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A preliminary seismic stratigraphic study of the Paleocene-Eocene section offshore southern West Greenland between 66° and 68° N

Thomas G. Ottesen

February 1991

GRØNLANDS GEOLOGISKE UNDERSØGELSE
The Geological Survey of Greenland
ØSTER VOLDGADE 10, 1350 KØBENHAVN K, DANMARK

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ISSN 0903-7322

GRØNLANDS GEOLOGISKE UNDERSØGELSE
Kalaallit Nunaanni Ujarassiortut Misissuisoqarfiat
GEOLOGICAL SURVEY OF GREENLAND

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ABSTRACT

Regional seismic stratigraphic interpretation of seismic data from the early 1970s has led to the identification of 17 Paleocene-Eocene seismic sequences. Interpretation of these in terms of relative changes of sea level showed a good correlation to the global sea level chart of Haq *et al*. (1987) for Lower Eocene sequences, indicating a tectonically calm period of thermal subsidence.

The Lower Eocene sequences exhibit alternately coast progradation and submarine channel and sheet sedimentation. The Paleocene and Middle-Late Eocene development was marked respectively by rifting and hinterland uplift. The Paleocene sequences probably consist predominantly of fairly marine sheet and channel deposits while the Middle-Upper Eocene sequences are of shallow marine or fluvially dominated sediments.

A tie to well Kangâmiut-1 showed the seismic stratigraphic subdivision to be more detailed than the lithostratigraphy of Rolle (1985). Within the Lower Eocene part of his shaly Ikermiut Formation there are several condensed sections not previously recognized. Sequences represented by condensed sections show coast progradation in more central parts of the study area where they are considered sand-prone. Thus potential Lower Tertiary reservoirs quite likely exist offshore West Greenland, contrary to what has previously been inferred from well data alone (Rolle, 1985).

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INTRODUCTION

In the early 1970s regional seismic surveys were carried out over much of offshore southern West Greenland. More detailed surveying followed in the mid-70's after the awarding of licenses in 1975. The drilling of 5 dry exploratory wells, all on prominent structural highs, coupled with uncertainty as to whether continued offshore activity could win political approval, led to subsequent abandonment of the area by the oil industry.

A characteristic feature of the sediments encountered in the five exploration wells is the lack of reservoir rocks in their deeper parts, where potential source rocks are present, and the lack of seals higher in the sequence, where porous sandstone occurs. The source potential identified so far is mainly for gas, but some oil potential has also been identified. Source rocks are largely immature in the drilled sections, but are expected to have reached maturity deeper in the basin (Rolle, 1985; Issler & Beaumont, 1987).

The realization of the ability of seismic stratigraphic methods to provide reliable and detailed information on the stratigraphy of sediments has created a renewed interest in the old seismic data. This report deals with the results of a seismic stratigraphic study of the Paleocene-Eocene sediments in the area between 66^{o} and 68^{o}N, offshore southern West Greenland (Figs 1A and 1B). Seventeen seismic sequences have been identified, mapped and interpreted geologically using the method described by Vail *et al.* (1977), Vail (1987) and Macurda (1986).

The study was supported by a grant from the Ministry of Energy, Mineral Resources Administration for Greenland, and should be considered provisional; more detailed and complete studies are presently being carried out by the Geological Survey of Greenland (Chalmers, 1989 and 1990).

DATA

Interpretation is based on the study of the northern part of the 1971 Burmah Group 24-fold CMP seismic data (Fig. 1B). The survey has a total length of slightly less than 2000 km and covers about 20 000 km^2. The grid is variable, 10-20 km by 20-30 km. Auxiliary lines have been used as tie lines and as ties to the wells Kangâmiut-1, Ikermiut-1 and Hellefisk-1. Among these are lines from Total's 1975 and 1977 surveys, Chevron's 1975 survey, plus ARCO's 1975 northern and southern surveys. The quality of the Burmah Group lines is fairly good in the central part of the area. In more marginal areas, especially to the south and west, the quality decreases, primarily due to strong multiple energy in the stacked data.

