed in three north-trending zones, one in the western portion of the study area and two in the east, and are continuations of wrench faults recognized to the south. The wrench faults in the basin are transtensional and right-lateral. The amount of lateral offset across an individual wrench zone is probably relatively minor (less than 10 km). Wrench faulting in the basin was accompanied by 10 to 15 km of east-west extension that formed numerous extensional faults outside of the wrench zones. The wrench faulting and extension ended by the Late Eocene and was a relatively short-lived tectonic event superimposed on the northward subsidence of the basin.

INTRODUCTION

The North Chukchi Basin is located on the continental shelf of the Chukchi Sea (Fig.1). The basin extends to the west, across the continental shelf of the East Siberian Sea, where it is known as the Vilkitskii Basin (Haimila et al., 1990). The northern extent of the basin is uncertain due to a lack of seismic data.

Previous studies suggest that the basin is bounded on the north by the continental blocks of the Chukchi Borderland (Grantz et al., 1979; Grantz and May, 1983). The basin is bounded on the south by the Chukchi Platform and the Central Chukchi Basin, and on the east by the North Chukchi High (Thurston and Theiss, 1987) (Fig.2). The edge of the basin is characterized by a tectonic hinge line at which the sedimentary fill thickens to the north and west. The basin axis trends generally east-west as indicated by continuous northward-thickening strata to the northern limit of the seismic data coverage.

The North Chukchi Basin may have formed by rifting that moved the Chukchi Borderland relatively northward from a spreading axis beneath the basin (Grantz and May, 1983). The age of basin formation presumably correlates with the Late Neocomian rifting event that produced the Canada Basin and the continental margin of the Alaskan Beaufort Sea (Grantz and May, 1987).

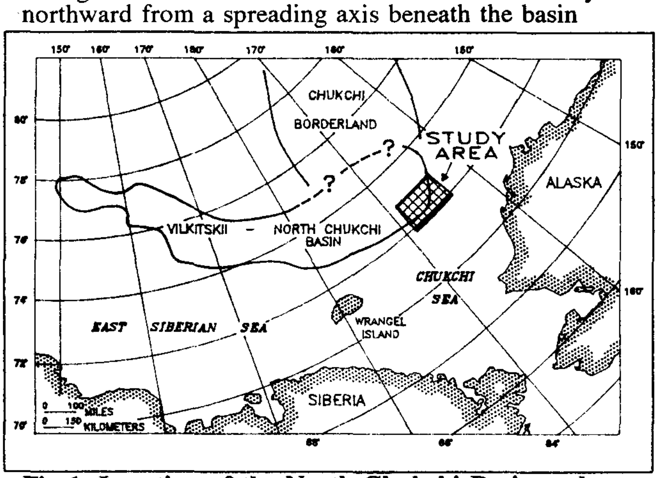

Fig.1. Location of the North Chukchi Basin and study area. Modified from Haimila et al. (1990).

In this paper, I examine the structural characteristics of faults in the southeastern portion of the North Chukchi Basin. The study is based on my interpretation of multi-channel seismic-reflection data. The seismic lines form a roughly 10-km by 10-km grid throughout the study area. The western limit of the seismic data coverage is the Russian border near 169°W. longitude. The northern limit of the data is approximately 73°N. latitude, beyond which seismic data acquisition is hindered by the Arctic pack ice.

Wrench faults on the Chukchi shelf, south of the North Chukchi Basin, were reported by Thurston and Theiss (1987). These authors mapped several north-trending wrench zones referred to collectively as the Hanna wrench-fault zone (Fig.2).

