A SEDIMENTARY BASIN IN THE NORTHERN LABRADOR SEA

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JOHNSON, G. L., CAMPSIE, J., RASMUSSEN, M., EGLOFF, J., DITTMER, F. & FREITAG, J.: A Sedimentary Basin in the Northern Labrador Sea. *Bull. geol. Soc. Denmark*, vol. 22, pp 1–6. Copenhagen, January, 16th 1973.

Seismic reflection profiles and bathymetric data obtained during a survey of the northern Labrador Sea delineate the structure and morphology of a sedimentary basin in the eastern part of the survey area. The sedimentary column of the basin reaches a thickness of at least 1.5 km. Within this sequence an unconformity with horizontal layers overlying eastward dipping strata is observed. Evidence is presented which suggests that the sediments of the basin are mainly Mesozoic and Lower Tertiary in age.

The data suggest that the basin may be a down faulted portion of the original Greenland continental block. The presence of the unconformity might thus be explained by rapid subsidence during the early rifting history of the continental margin.

A N to NW trending basement high in the northern Labrador Sea may represent the ancient spreading axis.

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During the summer of 1971 the USNS LYNCH conducted a reconnaissance survey of selected parts of the Labrador Sea. Parameters measured were magnetics, bathymetry and seismic reflection. A proton precession magnetometer (Varian 4937 DR) was employed to measure the absolute value of the earth's magnetic field. Magnetic tapes were scaled at 100 gamma intervals and at all magnetic highs and lows. Echo soundings were obtained with a 3.5 kHz hull mounted transducer, which also gave information on shallow sub-bottom sedimentary structures as penetration averaged about 15 m. Sounding data was recorded on an EDO (333 PSR) recorder. The echo distances measured in units of 1/400 sec. travel time are probably accurate to at least 1 part in 3000. Seismic reflection data were collected with a 30,000 joule Teledyne sparker and hydrophone system. These data

were recorded on two Raytheon PSR recorders. The incoming signal was band pass filtered from 40 to 76 Hz. All navigation was by satellite with supplementary LORAN A and radar fixes when within range of land masses and is accurate to about 500 m.

This cruise was a cooperative expedition between the US Naval Oceanographic Office and the Ocean Study Group of Copenhagen. Analyses of dredged basalts from the Greenland continental margin will be reported by Campsie et al., (1973) and Rasmussen et al., (1973). Johnson et al., (1972a, 1973a,b) are reporting on the sedimentary rocks recovered from the Greenland margin. The sediment distribution, crustal structure and magnetic anomalies of the Labrador Sea south of Kap Farvel are described by Johnson et al. (1972b).

The evolution of the Labrador Sea has been thoroughly treated by Vogt et al., (1970), Le Pichon et al., (1971) and Laughton et al., (1972) and will not be discussed in this report.

