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The Continental Margin of West Spitsbergen*

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Abstract: Three main depositional sequences have been determined in the seismic records taken off West Spitsbergen:

(1) a Plio-Pleistocene sequence SPI-I with velocities of 1.7 to 2.8 km/sec;
(2) a Pliocene allochthonous sequence SPI-II with velocities of 2.4 to 2.8 km/sec underlying unconformity U 1;
(3) a pre-Middle Oligocene sequence SPI-III with velocities of 2.9 to 4.8 km/sec underlying a distinct unconformity (U 2) and deposited in front of the downfaulted Spitsbergen Platform indicating some opening of the Greenland Sea already before the time of magnetic anomaly 13 (36 m. y. b. p.).

A marked change in the seismic configuration of the oceanic basement has been observed about 30 to 40 km east of the central Knipovich graben. The transition from the oceanic crust of the Knipovich Ridge to the strongly faulted, continental substratum of the Spitsbergen Platform occurs over a narrow zone and is associated with a pre-Middle Oligocene depocenter.

Zusammenfassung: In den seismischen Registrierungen vor Westspitzbergen sind drei sedimentäre Hauptsequenzen festgestellt worden:

(1) Eine plio-pleistozäne Sequenz SPI-I mit Geschwindigkeiten von 1.7 bis 2.8 km/s;
(2) eine pliozäne, allochthone Sequenz SPI-II mit Geschwindigkeiten von 2.4 bis 2.8 km/s, deren obere Begrenzung die Unkonformität U 1 bildet;
(3) eine prä-mitteloligozäne Sequenz SPI-III mit Geschwindigkeiten von 2.9 bis 4.8 km/s, die unter einer markanten Unkonformität (U 2) liegt und die vor der Spitzbergen Plattform abgelagert worden ist, welche entlang von Störungen abgesunken ist. Daraus wird geschlossen, daß schon vor der Zeit der magnetischen Anomalie 13 (36 Millionen Jahre vor heute) eine Öffnung der Grönländischen See stattgefunden hat.

Etwa 30 bis 40 km östlich des Knipovich-Grabens ist eine deutliche Änderung in der seismischen Konfiguration des ozeanischen Basements beobachtet worden. Der Übergang von der ozeanischen Kruste des Knipovich-Rückens zum stark gestörten kontinentalen Substratum der Spitzbergen Plattform ist auf eine schmale Zone begrenzt, die mit einem prä-mitteloligozänen Sedimentationszentrum assoziiert ist.

1. INTRODUCTION

The geophysical investigation of the offshore area west of Spitsbergen and the adjacent Boreas Sea started a decade ago with the Vema cruises 23 and 27 (ELDHOLM & EWING, 1971) by the Lamont Doherty Geological Observatory, an airborne and shipborne magnetic survey (ÅM, 1973) by Norges Geologiske Undersøkelse & Norsk Polarinstitutt, and geophysical studies (RENARD & MALOD, 1974) during the Nestlante-II program. Additional geophysical data have been collected by Lamont Doherty Geological Observatory during Vema cruises 28 and 30, but very little data from these cruises have been published.

A reconnaissance survey was carried out in 1974 within the framework of the BGR program "Geoscientific studies in the North Atlantic". The areas covered were the continental margin of Spitsbergen, the Barents Sea (HINZ & SCHLÜTER, 1978) and the Norwegian continental margin (HINZ & WEBER, 1975). These studies were followed by reflection and refraction seismic surveys off West Spitsbergen with R/V Sverdrup by the Seismological Observatory, Bergen in 1975—1977 (SUNDVOR & ELDHOLM, 1976, 1977) and by a co-operative project of the Seismological Observatory, the Polish Academy of Science, the University of Hamburg, and the St. Louis University in 1976. During Leg 38 of the Deep Sea Drilling Project (DSDP) site 344 was drilled on the lower slope off Spitsbergen (TALWANI & UDINTSEV, 1976). Commercial geophysical surveys have been carried out on behalf of oil companies inside the fjords of the west coast of Spitsbergen, however, the data have not been released.

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This paper reviews the results from the BGR seismic survey (1974) and integrates these data with published data from the Vema cruises 23 and 27, Nestlante-II cruise, 1970 and Sverdrup cruises 1975/1976 (see Fig. 1). Representative portions of the reflection seismic data discussed in this paper are indicated by heavy lines in Fig. 1.

2. PHYSIOGRAPHY

The area considered here (Fig. 2) lies between West Spitsbergen's coast and the abyssal Boreas Basin between latitudes 76° N and 79° N.

The shelf, 55 km wide in the south and 35 km wide in the north, is crossed by several channels, the Isfjord, Bellsund and Hornsund. The continental slope lies between 400 m and 2000 m and is bordered on the west by the N-trending Knipovich Ridge. The width of the continental slope ranges from 125 km in the south (average slope 1°) to 45 km in the north (average slope 2—2.8°).

The N-S-running Knipovich Ridge (JOHNSON & ECKHOFF, 1966; GRØNLIE & TALWANI, 1978) consists of a series of topographic peaks and a narrow (13 km — 20 km wide) central depression zone, the Atka Graben (MALOD & MASCLE, 1975), with water depths more than 3200 m. East-trending shifts of the bathymetric contours at latitudes 76° 35'/40' N and 77° 30' N suggest the existence of transform faults in these areas. North of 78° 30' N the narrow central depression zone no longer exists.

The 5 km to 16 km wide, sometimes elongated, topographic highs rise above depths of 2000 m on the eastern flank and above depths of 1500 m on the western flank of the Knipovich Ridge. There is a NE-trending submarine ridge with two topographic peaks rising above 1500 m in the northwestern part of the surveyed area. This submarine ridge is next to the Hovgaard Fracture Zone (GRØNLIE & TALWANI, 1978). Water depths over the surveyed part of the Boreas Basin range from 2600 m to 3200 m.

3. GEOLOGICAL FRAMEWORK

On Spitsbergen which can be regarded as an uplifted part of the northern Barents Sea Shelf (NYSAETHER & SAEBØE, 1976), the Precambrian to early Paleozoic Hecla Hoek complex (Fig. 3) is covered by a series of Devonian to Tertiary marine and non-marine sediments (ORVIN, 1940) A north-south trending block faulting occurred in Late Devonian/Early Carboniferous (Spitsbergen Orogeny) mainly along the present west coast of Spitsbergen with vertical displacements of several thousand meters (NYSAETHER & SAEBØE, 1976) and major lateral movements (HARLAND et al., 1974). During the Carboniferous to Permian on central West Spitsbergen carbonate and sandstone strata were deposited alternating with evaporites and shales (Gipsdalen Group). The overlying Triassic sediments are separated from the Jurassic sequence, consisting mainly of black shales, by a major unconformity. Shallow marine to continental sediments predominate in the Lower Cretaceous of Spitsbergen and in the Barents Sea (NYSAETHER & SAEBØE, 1976).

Most of the older sediments were extensively eroded as a result of the epeirogenic uplift of Spitsbergen in the Upper Cretaceous. Therefore, Tertiary sediments onlap rocks of different age.