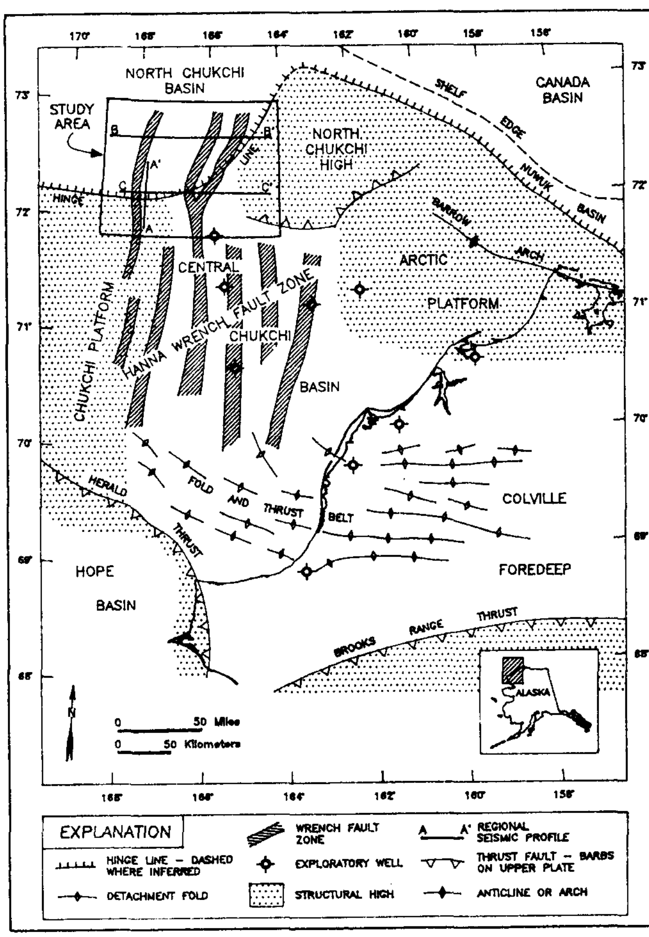

Fig.2. Major geologic features of the Chukchi shelf and the location of selected exploratory wells. Location of the Hanna wrench-fault zone south of the present study area from Thurston and Theiss (1987).

SEISMIC STRATIGRAPHY

The strata of the North Chukchi Basin correlate to the stratigraphic section of the North Slope of Alaska (Fig.3). Seismic-stratigraphic sequence boundaries in the study area are tied to exploratory wells in the Chukchi Sea and the northwestern coast of Alaska (Fig.2).

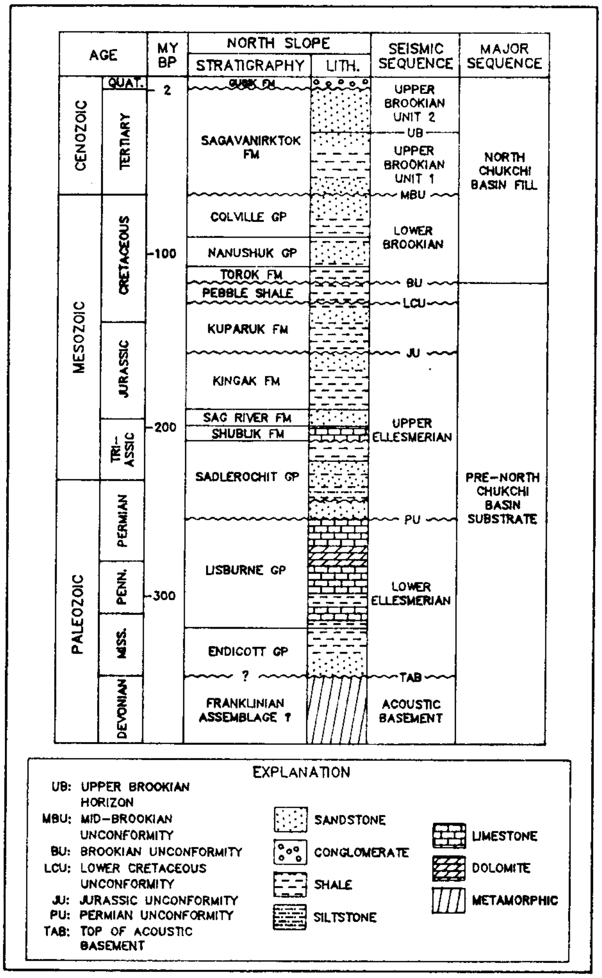

Fig.3. Generalized stratigraphic column of the North Slope of Alaska and correlative seismic stratigraphy of the Chukchi shelf.