The well Kangâmiut-1 supplied information on lithology and age of the formations encountered. Interval velocity and TWT-depth information was provided by calibrated sonic logs. The use of other wireline logs was restricted to identification of the exact ties to the Kangâmiut-1 well. Tentative ties to the Hellefisk-1 and Ikermiut-1 wells were carried out in order to gather more information on velocity relations in the area. More reliable ties must await detailed structural analysis of the surrounding regions. In addition to being located in highly structured areas, the wells are all situated in the western margin of the basin, distally to the predominantly eastern source of sediment.

INTERPRETATION PRINCIPLES

Sequence and Facies Analysis

Seismic stratigraphic interpretation methods include the following steps:

1) Sequence analysis. Identification of depositional sequence boundaries representing unconformities (or their correlative conformities).
2) The tracing of these boundaries round the seismic grid.
3) Description and geological interpretation of the sequences.

The seismic stratigraphic method is based on the well-founded hypothesis that seismic reflectors most often represent isochron surfaces. This makes it possible to delineate the primary depositional patterns where post-depositional processes have not occurred to any considerable extent. The main tool in the interpretation is facies analysis - an objective description of the seismic appearance of the individual sequences in terms of the following parameters: geometric configuration of reflectors within the sequence, geometric relations of reflectors at sequence boundaries, reflection strength, continuity etc. Mapping the lateral distribution of the parameters enables interpretation of the depositional sequence in terms of depositional systems and systems tracts. From this the depositional environment may be inferred and a probable lithological distribution within the sequence proposed.

The seismic stratigraphic interpretation method is described in detail by Vail *et al.* (1977) and Vail (1987). The definition of the term seismic sequence has changed somewhat in the time between the two papers. The original version is adopted in this report. This means that sequences are bounded by downlap surfaces which are represented by condensed sections in the newer version of the theory as well as by sequence boundaries (Fig. 2). Using this technique, 17 sequences, sequences S1-S16, have been identified and mapped (Figs 4-20) within the Paleocene-Eocene interval in the studied area.

Correlation with the Vail Curves

Sequence boundaries are associated with changes in base level. On a continental shelf, base level is commonly controlled by the relative height of sea level. Changes in relative sea level are the outcome of changes in eustatic sea level, changes in sediment input rate, changes in rate of subsidence, and other tectonic processes. Interpretation of the succession of sequences and of the individual sequences in terms of systems and systems tracts (Macurda, 1986; Wagoner *et al.*, 1987) has enabled a correlation to the global sea level chart (Haq, Hardenbol & Vail, 1987) to be made. Although there has been some feedback to the geological interpretation, no correlation has been forced where none was evident. The degree of correlation may indicate the relative influence of local/regional tectonics and fluctuation in the eustatic sea level on the sedimentological development in the studied area. In addition, an independent means of dating sequences is offered where there is convincing correlation.

Well Ties and Depth Conversion

The velocities used for depth conversion were obtained from the information provided by the calibrated sonic logs of the wells, primarily Kangâmiut-1 and Hellefisk-1. Two-way-travel times (TWT) and depths of top and base of each sequence tied to the wells were used to calculate the interval velocities belonging to that sequence at that specific depth. Where only one or no interval velocity-TWT pair was obtained, the interval velocity was taken to be constant or to increase linearly with TWT. Where interval velocity-TWT pairs were obtained from both Hellefisk-1 and Kangâmiut-1, a linear relationship between interval velocity and TWT to the base or middle of the sequence was assumed. Where necessary, this linear segment was joined to another segment, thus forming a continuous piece-meal linear relationship in order to ensure reasonable conversion velocities at shallow and large depths. The velocity functions obtained are shown in Table 1, p. 10. Depth conversion was carried out by computer from the top down. First water depths were calculated at every digitized point, then conversion velocities and thicknesses of the section above the shallowest mapped horizon, Level C, were calculated. Thicknesses were added to water depths to obtain the depth to the top of the youngest seismic sequence treated in this study, sequence S16, and so on. After depth conversion the thickness of each seismic sequence was contoured and selected horizons considered important to the interpretation, Levels A, B, C and O, contoured in depth. The isopach maps are shown with seismic facies maps in Figs 4-20. An isobath map of the deepest mapped horizon, Level O, is shown in fig. 3; isobath maps of Levels A, B and C are not reproduced in the present report.