With the initial opening of the Norwegian-Greenland Sea at the time of magnetic anomaly 24 (TALWANI & ELDHOLM, 1977) — 56 m. y. ago after the revised magnetic time scale of LABRECQUE et al. (1977) — Spitsbergen subsided during the Paleocene

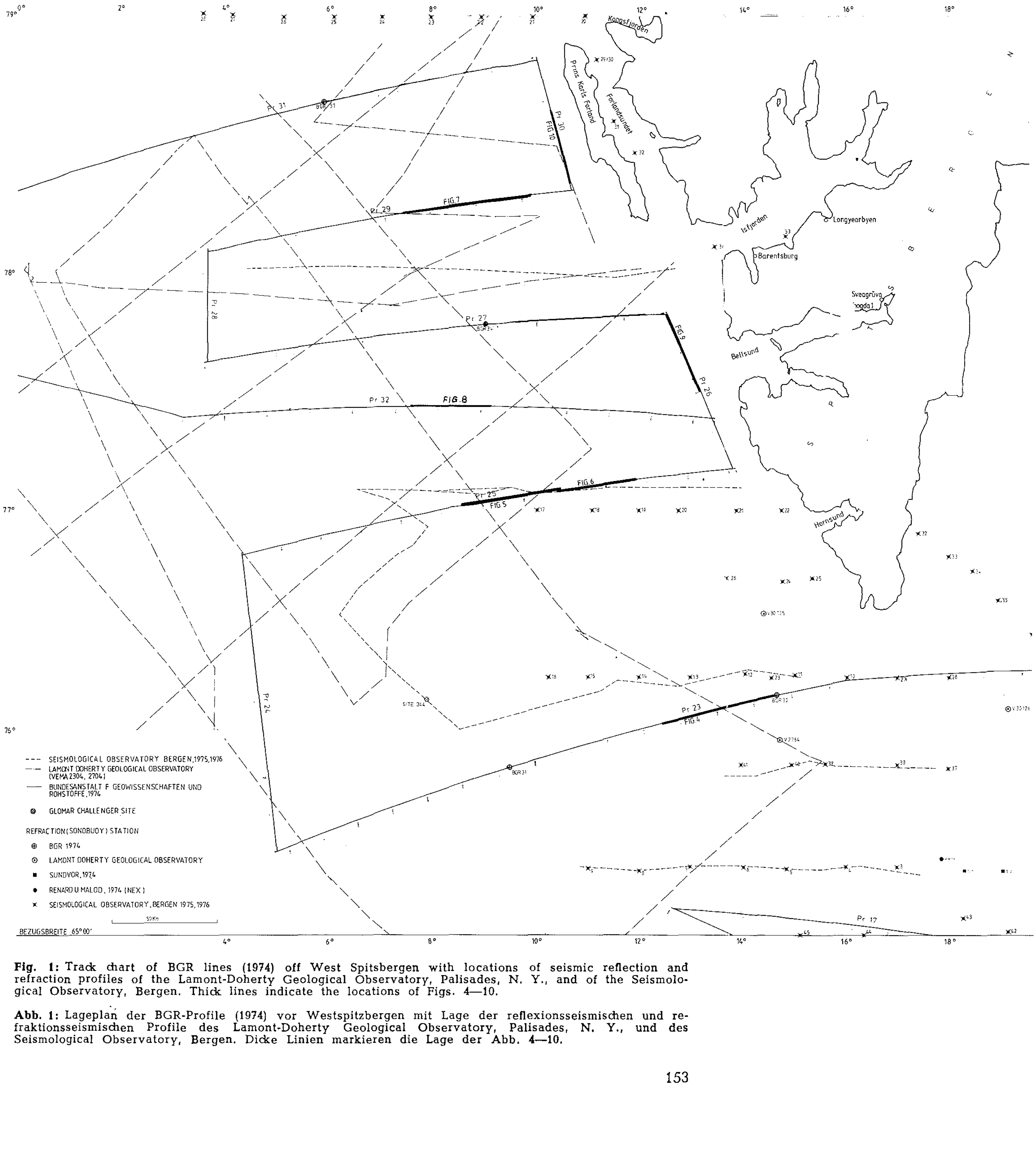

Fig. 1: Track chart of BGR lines (1974) off West Spitsbergen with locations of seismic reflection and refraction profiles of the Lamont-Doherty Geological Observatory, Palisades, N. Y., and of the Seismological Observatory, Bergen. Thick lines indicate the locations of Figs. 4—10.

Abb. 1: Lageplan der BGR-Profile (1974) vor Westspitzbergen mit Lage der reflexionsseismischen und refraktionsseismischen Profile des Lamont-Doherty Geological Observatory, Palisades, N. Y., und des Seismological Observatory, Bergen. Dicke Linien markieren die Lage der Abb. 4—10.

Fig. 2: Bathymetric map; contours are in meters using a nominal sound velocity of 1480 m/sec. Da sources: Lamont-Doherty Geological Observatory, Palisades, N. Y. (1966, 1969—70); Seismological Obs vatory, Bergen (1975—76); Federal Institute for Geosciences and Natural Resources (BGR), Hannov (1974).

Abb. 2: Bathymetrische Karte; Konturen in Meter, unter Verwendung einer Ausbreitungsgeschwindigk des Schalls im Wasser von 1480 m/s. Datenquellen: Lamont-Doherty Geological Observatory, Palisad N. Y. (1966, 1969—70); Seismological Observatory, Bergen (1975—76); Bundesanstalt für Geowissenschaft und Rohstoffe (BGR), Hannover (1974).

and Eocene, which is explained by a tensional stress (transtension) perpendicular to the transform-faulted Spitsbergen Fracture Zone (KELLOGG, 1975). Up to the Lower Oligocene, no major opening is assumed between the Greenland and the Spitsbergen/Barents Sea blocks, whose plate boundaries are thought to be represented by the Spitsbergen Fracture Zone (TALWANI & ELDHOLM, 1977). Greenland and Eurasia moved in opposite directions, northeast and southwest, along the Spitsbergen Fracture Zone (HORSFIELD & MATON, 1970; VOGT et al., 1970).

A renewed uplift with compressional stress along the western edge of Spitsbergen has been responsible since the Lower Oligocene not only for the deformation of the NNW-SSE striking Spitsbergen trough, but also for downfaulting and wrench faulting along southern Spitsbergen and folding in central Spitsbergen (KELLOGG, 1975). The continuation of the Tertiary fault pattern into the offshore area is suggested by HOLTEDAHL (1936) and the evidence for a large fault between the Bear Island and the Hornsund (Hornsund Fault) is described by SUNDVOR & ELDHOLM (1976). The Hornsund Fault separates low velocity rocks of the continental slope and outer shelf from high velocity rocks of the Spitsbergen Platform (SUNDVOR & ELDHOLM, 1976).

The origin of this compression in Lower Oligocene is related to a transpressional collision of northward-drifting Greenland against Spitsbergen (KELLOGG, 1975), probably caused by a change of the pole of rotation after the time of magnetic anomaly 13 (TALWANI & ELDHOLM, 1977), approximately 36 m. y. ago (LABRECQUE et al., 1977).

It is concluded that the separation of the Greenland and the Spitsbergen/Barents Sea blocks took place after the time of magnetic anomaly 13 associated with a continuous uplift of Spitsbergen since the Miocene. This uplift was accompanied by tension, forming the Forlandsundet graben. The complex slumping and sliding structures of the 2 km thick Tertiary infill of the Forlandsundet graben (ATKINSON, 1962) might have resulted from vertical movements since post Middle Oligocene time.

Below the continental slope off West Spitsbergen a prograding wedge with low velocity sediments has been described by MALOD & MASCLE (1975), SUNDVOR & ELDHOLM (1976) and TALWANI & ELDHOLM (1977). This wedge represents the continuation of the Tertiary wedge of the western Barents Sea (ELDHOLM & TALWANI, 1977 b; HINZ & SCHLÜTER, 1978). To the west this wedge is dammed up by the marginal basement highs of the Knipovich Ridge (ELDHOLM & WINDISCH, 1974; MALOD & MASCLE, 1975), which is interpreted as the continuation of the Mohns Ridge sea-floor spreading centre (JOHNSON & HEEZEN, 1967). It is assumed from magnetic and free air gravity anomalies (GRØNLIE & TALWANI, 1978) that the Knipovich Ridge represents the present sea-floor spreading centre of the Greenland Sea (JOHNSON, 1971). Considering the asymmetric position of the Knipovich Ridge within the Greenland Sea an eastward migration of the ridge axis is postulated (TALWANI & ELDHOLM, 1977; VOGT et al., 1978).