The composition of acoustic basement in the North Chukchi Basin is unknown. The acoustic basement on the margins of the basin is presumed to correlate to the pre-Late Devonian Franklinian sequence, which is widely distributed along the Arctic margin of North America.

A wedge of Ellesmerian strata is present on the southeast margin of the basin. This sequence thickens westward, into what may have been a precursor of the North Chukchi Basin (profile C-C' in Fig.4). The Ellesmerian sequence is poorly resolved on seismic data and grades into acoustic basement in the northern and western portions of the study area.

The sedimentary fill of the North Chukchi Basin is correlative to the Brookian sequence, which ranges in age from Early Cretaceous to Quaternary. The Brookian sequence thickens to over 12,000 meters, below the base of the seismic profiles, in the northern portion of the study area (profile A-A' in Fig.4). The base of the Brookian sequence is defined by the Early Cretaceous Brookian unconformity (BU), which overlies the Ellesmerian sequence or acoustic basement.

The Brookian sequence is divided into lower and upper sequences by the basal Tertiary mid-Brookian unconformity (MBU). For the purposes of this study, the upper Brookian sequence is further subdivided into lower and upper units, referred to as upper Brookian unit 1 and unit 2 respectively, by the Late Eocene upper Brookian horizon (UB). The ages of the MBU and UB are based on biostratigraphic data from the exploratory well near the southern boundary of the study area (Micropaleo Consultants, 1991).

WRENCH FAULTING

During the Early Tertiary, strata in the North Chukchi Basin were offset by numerous north-trending faults (Fig.5). The faulting primarily affected lower Brookian and older strata, although syndepositional faulting of upper Brookian strata is also apparent (Fig.4). Vertical displacement of the MBU on some faults is very large, nearly 3,000 m. Based on the apparent absence of erosion of lower Brookian strata, the Tertiary faulting is interpreted to have formed a subsea horst and graben terrain that was subsequently covered by upper Brookian marine sediment. Most of the faults terminate within, or slightly above, upper Brookian unit 1 strata, indicating that faulting ended by the Late Eocene.

Structural features indicative of wrench tectonics, as outlined by Harding (1990), are evident on seismic profiles across some of the Tertiary faults in the basin. These features, which are distributed in north-trending zones, are illustrated in Fig.6 and consist of the following:

1. A laterally persistent root fault or fault zone that branches upward through overlying strata. Individual faults within the wrench zones exhibit a normal sense of offset. No reverse faults are recognized.
2. Antiformal or synformal structures within the wrench zones. The wrench zones primarily exhibit synformal structures. The synforms are characterized by a central graben, usually bounded by upward-branching faults. Antiformal structures, such as the one seen on profile F-F' in Fig.6, are uncommon in the study area.
3. The juxtaposition of different thicknesses of strata across the wrench zones, which is inconsistent with simple normal faulting or growth faulting. Anomalous thickness changes of the lower Brookian sequence across the wrench zones are evident on many of the profiles, such as F-F' and G-G' in Fig.6.
4. The changing character of the above three structural features along the trace of an individual wrench zone.

Based on the above criteria, three wrench zones are present in the study area, one in the west and two in the east (Figs.2 and 5). The eastern wrench zones merge toward the southern margin of the basin. Seismic mapping indicates that the wrench zones are a northern