The interval velocities, thicknesses and depths of the sequences encountered in the well Kangâmiut-1 are shown in Table 2, p. 11 (cf. Fig. 2). Also shown are the values obtained when the depth conversion is fed back to the well. A detailed retie to Kangâmiut-1 using wire-line logs was carried out subsequent to depth conversion. This slight adjustment in the location of sequence boundaries in the well is the cause of the discrepancies between feedback values and the actual values of interval velocity, thickness and depth of sequences.

While the ties to Hellefisk-1 and Ikermiut-1 are considered rather unreliable, the detailed tie to Kangâmiut-1 is considered 'true'. This view is supported by a seismic sequence analysis of the area south of Kangâmiut-1, which has revealed the same Paleocene-Eocene sequence boundaries, with only a few exceptions (J.A. Chalmers, pers. comm. 1989). Only the "true" lithological information from Kangâmiut-1 is quoted and used in the description and interpretation of sequences tied to the wells.

TABLE 1

Velocity functions

Seawater	V = 1490 m/s	
Above Level C	V = (1588 + 577 x TB) m/s	
S16	V = (1707 + 692 x TB) m/s	
S15	V = (2000 + 559 x TB) m/s	
S14	V = (2000 + 571 x TB) m/s	
S13b & S13a	V = (2000 + 349 x TB) m/s	
S12	V = (2000 + 450 x TB) m/s	
S11	V = (2000 + 600 x TM) m/s,	TM<1.333s
	V = 2800 m/s	, TM>1.333s
S10 & S9	V = 2240 m/s	
S8	V = (2500 + 417 x TM) m/s,	TM<1.440s
	V = (4678-1096 x TM) m/s,	1.440<TM<2.343s
	V = 2100 m/s	, TM>2.343s
S7	V = (2500 + 277 x TM) m/s,	TM<1.625s
	V = 2950 m/s	TM>1.625s
S6	V = 2150 m/s	
S5	V = 2550 m/s	
S4	V = 2550 m/s	
S3	V = 2550 m/s	
S2	V = 2550 m/s	
S1	V = 2550 m/s	
Between Levels A & O	V = (2550+380 x TM) m/s,	TM<1.900s
	V = (4539-667 x TM) m/s,	1.900<TM<2.847s
	V = 2640 m/s	TM>2.847

TM is Two-Way-Travel time in seconds to the middle of the sequence/section;
TB is Two-Way-Travel time in seconds to the base of the sequence/section.

TABLE 2

Depth conversion feedback to well Kangâmiut-1

Horizon	Actual values: Interval velocity m/s	Actual values: Thickness m	Actual values: Depth m	Feedback values: Conversion velocity m/s	Feedback values: Thickness m	Feedback values: Depth m
Sea level			0			0
	1490	180		1490	180	
Sea bed			180			180
	2546	1777		2533	1768	
Top of S16			1957			1948
	2934	223		2946	224	
Top of S15			2180			2172
	3023	133		3050	134	
Top of S14			2313			2306
	3133	235		3158	237	
Top of S13a			2548			2543
	3250	65		2722	54	
Top of S9			2613			2597
	2533	152		2240	134	
Top of S8			2765			2731
	2125	170		2192	175	
Top of S6			2935			2906
	2164	158		2150	157	
Top of S5			3093			3063
	2449	142		2550	148	
Top of S4			3235			3211
	2636	427		2550	413	
Level A			3662			3624
	2889	26		2640	24	
Basement			3688			3648

Depths are below Mean Sea Level (MSL)