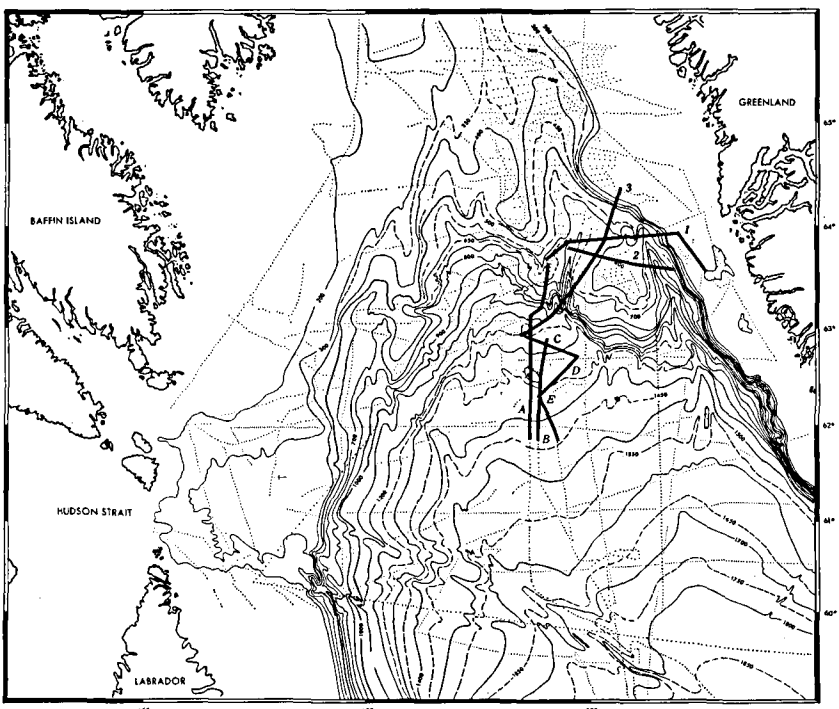

Fig. 1. Bathymetric sketch map of the northern Labrador Sea. Control is shown by dotted lines. Heavy dotted lines are sounding lines by *Lynch* and *Jean Charcot* which used satellite navigation. Other soundings were controlled by a variety of other navigational methods and are relatively inaccurate in this very difficult part of the world. Heavy solid lines indicate seismic reflection tracks shown in pl. 1 and 2. Depths are in nominal fathoms (1/400 sec. travel time).

The northern Labrador Sea

Fig. 1 is a bathymetric sketch map of the northern Labrador Sea. This is based on the chart published by Johnson et al. (1969) and has been revised to include the 1971 LYNCH echo sounding data and JEAN CHARCOT 1970 data (Anonymous, 1971). However, CHARCOT data in the vicinity of 63°N, 57°W was not used as the depths given seemed anomalously shallow.

Morphologically the northern Labrador Sea resembles a U-shaped valley. It is bounded to the north by Davis Strait at a depth of slightly more than 350 fathoms (640 m) and to the east and west by the continental blocks of Greenland and Baffin Island, Labrador respectively. The sea floor deepens southward, at an average gradient of approximately 1:240. The Labrador continental shelf ranges in depth from 250–300 fathoms, (457–549 m) whereas the west Greenland continental shelf lies close to the 100 fathom, (183 m) isobath. The east Greenland shelf is deep and lies in depths comparable to the Labrador shelf (Johnson et al. 1969, Johnson & Eckhoff, 1966). Why the west Greenland shelf is so shallow, being comparable to the shelf depths in more temperate regions (Heezen et al. 1959) is not at all clear.

Canyons

Unique topographic features found in the northern Labrador Sea are a number of sea floor canyons. They have no apparent connection to canyon systems on the shelf and slope although detailed surveys are required to conclusively demonstrate this. They strike generally north-south and the major ones in the northeastern area appear to commence as a general depression at the base of the Greenland continental slope at 65°N. Farther to the south the canyon system bifurcates around a prominent high which lies at less than 600 fathoms (1097 m) (fig. 1).

Pl. 1 shows three seismic reflection lines across the area of interest. Profiles 1 and 2 were taken across the broad topographic high on an east-west heading. The high as well as the eastern and western bordering depressions together comprise the sedimentary basin. The western canyon is clearly an erosional feature and appears to be a recent phenomenon which has eroded a channel through the westernmost edge of the upper sequence of the basin sediments (pl. 1, profile 3). Profiles 1 and 2 show that the western canyon has developed along the eastern edge of a prominent basement high which bounds the western side of the basin.

It is assumed that bottom currents are responsible for the cutting of this channel and general redistribution of sediments. It is noted in profile 3 that

the sediment pattern is distinctly anticonformable to basement topography. The basement peaks (pl. 1, profile 2) are kept bare of sediment, or nearly so even though the regional sediment build-up of the surrounding sea floor has reached a level of more than 180 m above the basement elevation (pl. 1, profile 2).

Le Pichon et al. (1971) have suggested that this basement high is a north-south transform fault active during the second phase of opening of the Labrador Sea commencing in the Paleocene.