4. SEISMIC RESULTS

The survey was carried out with R. V. Longva, chartered from GECO, using a 48-trace digital seismic recording system (DFS IV) and a sonobuoy refraction seismic system. Two airgun arrays with a total capacity of 31 l were used as the seismic source. The positioning was done by an integrated Magnavox satellite navigation system.

A total of 2100 km of reflection seismic lines and 4 sonobuoy refraction profiles were recorded off Spitsbergen during the BGR survey.

Fig. 3: Structure map; the main geological features of Spitsbergen are taken from KORNFELD (1965).

Abb. 3: Strukturkarte; die wichtigsten geologischen Einheiten von Spitzbergen sind von KORNFELD (1965) übernommen worden.

Representative portions of the seismic records have been chosen for the following discussion of the reflection seismic results.

4. 1. *Depositional sequences*

Three depositional sequences are recognizable in our seismic records. The youngest sequence, SPI (Spitsbergen)-I (upper sedimentary series of MALOD & MASCLE, 1975) is beneath the outer shelf and slope characterized by slightly downsloping divergent to subparallel reflections showing high continuity and relatively narrow cycle width (Fig. 4). A distinct unconformity, U 1 (horizon "E" of SUNDVOR & ELDHOLM, 1976), marks the lower boundary of sequence SPI-I. The derived seismic velocities within this sequence vary from 1.7 km/sec to 2.8 km/sec.

In general, sequence SPI-I thins towards the west by downlapping (Fig. 5) and erosion (Fig. 7) or terminates against basement highs (Fig. 8).

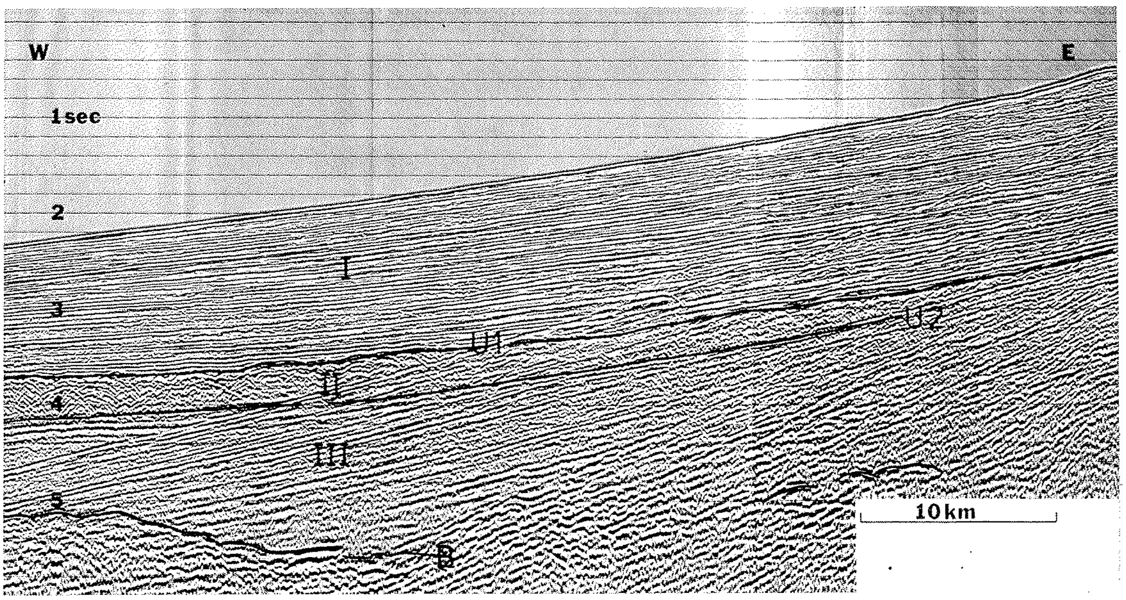

Fig. 4: Reflection seismic record (part of BGR-line 23) of the southern slope off West Spitsbergen. Roman numerals refer to sequences SPI—I to SPI—III; U1 and U2 = unconformities, B = top of oceanic basement.

Abb. 4: Reflexionsseismische Registrierung (Ausschnitt vom BGR-Profil 23) vom südlichen Kontinentalabhang vor Westspitzbergen. Römische Zahlen entsprechen den Sequenzen SPI—I bis SPI—III; U1 und U2 = Unkonformitäten, B = Top des ozeanischen Basements.

The sequence SPI-I beneath the inner shelf, which becomes thinner landwards, has a complex reflection pattern (Fig. 9) and is generally subject to considerable interference due to sea bottom multiples.

Within the area of the Knipovich Ridge, sequence SPI-I (locally contorted and faulted, and subdivided into an upper transparent and a lower stratified subunit) can be identified north of 78° N on our lines 29 and 31, whereas on lines 23, 25, 32 and 27 the central graben of the Knipovich Ridge is bare of sediments.

The thickness of sequence SPI-I is shown in Fig. 11 as reflection time interval between sea bottom and the unconformity U 1. Sequence SPI-I forms a prograding wedge beneath the present outer shelf and slope, up to 1.9 sec thick and thinning slightly to the north. On the inner shelf there is clear evidence for the existence of a N-trending, complex horst zone. East of this horst zone, sequence SPI-I exceeds 0.5 sec off Bellsund and Isfjorden and off Prins Karls Forland. Thicknesses of more than 1 sec have been observed in narrow depressions beneath the outer slope north of 78° N.

The unconformity U 1, gently dipping to the west separates the subparallel to divergent pattern of sequence SPI-I from the underlying chaotic sequence SPI-II, which is characterized by irregular and discontinuous reflectors and by diffractions (Figs. 4—7).

Since the upper boundary of sequence SPI-II, the unconformity U 1, is also hummocky, slump and related processes are thought to be responsible for its deposition.

In general, sequence SPI-II thickens seaward from about 0.1 sec (reflection time) at the outer shelf to about 0.5 sec beneath the lower slope and terminates against basement highs of the Knipovich Ridge. Therefore, it is not possible to unambiguously identify