GEOLOGICAL OVERVIEW

Age of Basin and Sediments

Present knowledge about the offshore stratigraphy is based on interpretation of well-logs and lithological data from the five exploratory wells drilled offshore West Greenland (Rolle, 1985), conventional seismic interpretation, and onshore studies. The oldest sediments recognized are of Early Cretaceous age (pre-middle-Albian, Croxton, 1978) and occur in the Nûgssuaq-Disko region about 300 km north of the area studied in this work. The total thickness of Cretaceous-Early Tertiary sediments is estimated to be >2000 m (Henderson *et al.*, 1981). The sediments are overlain by a thick sequence of Paleocene-Eocene basalts (Koch, 1964; Hansen, 1980; Jürgensen & Mikkelsen, 1974). 300 km to the south-south-west the well Hellefisk-1 bottomed in 700 m of basalt without reaching the base of the pile. Radiometric dating and dating based on microfossils suggested a Paleocene age for these basalts (Hald & Larsen, 1987).

Two of the remaining four wells, Kangâmiut-1 and Nukik-1, bottomed in Precambrian basement, Kangâmiut-1 after having first penetrated a thin sequence of Campanian sediment. Nukik-2 bottomed in basalts probably of Paleocene age (Hald & Larsen, 1987) and Ikermiut-1 in Campanian shales (Toxwenius, 1986) without having reached Precambrian basement. The age of the oldest sediments offshore is thus unknown, though it is considered reasonable to assume that the offshore basin was formed at the same time as the onshore Nûgssuaq Embayment, that is in the Early Cretaceous.

According to Srivastava (1978) active sea floor spreading and formation of oceanic crust started in the southern Labrador Sea during Campanian time (anomaly 31) while Baffin Bay and Davis Strait started to open in very Early Eocene time (anomaly 24). Recently Roest & Srivastava (1989) have revised the earliest sea-floor spreading anomaly to 33. However, Chalmers (in review) presents seismic and magnetic evidence which strongly suggests that areas offshore southern West Greenland that were previously believed to be underlain by oceanic crust of anomaly 28-33 age, are in fact underlain by thinned and dyked continental crust. Regardless of when sea floor spreading began, the pre-drift phase of rifting could have created a sea-way resulting in marine environments in parts of the region.

A review of the West Greenland basin geology, onshore an offshore, is provided by Henderson *et al.* (1981).

Lithostratigraphic Subdivision

Rolle (1985) subdivided the offshore sedimentary sequence into seven Formations: Narssarmiut, Ikermiut, Nukik, Hellefisk, Kangâmiut, Manîtsoq and Ataneq Formations.

The Ikermiut Formation consists of marine organic-rich unconsolidated mudstone. The organic content decreases upwards where thin siltstones and sandstones occur. In the well Kangâmiut-1 the formation overlies the Campanian Narssarmiut Formation from which it is separated by a hiatus, while continuous sedimentation across the Cretaceous-Tertiary boundary may have taken place in the well Ikermiut-1 (Toxwenius, 1986). A formation thickness of more than 2000 m in the Ikermiut-1 well is considered to be a consequence of shale diapirism experienced in the region (Henderson *et al.*, 1981), though an element of compressive or transpressive tectonics may be present. Whatever the cause of the updoming of the formation, a subsequent major hiatus in the area around Ikermiut-1 is its consequence, as mentioned below. In the well Kangâmiut-1 the thickness is 1049 m.

The Nukik Formation consists of rapidly alternating fairly thin beds of unconsolidated sand and mud interpreted by Rolle (1985) to be turbiditic. Its thickness is 286 m in the Nukik-2 well and only 65 m in the well Kangâmiut-1.

The Hellefisk Formation is the northern equivalent of the Ikermiut and Nukik formations and comprises shallow marine to paralic sandstone and mudstone.

The lithology of the Kangâmiut Formation is very varied, but the bulk of the sediment is clean shelf to muddier shallow marine sandstones. The thickness is 1005 m in the well Kangâmiut-1. In the Ikermiut-1 well the formation is separated from the underlying Ikermiut Formation by a hiatus comprising the greater part of the Middle and Late Eocene.