Vogt (1972) on the other hand has suggested this presumably basaltic ridge may be the apex of V-shaped aseismic ridges associated with mantle plume ("hot spot") activity. The Cape Dyer and West Greenland Tertiary basalts would be trails of magma extruded from the "hot spot" and carried northward by the movement of the Labrador and Greenland plates. A thorough study of possible effects of mantle plumes is contained in Vogt (1971).

The eastern channel appears to be fault controlled rather than an erosional surface. In pl. 1, profile 2 prominent layers appear to be down faulted to form a graben like feature. The rather rugged terrain in pl. 1, profile 1 may also represent fault blocks. At 64° 30'N the sea floor at the base of the Greenland slope is smooth with no indication of either erosional or tectonic activity.

Basement Structure

A series of basement highs in the northern Labrador Sea were investigated by the LYNCH (pl. 2). A large blocky high which is partially emergent above the thick sedimentary blanket forms a topographic high striking 325° (fig. 1, 62° 25'N, 56° 30'W). Morphologically this massive basement peak does not resemble the typical narrow double crested fracture zones of the Atlantic and their associated median deep. It would seem likely that this high rather represents the ancestral Labrador Sea spreading centre which has been highly fractured by NNE-SSW fracture zones of which the linear north-south basement high mentioned in the previous section (pl. 1) is one. The smooth basement high at the north end of profile. A (pl. 2) is the same feature reported by Johnson et al. 1969. The authors believe this structural high may well continue on a northwesterly strike tovard Cape Dyer as an extension of the proposed relic spreading center noted at 65° 25'N, 56° 30'W, which has been offset to the north by fracture zones.

Without further data it is impossible to determine if this basement high represents magma discharged from a mantle plume as suggested by Vogt, (1972). Further surveys would be needed to trace the basement highs which

according to his hypothesis should form a V-shaped ridge with the limbs pointing toward Cape Dyer and Disko Island. The authors favour a ridge-fracture zone explanation.

Sedimentary Basin

The sedimentary basin is well depicted in pl. 1, profiles 2 and 3. It is seen to consist of approximately 1 km of horizontal reflective layers. These opaque layers are assumed to consist of turbidite sequences of sands and silts originating from the nearby land masses. Beneath these layers there is an angular unconformity with eastward dipping layers. Le Pichon et al. (1971) also noted that the deeper sedimentary layers near the continental margin of Greenland dipped toward the east. They explain this by a rapid subsidence of the margin during its early history with maximum subsidence at the continental margin and decreasing subsidence toward the continent and ocean basin. That the rifting history of continental margins involves first uplift followed by subsidence is fairly well established (Pautot et al. 1970; Sleep, 1970; Schneider & Johnson, 1970). The basin is seen to extend to a depth of 1.5 km and it is assumed that its depth may be much greater. Le Pichon et al. (1971) show an average of 2000 m of sediment on the western extremity of the basin. A dredge from the eastern end of profile 2 at 63° 34′N, 52° 57′W on the Greenland continental slope from a depth of 770–840 m recovered sedimentary rocks which yielded an Upper Cretaceous date (Johnson et al. 1972 a, 1973 b). This implies that this basin primarily consists of Mesozoic and Lower Tertiary sediments if it is assumed to be a down faulted portion of the original continental block. The unconformity may well date to a slow down in spreading rates at about 49 mybp, (Vogt et al. 1970) with a concomitant loss of heat. This would accelerate thermal contraction of the crust and perhaps open Davis Strait which in turn would accelerate the thermohaline circulation patterns. The Baffin Island and Disko Island basalts on either side of the Davis Strait also date at about 50–60 mybp and would appear to be related to the initiation of the second slower phase of spreading and possible ridge reorientation in the Labrador Sea (Le Pichon et al. 1971).

This basin with its angular unconformity and thick sedimentary sequence would seem to offer an excellent potential for petroleum reserves.

Acknowledgements. Thanks are due the officers and crew of the USNS LYNCH for their assistance on this survey. This research was partially supported by the Office of Naval Research, Task Number 307–329.