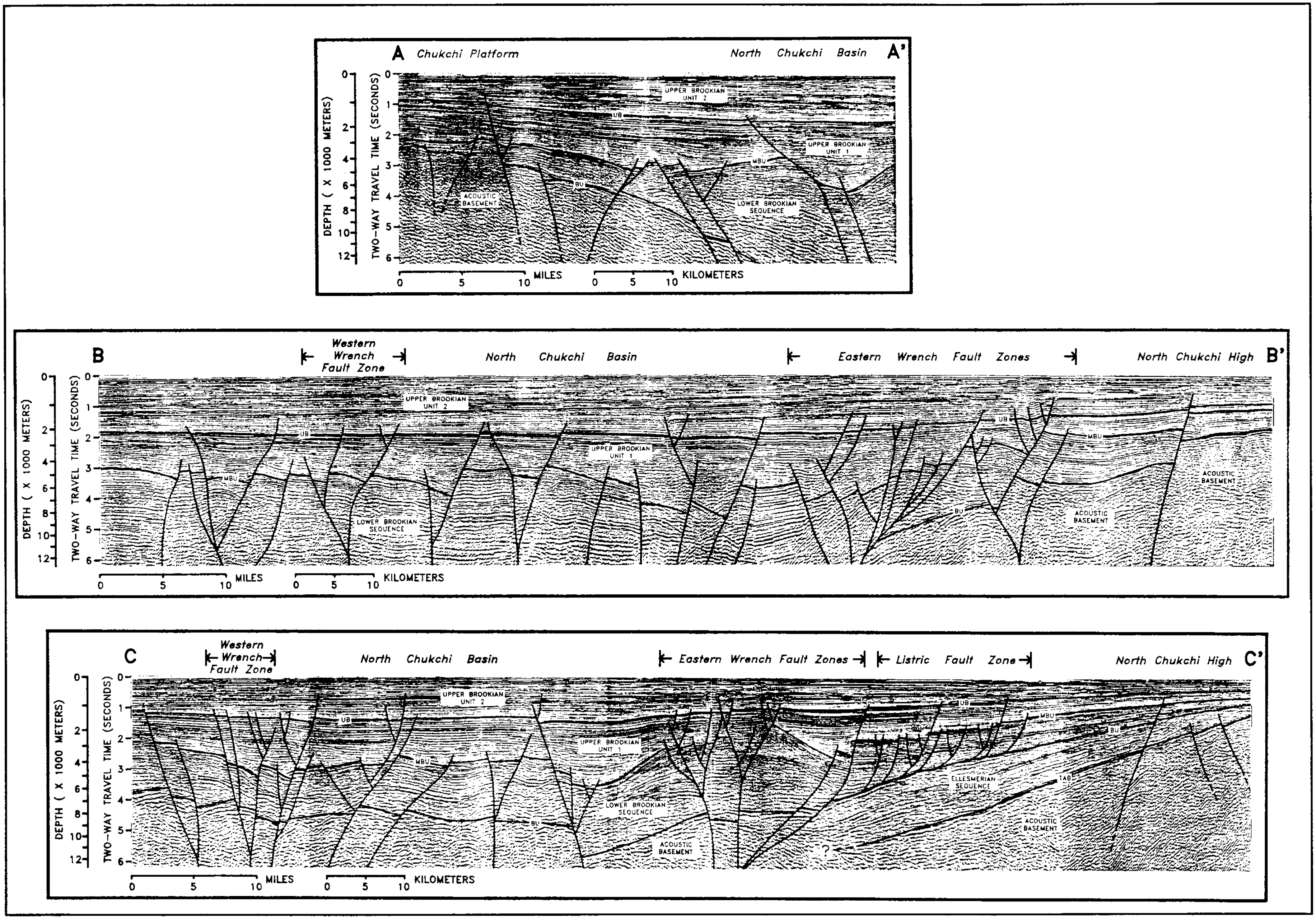

Fig.4. Regional seismic profiles of the study area. Location of profiles shown in Figs.2 and 5. Abbreviations as in Fig.3.

Fig.5. Fault map of the mid-Brookian unconformity in the study area. Map location shown in Figs.1 and 2.

continuation of the Hanna wrench-fault zone. The southern terminus of the Hanna wrench-fault zone is located over 200 km away in the Fold and Thrust Belt north of the Herald Thrust (Fig.2).

Please note that Fig.5 shows the location of the wrench root zone. The width of the wrench zone at the structural level of the MBU is somewhat wider, as shown on the seismic profiles in Fig.6. Tertiary faults outside of the wrench zones are interpreted to be extensional faults caused by east-west extension related to the wrench tectonics.