The Manîtsoq and Ataneq Formations are both younger than the interval described in this report, and hence will not receive further attention here.

INTERPRETATION

The main result of the present study is the geological interpretation of individual seismic sequences and the succession of sequences in terms of depositional systems and predicted lithology distribution within the sequences. Consequently this aspect is given the greater weight in the following section. Firstly, though, the main structural and stratigraphic features of the study area are presented. Results obtained through well ties, correlation to the global sea level chart of Haq *et al*. (1987), and through combinations of observations, are treated in separate sections, followed finally by a somewhat speculative section in which an attempted correlation to the regional tectonic development of the Labrator Sea - Davis Strait - Baffin Bay area is described.

"Basement" and Structures

Level 0 referred to in the following is the deepest, regionally mapped seismic event. Though it represents Precambrian basement in the well Kangâmiut-1, this is probably not the case generally. As can be seen on Figs 21-24, reflections from below Level 0 are common. Volcanics are possible, perhaps even covering older sediments. For practical purposes, however, Level 0 acts as a basement equivalent in the present study.

The following important and conspicuous features surround the area studied (letters in brackets refer to the areas outlined in Fig. 3):

(a) A high that remained topographically positive during deposition of large quantities of Paleocene and pre-Paleocene sediments is located in the south-east (Fig. 21). Prograding volcanics are apparently indicated by the reflection patterns and the NMO-velocities, although diffractions associated with faults are likely to make up a great part of the pattern.

(b) Centrally to the north, basement is upfaulted to close below the sea bed. Upfaulting took place contemporaneously with deposition of Upper Paleocene and Eocene sediments.

(c) The Kangâmiut Ridge is situated in the south-west. It is a N-S striking basement horst bounding the oldest sediments and draped by the younger. The well Kangâmiut-1, drilled on the western flank of the ridge, encountered deeply weathered gneissic basement at a depth of approx. 3700 m. Immediately to the east of the ridge, Level 0 is 5500 metres or more below sea level. To its west a deep trough (> 7 km) exists.

(d) To the north-west a N-S-striking fault-zone predominates. Basement is upfaulted to the west. Primary faulting affects the whole Paleocene (and pre-Paleocene) section strongly, while the Eocene sediments are affected to a lesser degree by smaller-scale faulting. The well Hellefisk-1 was drilled on a high in this area and encountered almost 700 m of Paleocene basalts without reaching their base.

(e) Depth to Level 0 in the north-east changes rapidly due to the existence of horst and graben structures. Although depths are typically 3000 m, the existence of rather deeper sub-basins is indicated. Intrusions at various levels render the identification of Level 0 difficult.

(f) Between areas (d) and (e) - and on strike with them - is situated an area of complex domal structure. The well Ikermiut-1 was drilled on this domal structure and encountered more than 2000 metres of shale and clay without reaching the base. The structures are generally interpreted as shale diapirs (Henderson *et al.*, 1981), though an element of compression (or transpression) should not be excluded. Level 0 has not been identified in this area, so it is not clear to what extent basement tectonics is involved. It is however noted that the "Ikermiut" structure is situated where two fault trends intersect.

In the structurally undisturbed central area, Level 0 dips westwards to south-westwards at 2.0°.

Gross Stratigraphy

An immediately conspicuous feature is the general westwards dip of reflectors/bedding planes and the distinct erosional truncation that has taken place at a level close below and parallel to the present sea bed (Fig. 22). The erosional event is generally considered to be connected to the Pleistocene glaciation (Henderson *et al.*, 1981), a view adopted here. The westwards dip (with a smaller southwards component) is a consequence of differential shelf subsidence and/or hinterland uplift.

In addition to Level 0, three levels (Figs 2, 21-24) considered important to the overall sedimentological development of the area, have been contoured in depth (the maps are not shown). They are:

(A) Top of the lower uninterpreted section. Depths range from less than 500 m in the extreme east to more than 4000 m in the central western part of the area. A 'representative' dip value is 2.1^{o}.

(B) The boundary between sequences S6 and S7. Depths range from less than 500 m to 3000 m in the south-west. Dip value is 1.9^{o}.