Dansk sammendrag

Seismiske reflektions profiler og ekkolodninger indsamlede under en ekspedition i det nordlige Labrador Hav viser tilstedeværelsen af et sedimentært bassin i den østlige del af undersøgelsesområdet. Bassinets struktur og morfologi beskrives. Lagmægtigheden i bassinet er mindst 1,5 km. I sedimentations-serien ses en vinkeldiskordans, hvor horisontale lag overlejrer østligt hældende lag. De indsamlede data antyder, at bassinet måske repræsenterer en nedforkastet del af den oprindelige grønlandske kontinentale blok. Øvre kretassiske sedimentære bjergarter optagne i den østlige ende af bassinet, i forbindelse med formodet nedforkastning, leder til den konklusion, at bassinets sedimenter hovedsagelig er af Mesozoisk og Nedre Tertiær alder. Tilstedeværelsen af vinkeldiskordansen kan muligvis forklares ved en hurtig indsynkning på et tidligt stadium af opbrydningen af den kontinentale margin. Dette bassin med sin vinkeldiskordans og betragtelige sedimentære serie synes at besidde et lovende potentiel for olie-resourcer.

References

Anonymous. 1971: 1971 N. O. Jean Charcot, Campagne Nordatlante. *Resultats des campagnes a' la mer,* No **01–1971.** 385 pp. Centre National pour l'exploitation des oceans, Paris.

Campsie, J., Rasmussen, M., Dittmer, F., Bailey, J. & Brooks, C. K. 1973: Bassalts from the southwestern Greenland continental margin. (In preparation).

Hezen, B. C., Tharp, M. & Ewing, M. 1959: The floors of the oceans, I: The North Atlantic. *Geol. Soc. of Amer. sp. Paper* **65,** 122 pp.

Johnson, G. L. & Eckhoff, O. B. 1966: Bathymetry of the North Greenland Sea. *Deep Sea Res.* **13,** 1161–1173.

Johnson, G. L. Closuit, A. W. & Pew, J. A. 1969: Geologic and geophysical observations in the northern Labrador Sea. *Arctic* **22,** 56–68.

Johnson, G. L., Campsie, J., Rasmussen, M. & Dittmer, F. 1972a: Mesozoic rocks from the Labrador Sea. *Nature phys. Sci., Lond.* **236,** 86–87.

Johnson, G. L., Egloff, J., Campsie, J., Rasmussen, M., Dittmer, F., & Freitag J., 1972b: Sediment Distribution and Crustal Structure of the Southern Labrador Sea. *Bull. geol. Soc. Denmark* **22,** 7–24.

Johnson, G. L., Campsie, J., Rasmussen, M. & Dittmer, F. 1973a: Paleozoic rocks from the Labrador Sea. (In preparation).

Johnson, G. L., Rasmussen, M., Campsie, J. & Dittmer, F. 1973b: Sedimentary dredge hauls from the Greenland continental margin. (In preparation).

Laughton, A. S. 1972: The southern Labrador Sea – a key to the Mesozoic and early Tertiary evolution of the north Atlantic. 1155–1179. *In* Laughton, A. S., Bergren, W. A., et al.: *Initial report of the deep sea drilling project, leg* **12,** Washington.

Le Pichon, X., Hyndman, R. D. & Pautot, G. 1971: Geophysical study of the opening of the Labrador Sea. *J. geophys. Res.* **76,** 4724–4743.