Structural characteristics, as discussed by Harding et al. (1985), suggest that the wrench faults in the study area are transtensional. Transtensional stress is indicated by the normal sense of offset of faults within the wrench zones, by the presence of numerous extensional faults outside of the wrench zones, and by the absence of compressional features, such as en echelon folds and reverse faults.

The wrench faults are interpreted to be right-lateral. This conclusion is based, in part, on the substantial increase in the amount of extension across the wrench zones as they turn eastward, forming releasing bends. The releasing bend in the eastern wrench zones formed a listric fault zone along the eastern margin of the basin (Fig.5). On seismic profiles, the listric faults merge into a detachment surface at the base of the lower Brookian sequence (profile C-C' in Fig.4). The detachment zone terminates in the easternmost wrench root zone. Formation of the releasing bend where the wrench zones turn eastward is consistent with right-lateral offset.

ISOPACH MAPS

A northward-thickening wedge of lower Brookian sediment was deposited in the North Chukchi Basin during the initial subsidence of the basin. The isopach map of this sequence displays patterns that may reflect lateral offset of this wedge by wrench faulting. The isopach contours exhibit a distinct right-lateral deflection of 5 to 8 km across the western wrench zone, which may have been caused by right-lateral fault movement (Fig.7A). However, this estimate of the sense and amount of lateral offset is, at best, a rough approximation. Undoubtedly, the isopach contours of this sequence have also been influenced by syndepositional thickness variations of lower Brookian strata, and by the Tertiary extensional faults outside of the wrench zones. In addition, unidentified wrench