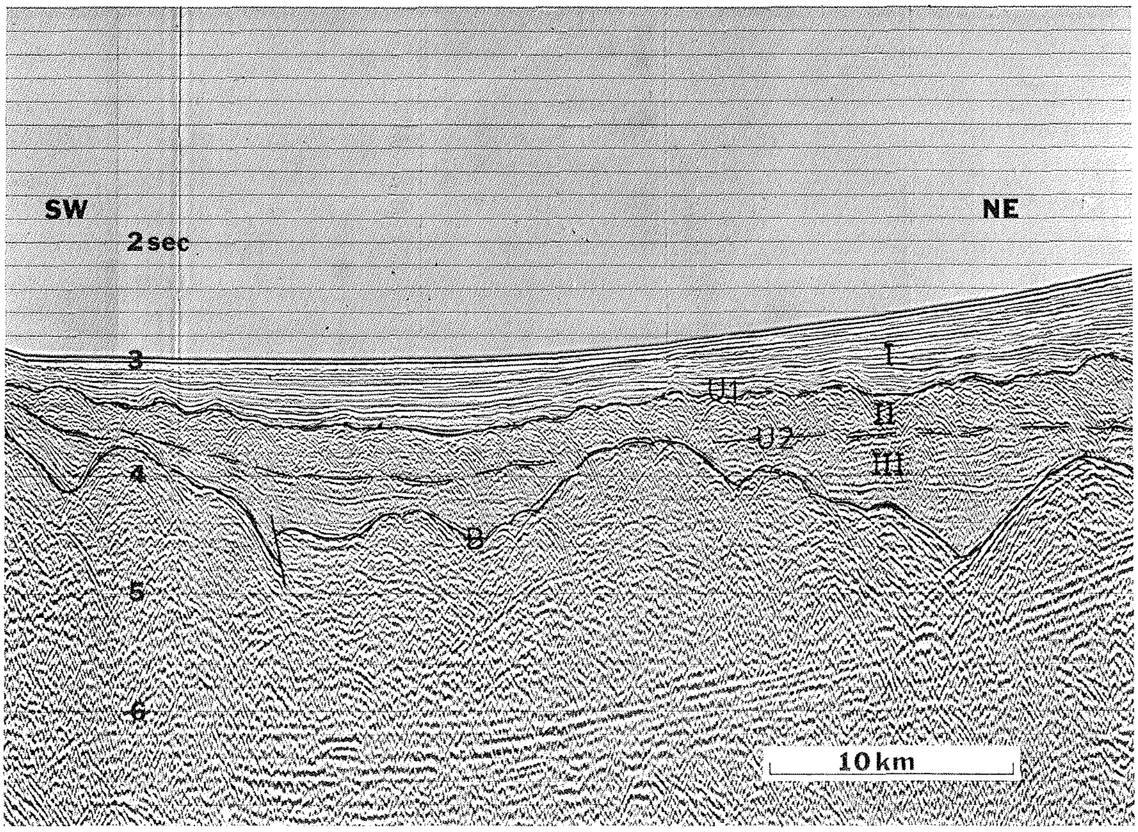

Fig. 5: Reflection seismic record (part of BGR-line 25) of the lower slope off West Spitsbergen. Roman numerals and letters as in Fig. 4.

Abb. 5: Reflexionsseismische Registrierung (Ausschnitt vom BGR-Profil 25) vom unteren Kontinentalabhang vor Westspitzbergen. Römische Zahlen und Buchstaben wie in Abb. 4.

sequence SPI-II in the sediment-bearing parts of the Knipovich Ridge. The thickness of sequence SPI-II is shown in Fig. 12 as reflection time isopachs.

The lower boundary of sequence SPI-II is marked by a strong reflection horizon, the unconformity U 2 (Figs. 4—6), dipping gently downslope. Seismic velocities of 2.4—2.8 km/sec have been derived from the stacking velocities for sequence SPI-II at the lower slope and velocities of 2.8—3.1 km/sec at the upper slope/outer shelf, suggesting lateral facies changes within this depositional sequence.

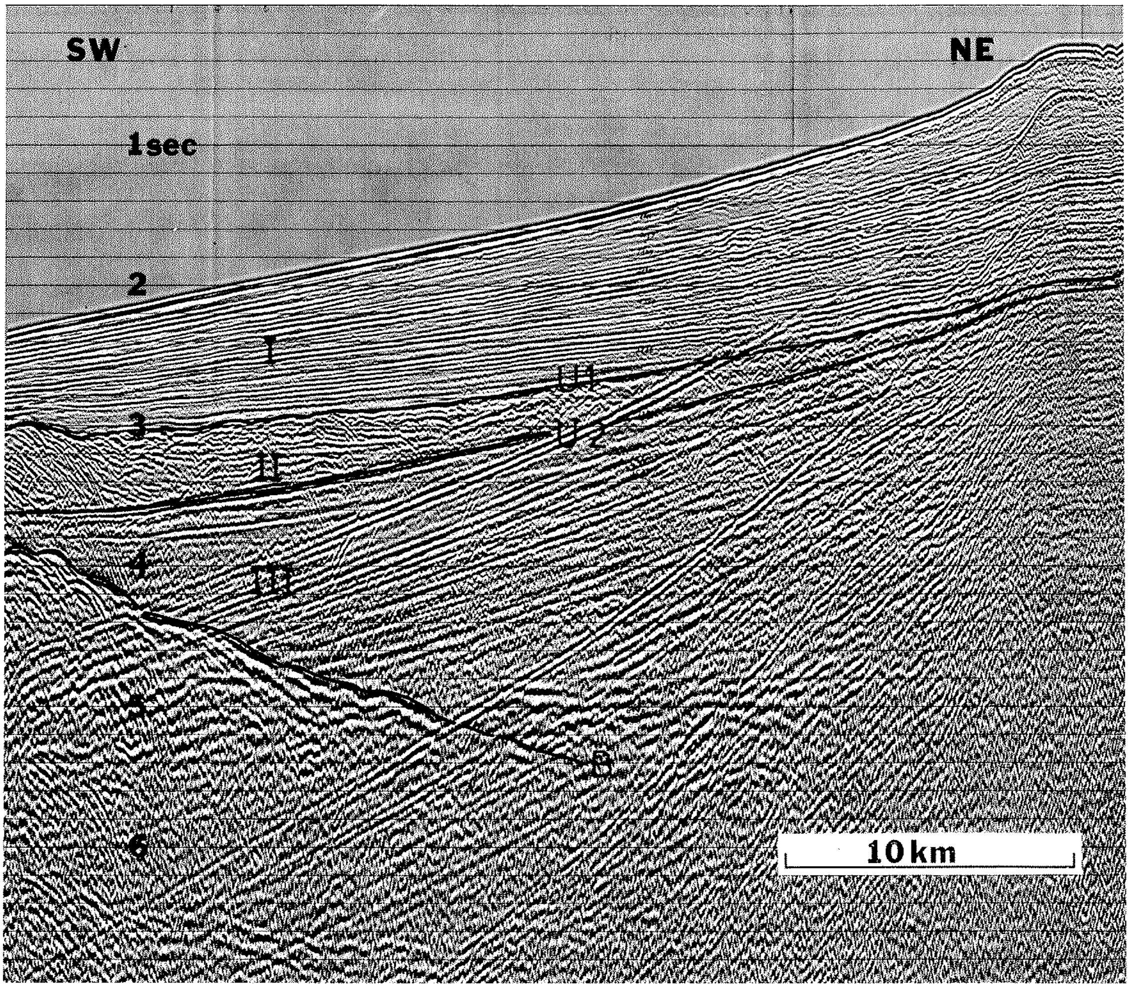

Fig. 6: Reflection seismic record (part of BGR-line 25) of the upper slope off West Spitsbergen. Roman numerals and letters as in Fig. 4.

Abb. 6: Reflexionsseismische Registrierung (Ausschnitt vom BGR-Profil 25) vom oberen Kontinentalhang vor Westspitzbergen. Römische Zahlen und Buchstaben wie in Abb. 4.

The internal seismic configuration of sequence SPI-III, underlying unconformity U 2 and overlying the acoustic basement (marker B), consists of subparallel, continuous, highamplitude reflection horizons beneath the lower slope and transparent units between these horizons (Fig. 5, 6), or as in the case of Fig. 7 (line BGR-29) of mainly discontinuous, subparallel reflectors, probably faulted. Below the upper slope and shelf, the internal seismic configuration is masked by multiples. Locally (Fig. 5, right side), the individual reflectors of sequence SPI-III toplap against unconformity U 2 indicating that unconformity U 2 is caused by erosion. Sequence SPI-III, more than 2 sec (reflection time) thick beneath the slope, thins towards the west mainly by successive termination against basement highs of the Knipovich Ridge (Figs. 5, 6).

Sonobuoy no.	Lat. (N)	Long. (E)	Water depth (sec refl. time)	v_1 h_1	v_2 h_2	v_3 h_3	v_4 h_4	v_5 h_5
30/74	76° 08, 59'	14° 19, 32'	0.43	1.85 0.38	2.10 0.29	2.35 0.36	2.55 0.36	2.70
31/74	75° 47, 14'	09° 28, 88'	3.20	2.10 0.64	2.70 0.89	3.70 0.52	6.10	
34/74	77° 46, 64'	08° 59, 83'	2.03	2.65 1.78	3.55 0.87	4.80 1.09	5.65	
37/74	78° 38, 25'	05° 52, 98'	3.22	2.80 2.13	3.50 0.45	4.50 0.69	5.40	

Tab. 1: Listing of BGR seismic refraction results. Velocity (v) in km/sec; Thickness (h) in km.