Pautot, G., Suzende, J. M. & Le Pichon, X. 1970: Continuous deep sea salt layer

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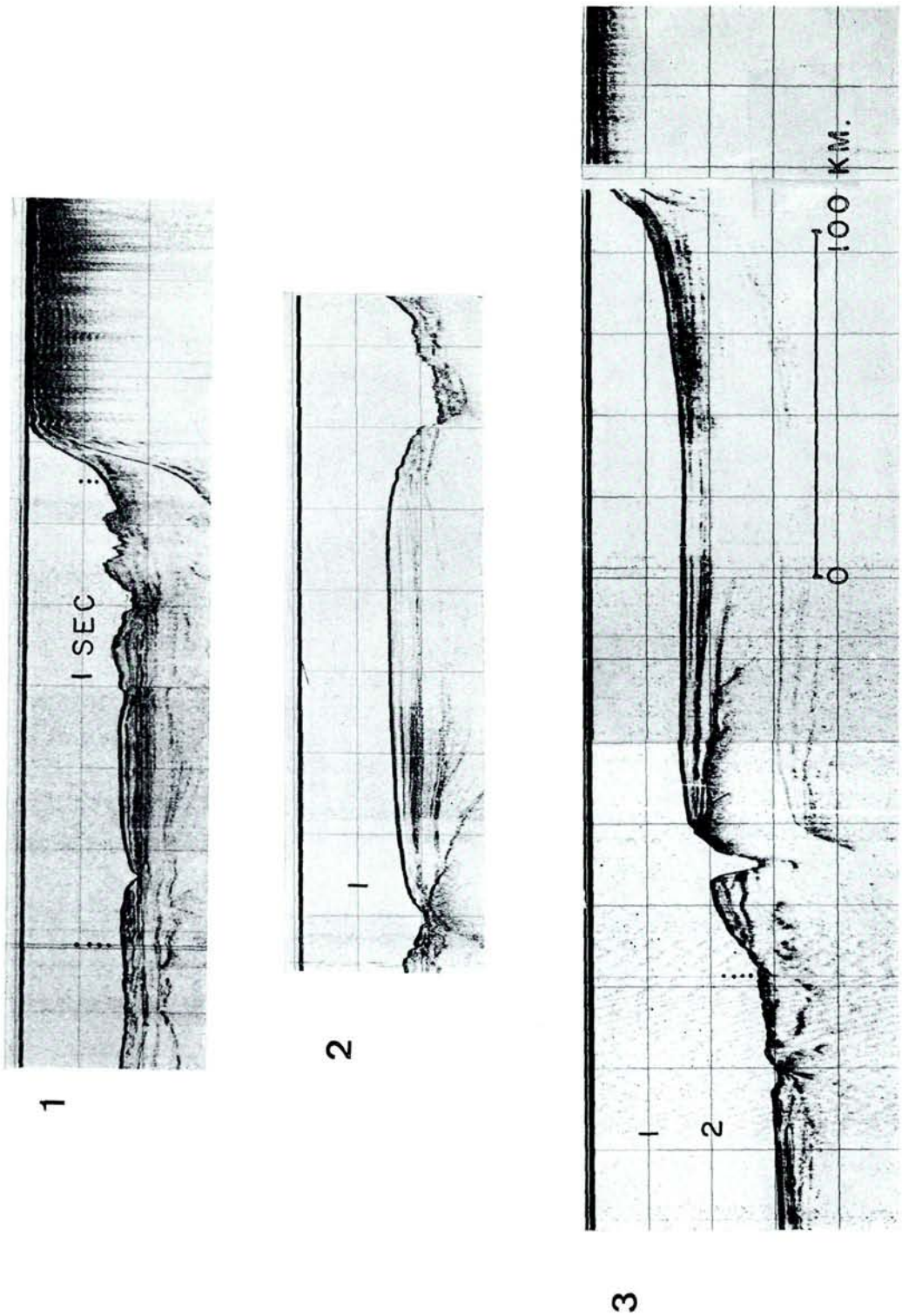
Plate 1. Three seismic reflection profiles across the sedimentary basin. One second of travel time is equal to approximately 1 km. West is to the left in all three profiles.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along North Atlantic margins related to early phase of rifting. *Nature, Lond.* **227,** 351–354.

Rasmussen, M., Campsie, J., Dittmer, F. & Bailey, J. 1973: Basalts from the south-eastern Greenland continental margin. (In preparation).

Schneider, E. D. & Johnson, G. L. 1970: Deep-ocean diapiric occurences. *Bull. Amer. Assoc. Petrol. Geol.* **54,** 2151–2169.