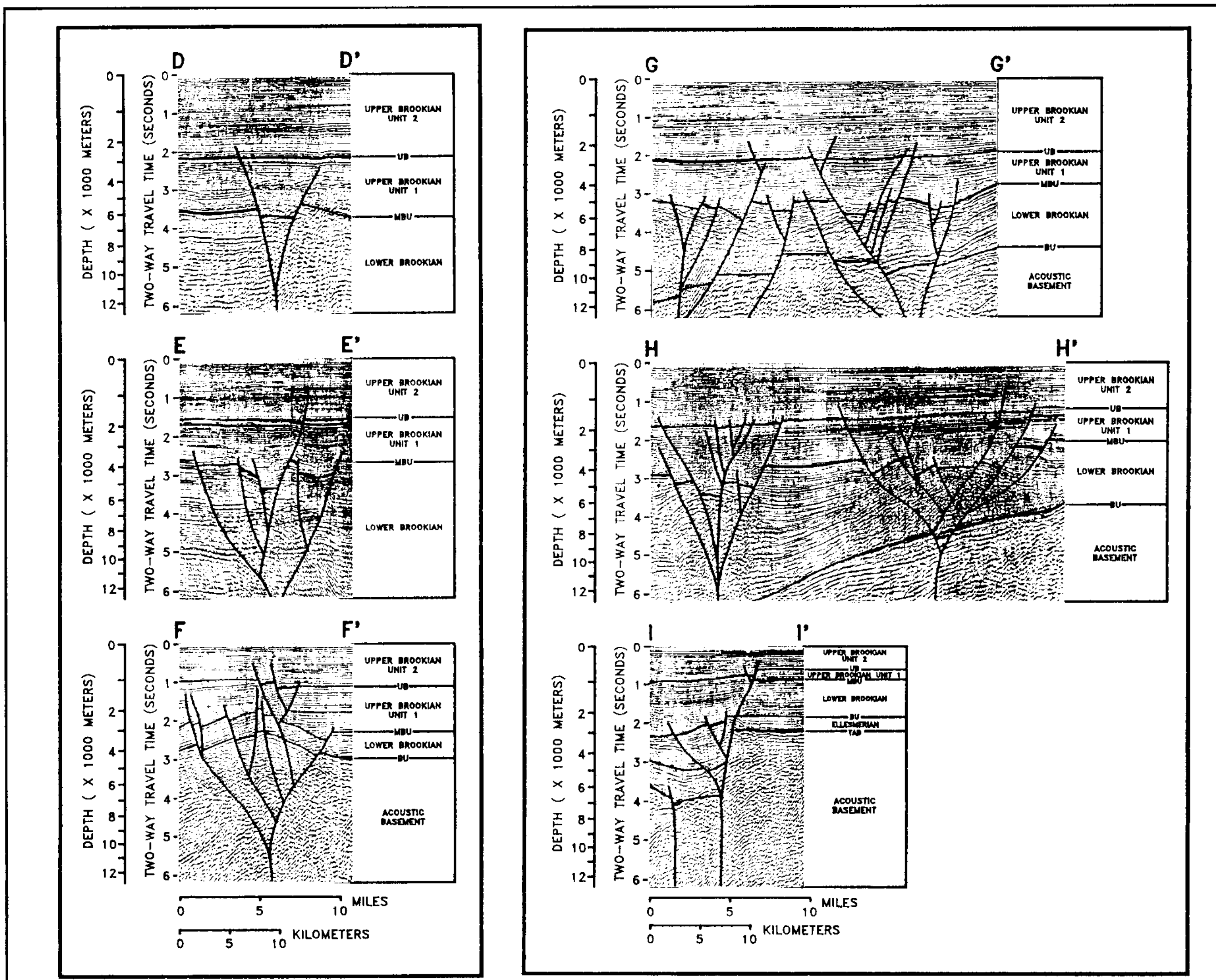

Fig.6. Seismic profiles across wrench zones in the study area. The left column is a series from north (top) to south (bottom) along the western wrench zone, and the right column is a similarly oriented series along the eastern wrench zones. Location of profiles shown in Fig.5. Abbreviations as in Fig.3.

faults in the basin may have caused other linear deflections of the contours. No definitive deflection is apparent across the eastern wrench zones, probably because these faults are generally parallel to the isopach contours.

Upper Brookian unit 1 sediment was deposited in the basin during the Tertiary wrench and extensional faulting. The sediment filled and covered the subsea horsts and grabens formed by the faulting. This interpretation is based, in part, on the isopach map of this sequence, which reflects sedimentation in local depocenters (Fig.7B). However, the isopach map also reveals general northward thickening of the sequence. The northward thickening suggests that deposition of upper Brookian unit 1 sediment was partially controlled by continued northward subsidence related to the initial formation of the basin.

Upper Brookian unit 2 sediment was deposited in the basin as the Tertiary wrench and extensional faulting declined, and sedimentation continued after faulting ended. Uniform northward thickening of this sequence indicates that sedimentation following the Tertiary faulting was controlled entirely by northward subsidence (Fig.7C).

CONCLUSIONS

The northerly trend of the Tertiary faults in the North Chukchi Basin is orthogonal to the east-west axis of the basin. This anomalous trend suggests that the tectonic mechanism that produced the faults is not related to the initial formation of the basin. This conclusion is supported by the isopach maps of seismic sequences in the study area. The isopach maps show the continuous deposition of northward-thickening sediment since the time of basin formation. The continuation of northward-thickening sediment deposition following the Tertiary faulting, as seen on the isopach map of upper Brookian unit 2 strata (Fig.7C), indicates that the faulting was a relatively short-lived tectonic event superimposed on the primary regime of northward subsidence.

Grantz and May (1987) and Grantz et al. (1990) interpreted the north-trending faults in the basin to be