Tab. 1: Liste der refraktionsseismischen Ergebnisse der BGR. Geschwindigkeit (v) in km; Mächtigkeit (h) in km.

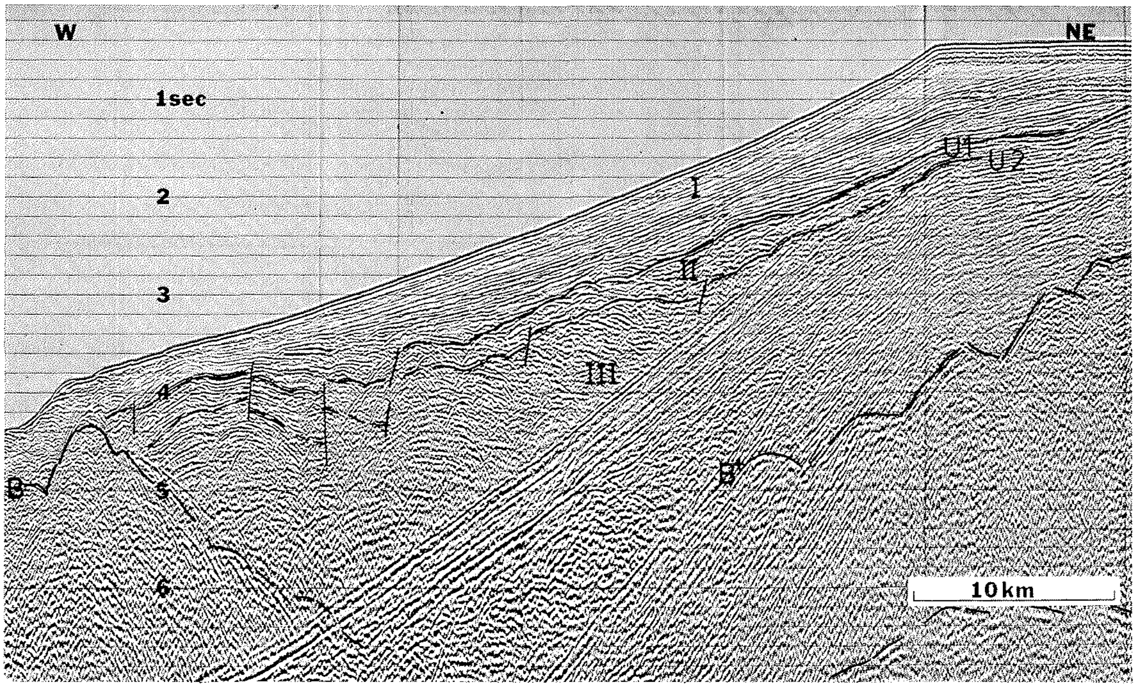

Fig. 7: Reflection seismic record (part of BGR-line 29) of the slope off central West Spitsbergen. Roman numerals and letters as in Fig. 4. B* = top of acoustic basement beneath the Spitsbergen Platform.

Abb. 7: Reflexionsseismische Registrierung (Ausschnitt vom BGR-Profil 29) vom Kontinentalhang vor dem zentralen Westspitzbergen. Römische Zahlen und Buchstaben wie in Abb. 4. B* = Top des akustischen Basements unter der Spitzbergen Plattform.

Seismic velocities of 2.9—3.8 km/sec have been derived from the stacking velocities for sequence SPI-III on the lower slope with velocities increasing with depth from 2.9 to 4.8 km/sec on the upper slope and outer shelf (see also Tab. 1).

4.2. *Age and interpretation of seismic sequences*

The results from DSDP site 344, located about 16 km east of the axis of the prominent rift of the Knipovich Ridge, suggest that sequence SPI-I consists of Pleistocene to Pliocene terrigenous muds, sandy muds and clays. The internal seismic configuration of sequence SPI-I is interpreted to represent mainly muds interbedded with turbidites and mass-transported sands being deposited during a changing glacial regime.

Our seismic data indicate pronounced changes in the sedimentation at unconformities U 1 and U 2, although the Shipboard Scientific Party states that the sediment cores from site 344 argue against such pronounced changes (Initial Reports of the Deep Sea Drilling Project 28: 400, 1976).

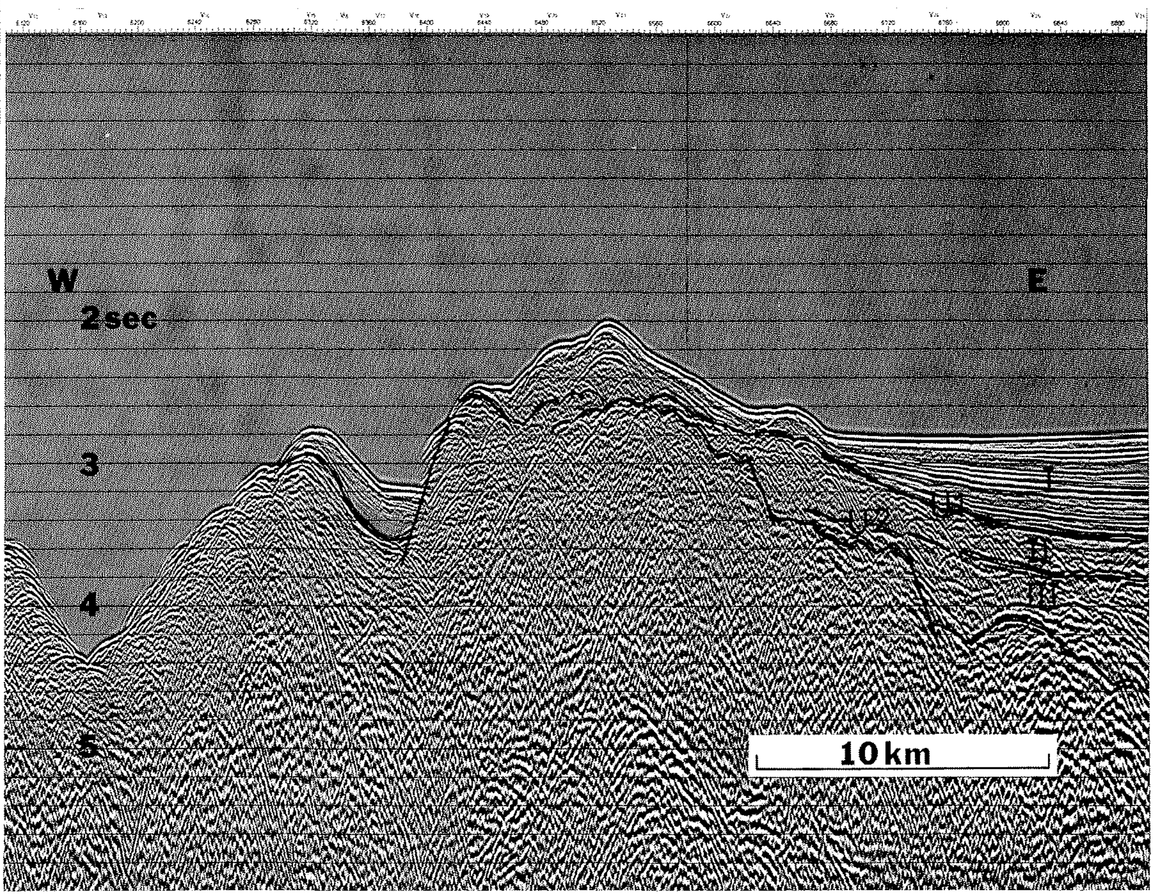

Fig. 8: Reflection seismic record (part of BGR-line 32) of the Knipovich Ridge area; the termination of sequences SPI—I and SPI—II against basement highs can be seen. Roman numerals and letters as in Fig. **4.**

Abb. 8: Reflexionsseismische Registrierung (Ausschnitt vom BGR-Profil 32) vom Knipovich-Rücken; erkennbar ist das Aufhören der Sequenzen SPI—I und SPI—II an Basementhochlagen. Römische Zahlen und Buchstaben wie in Abb. **4.**

Sequence SPI-II (with the exception of our northernmost line 31, clearly recognizable in all our records) is characterized by a chaotic internal reflection pattern, which is typical of (although by no means always confined to) slump masses. Since onshore geological evidence indicates a slight, continuous uplift of Spitsbergen since at least the Miocene (KELLOGG, 1975), associated with the formation of horsts and grabens such as the Forelandsundet graben (ATKINSON, 1962), sequence SPI-II is interpreted as an allochthonous wedge of gravity-driven masses triggered by the emergence of Spitsbergen.