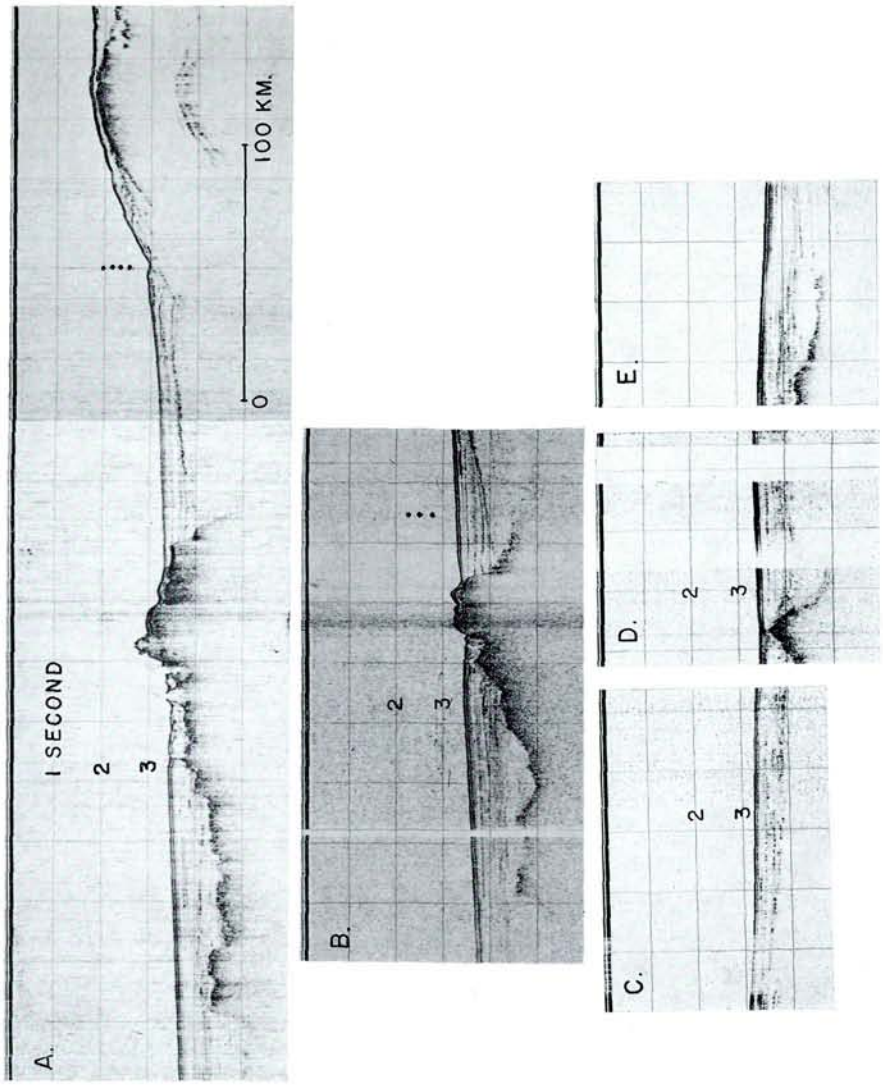
Sleep, N. H. 1970: Thermal effects of the formation of the Atlantic continental margins by continental break-up. *Trans. Amer. geophys. Un.* **51,** 429 only.

Vogt, P. R., Ostenso, N. A. & Johnson, G. L. 1970: Magnetic and bathymetric data bearing on sea floor spreading north of Iceland. *J. geophys. Res.* **75,** 903–920.

Vogt, P. R. 1971: Asthenosphere motion recorded by the ocean floor south of Iceland. *Earth and planet. Sci. Letts.* **13,** 153–160.

Vogt, P. R. 1972: Comments on "Geophysical Study of the Opening of the Labrador Sea" by X. Le Pichon, R. D. Hyndman & G. Pautot. *J. geophys. Res.* (In press).

Plate 2. Seismic reflection profiles across a basement high in the northern Labrador Sea. One second of travel time is equal to approximately 1 km. Profiles are oriented so that north is to the right in profiles A and B; west to the left in profiles C–E.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