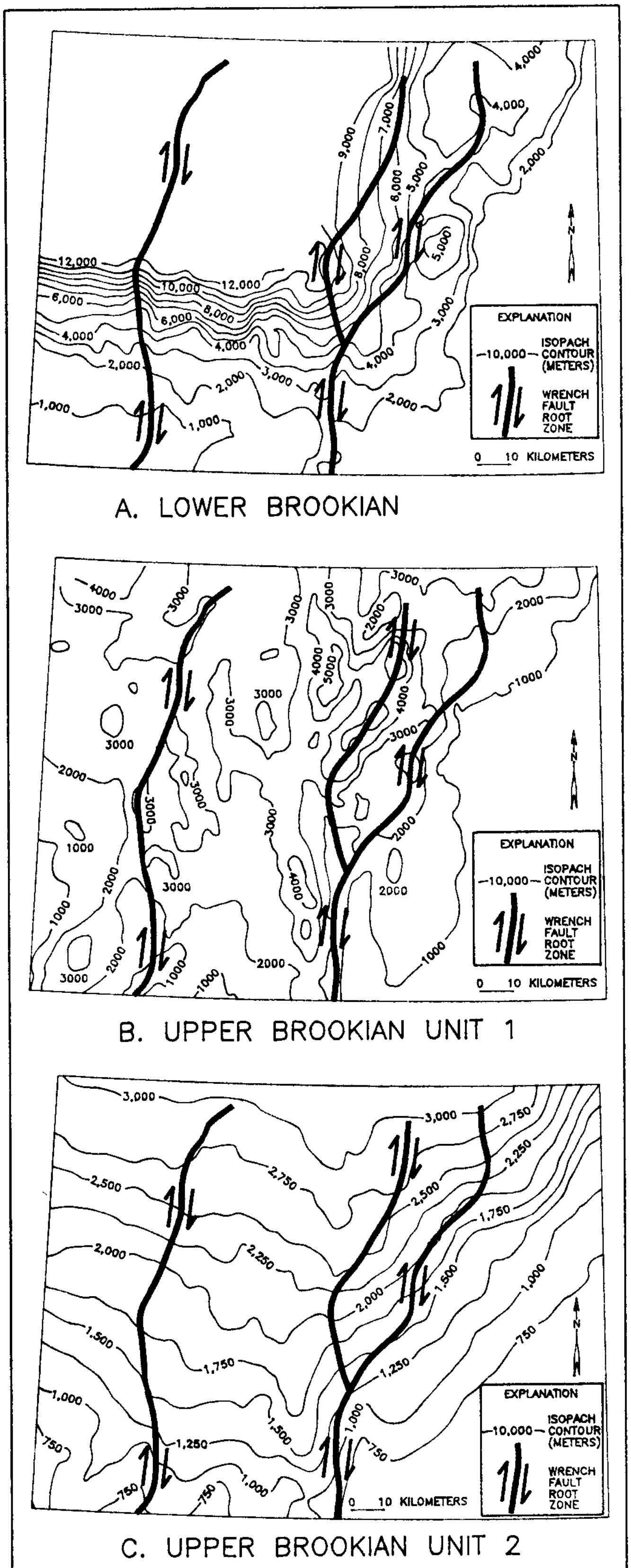

Fig.7. Isopach maps of seismic sequences in the study area. Map locations shown in Figs.1 and 2.

listric normal faults formed by extensional tectonics. These authors proposed that the extension was caused by a second, north-south-trending rift in the Late Cretaceous or Early Tertiary that resulted in crustal thinning, subsidence of the sea floor over the thinned crust, and deepening of the basin. However, if the faults were formed by extension due to a north-south-trending rift, the isopach contours of the upper Brookian unit 2 sequence would be expected to trend north-south, reflecting subsidence of the basin following rifting. As stated previously, this is not the case.

The present study concludes that some of the Tertiary faults in the North Chukchi Basin were formed by transtensional wrench tectonics. The amount of lateral offset across each of the three identified wrench zones is probably relatively minor (less than 10 km), as suggested by analysis of the isopach map of the lower Brookian sequence. The wrench faulting was accompanied by east-west extension that formed numerous extensional faults outside of the wrench zones. The amount of east-west extension across the study area, as measured on the MBU, is approximately 10 to 15 km. The wrench faulting and extension ended by the Late Eocene.

The underlying cause of the wrench faulting and extension is presently unknown. However, the two events are temporally and spatially related, therefore probably genetically related as well. Although further study is needed to fully understand the tectonic evolution of the basin, the clear existence of wrench faulting is a significant clue that may help unravel the complex geologic history of the Arctic Ocean region.

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