A Pliocene age of the allochthonous sequence seems reasonable because the oldest sediments drilled at site 344 are of early Pliocene or Miocene age (Initial Reports of the Deep Sea Drilling Project 28, 1976). The distinct unconformity U 1, e. g. the upper

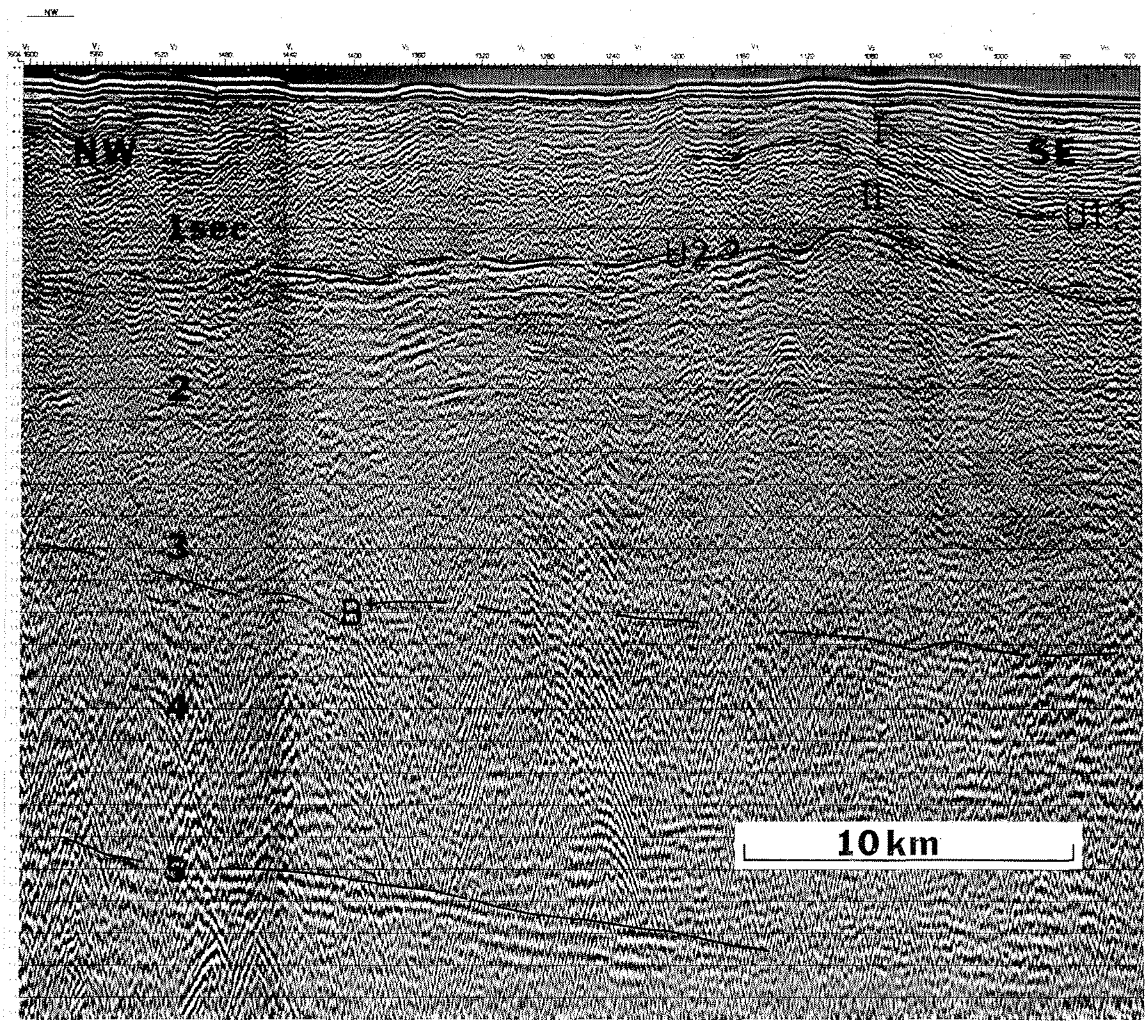

Fig. 9: Reflection seismic record (part of BGR-line 26) of the inner shelf off Spitsbergen between the Isfjorden (left side) and the Bellsund (right side). Roman numerals and letters as in Fig. 7.

Abb. 9: Reflexionsseismische Registrierung (Ausschnitt vom BGR-Profil 26) vom inneren Schelf von Spitzbergen zwischen dem Isfjorden (linke Seite) und dem Bellsund (rechte Seite). Römische Zahlen und Buchstaben wie in Abb. 7.

boundary of sequence SPI-II, cannot be related only to a global fall of relative sea level (VAIL & MITCHUM, 1977).

Due to evidence of downdipping downlap (Fig. 5, right side) and probably updipping onlap (Fig. 7, right side) the internal seismic configuration of sequence SPI-III, although locally disturbed by faults and intrusions and masked by multiples below the present upper slope, suggests a deposition in front of the downfaulted Spitsbergen Platform. Although the exact age and nature of the distinct erosional unconformity U 2, forming the upper boundary of sequence SPI-III, is unknown, a Lower to Middle Oligocene age seems reasonable because

i) during Lower Oligocene time a direct connection between the Arctic Ocean and the Norwegian-Greenland Sea was established along the Knipovich Ridge (SCHRADER et al., 1976), and

ii) unconformities of Lower/Middle Oligocene age, probably caused by the inflow of Arctic waters, have been determined on the Jan Mayen Ridge at DSDP/IPOD-sites 346, 349 and on the Vøring Plateau at DSDP-site 338, and

iii) a major unconformity of Middle Oligocene age (basal Middle Chattian), which is related to low, global, sea-level stands, has been determined in the North Atlantic (VAIL & MITCHUM, 1977).

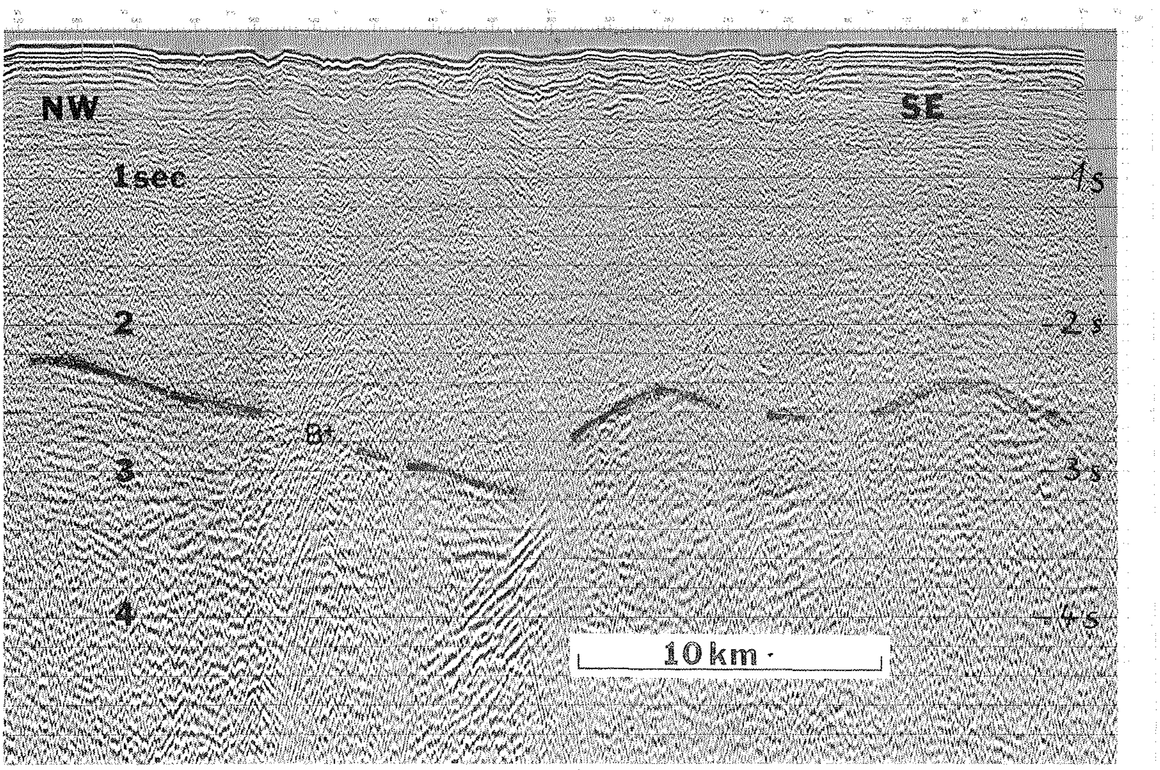

Fig. 10: Reflection seismic record (part of BGR-line 30) of the inner Spitsbergen shelf off Prins Karls Forland. Letter B' as in Fig. 7.

Abb. 10: Reflexionsseismische Registrierung (Ausschnitt vom BGR-Profil 30) vom inneren Schelf Spitzbergens, vor dem Prins Karls Forland. Buchstabe B' wie in Abb. 7.

Fig. 11: Map of reflection time intervals for sequence SPI—I between the seafloor and the unconformity U1 (horizon E of SUNDVOR & ELDHOLM, 1976).

Abb. 11: Karte der Laufzeitdifferenzen für Sequenz SPI—I zwischen dem Meeresboden und der Unkonformität U1 (Horizont E bei SUNDVOR & ELDHOLM, 1976).

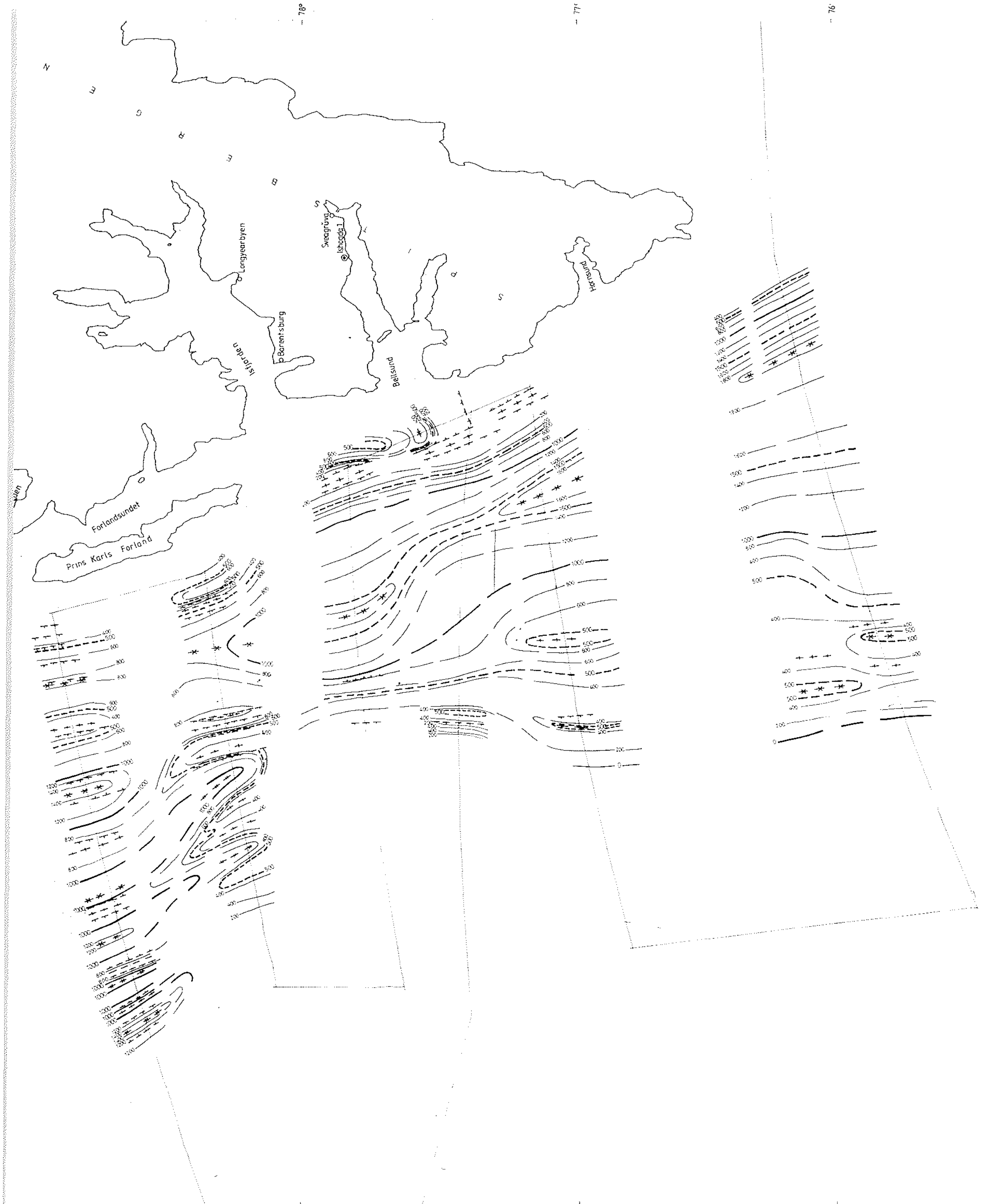

Fig. 12: Map of reflection time intervals for sequence SPI—II between the unconformity U1 and the unconformity U2.

Abb. 12: Karte der Laufzeitdifferenzen für Sequenz SPI—II zwischen der Unkonformität U1 und der Unkonformität U2.

Since firm dates of sedimentation rates and the age of the U 2-unconformity are not available, an estimation of the age of sequence SPI-III is speculative. Assuming an average velocity of 3.8 km/sec and a high sedimentation rate of 15 cm/10^3 y. and assuming the age of unconformity U 2 to be Middle Oligocene (29 m. y.), the deposition of sequence SPI-III started in front of the down-faulted Spitsbergen platform about 55 m. y. ago. From our interpretation, it follows that some opening of the Greenland Sea occurred already before the time of anomaly 13 (36 m. y.) and possibly already during Late Mesozoic (?)/Early Tertiary times.

The internal seismic configuration and the derived velocities ranging from 2.8 km/sec to 4.8 km/sec of sequence SPI-III is interpreted to represent a highly consolidated, interbedded succession of sandstones and shales, because seismic refraction measurements on exposed bedrock in the Isfjorden area of Spitsbergen established velocities of 4.5 to 4.9 km/sec for Tertiary sandstones and of 2.5 to 3.8 km/sec for Tertiary shales (GRØNLIE, 1978).

4. 3. *The acoustic basement*

There are at least two different types of acoustic basement in the surveyed area:
Within the Knipovich Ridge area, the acoustic basement is characterized by a relatively strong discontinuous top-reflector (marker B). There are often diffractions beneath this top reflection which has a rough and hummocky relief (Figs. 5 and 8). The flanks of the Knipovich Ridge are strongly faulted (Fig. 8).

Refraction seismic velocities of about 5 km/sec (SUNDVOR & ELDHOLM, 1976) and reflection seismic velocities ranging from 3.5 to 5.9 km/sec (this survey) have been determined for this acoustic basement type. Although no identifiable magnetic lineation pattern has been observed (TALWANI & UDINTSEV, 1976), the acoustic basement of the Knipovich Ridge is interpreted as oceanic crust. This is because the seismic configuration of the acoustic basement is similar to that of active ocean ridges and the rift valley of the active Mohns Ridge continues into the Knipovich Ridge associated here with a positive magnetic anomaly (TALWANI & UDINTSEV, 1976).

The top of the interpreted oceanic crust on the eastern flank of the Knipovich Ridge, as it approaches a depth of about 4.5—5 sec reflection time, becomes smooth (only locally disturbed by intrusions) and continually deepens landwards (Fig. 6). This marked change in the seismic configuration occurs about 30 to 40 km east of the Knipovich graben on our lines 23, 25, 27, 29, 32, reflecting a distinct change in the style of formation and/or composition and age of the oceanic crust. Since the depositional sequence SPI-III overlies the smooth oceanic basement, it follows from our interpretation that the smooth oceanic basement was formed in pre-Middle Oligocene time whereas the rough oceanic basement has a post-Middle Oligocene to Recent age.

There is a unit beneath the present shelf and upper slope, sometimes marked by a strong top-reflector (marker B*, Fig. 10) with deep-seated reflectors beneath it (Fig. 9) and characterized by velocities of 5.7 to 6.4 km/sec. This unit is interpreted as the substratum of the continental Spitsbergen Platform (GUTERCH et al., 1978) possibly consisting of the folded Caledonian Hecla-Hoek complex and/or of highly consolidated Paleozoic sediments.

Strong interference with sea-bottom multiples and intense block faulting makes it impossible at the present stage of investigation to correlate marker B* unequivocally. Our data suggest the existence of a mainly NNW-trending, very complex horst and graben zone beneath the central and inner part of the shelf, which fits the Hornsund fault (SUNDVOR & ELDHOLM, 1976).

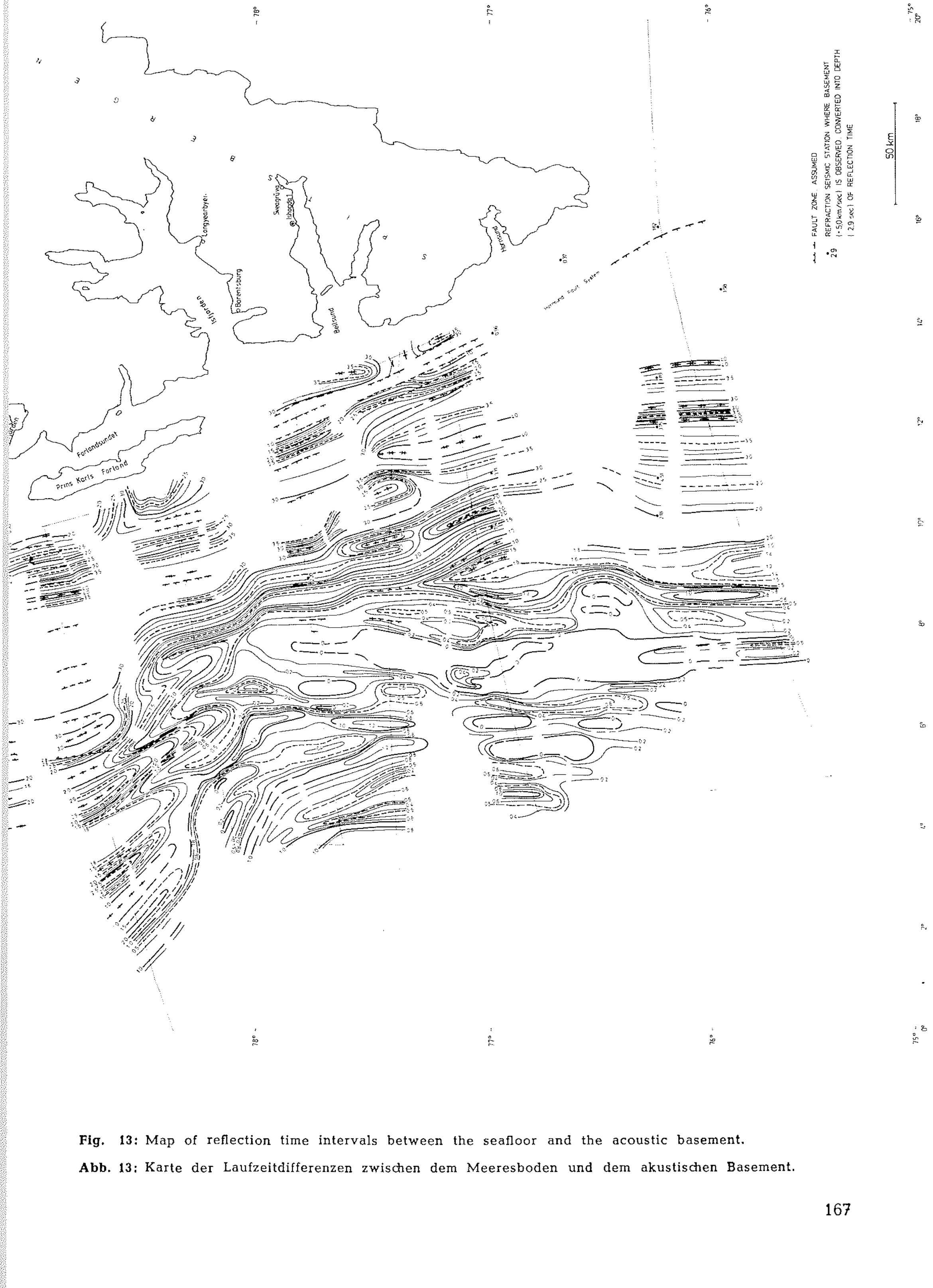

Fig. 13: Map of reflection time intervals between the seafloor and the acoustic basement.

Abb. 13: Karte der Laufzeitdifferenzen zwischen dem Meeresboden und dem akustischen Basement.

Marker B*, interpreted as the top of the substratum of the Spitsbergen Platform, deepens beneath the upper slope and outer shelf by downfaulting and disappears beneath the slope (Fig. 7). The transition from the smooth oceanic crust of the Knipovich Ridge (eastern limit indicated by small dotted line in Fig. 3) to the downfaulted substratum of the Spitsbergen Platform (western limit indicated by heavy dotted line in Fig. 3) occurs over a narrow 15 to 20 km wide zone and is associated with a pre-Middle Oligocene depocenter that is more than 2 sec (reflection time) thick.

The compiled results are presented in Figs. 3, 11, 12, 13. The striking features of the tentative structural map (Fig. 3) are the linear nature of the basement structure and the linear fault pattern. The available data also suggest the existence of transform faults, tentatively indicated in Fig. 3. Some of these faults seem to be related to established shear faults onshore West Spitsbergen (KELLOGG, 1975).

The map of total sediment thickness (Fig. 13) reflects subsidence and sedimentation on the continental margin of West Spitsbergen. The outstanding feature of this map is a more than 3 sec (reflection time) thick, elongated, prograding wedge beneath the present upper slope and outer shelf. This great thickness is due to the presence of sequence SPI-III, deposited in front of the downfaulted Spitsbergen Platform in pre-Middle Oligocene time.

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