(C) Top of the interpreted section, i.e. the top of sequence S16. Depths range from less than 500 m to 2000 m in the south-west. Dip value is 1.5^{o}.

Dip values were calculated in the central area approximately along line BG-18, which is considered far enough away from the structural features mentioned in the foregoing section to be representative of the regional stratigraphic dip. As the westwards to south-westwards dip of Level O is 2.0^{o}, Levels A, B and O are seen to be mutually parallel while Level C dips slightly less. Thus subsidence until Level B time (approx. Paleocene-Eocene boundary) seems to have been rather uniform. Onset of differential subsidence/hinterland uplift possibly occurred prior to Level C time, that is during the Eocene. The shallower dip of Level C and Levels A, B and O being parallel, however, should not be considered conclusive evidence, as the effect of differential compaction has not been taken into account.

Though Level A in the well Kangâmiut-1 separates Campanian and Paleocene sediments and represents a hiatus comprising at least the Maastrichtian, it is considered premature to positively identify Level A as the Cretaceous-Tertiary boundary. The 1000-1500 metres of uninterpreted section between Levels A and O (Figs 21-24) may comprise Lower Paleocene sediments elsewhere in the area. While this section is thin or absent over the south-eastern and Kangâmiut highs, thicknesses are likely to be considerably larger to the north-east, where deep sub-basins are possibly present. The seismic expression of the section changes from a relatively transparent and presumably homogeneous lower part to a more stratified upper part showing strong southwards progradation in the north-eastern part of the area. Level A may be equivalent to the Labrador Shelf Bylot unconformity of McWhae *et al.* (1980).

The section between Levels A and B comprises the sequences S1-S6, which are treated in the next section. The widespread occurrence of strong parallel reflections in the central area clearly distinguishes this section from the overlying and underlying sections. In the south-west strong reflections with complex configurations flank the south-eastern high. The thickness of the (Upper?) Paleocene section is typically 1000 m. Thinning towards the east is in part due to onlap onto the south-east high and in part to the erosional truncation (Pleistocene glacial; Henderson *et al.*, 1981). Thicknesses up to 1600 metres or more are reached within the dome structures in the west. The sequences S1-S6 of this section are less well understood than those above, partly due to data quality, but also due to the erosional truncation of the landwards (eastern) part of the sequences and to the presumed occurrence of volcanics within sequences S4-S6.

The section between Levels B and C comprises the Eocene sequences S7-S16, treated in the next section. The mixed appearance of aggradation and progradation is clearly different from the underlying section. Thickness decreases away from a central maximum of more than 1600 metres, eastwards thinning being partly due to erosional truncation (Pleistocene glacial; Henderson *et al.*, 1981).

The uninterpreted post-Eocene section above Level C shows a monotonous increase in thickness from <100 m in the east to more than 2000 m (including water layer) in the southwestern corner. Fluviatile and shallow marine shelf sedimentation is indicated by well information. Westwards progradation appears to be common.

Description and Interpretation of Sequences

Starting with the earliest sequence S1, each identified sequence will be discussed separately. The extent of interpretation is highly dependent on the data quality at the relevant depths. Sequences S7-S16 are all interpreted in terms of depositional systems/systems tracts and predicted lithology, while the interpretation of sequences S1-S6 is less detailed, due partly to the presumed occurrence of volcanics and to the lack of information on the eastern part of the sequences (Pleistocene glacial erosional truncation (Henderson *et al.*, 1981)). Figures referred to in the following are facies- and isopach maps of the individual sequences (Figs 4-20) and parts of seismic sections (Figs 21-24). The detail in the maps is limited to that needed to support the interpretation. Based on original, objective and detailed description and mapping of the seismic parameters: reflection configuration, relation at sequence boundaries, continuity and strength of reflections etc., the seismic facies have been grouped into separate areas of mutually different characteristic features. Isopach-contours do not show more details than are reliable considering the seismic line spacing. As a comprehensive structural analysis has not been carried out, faults are mapped only when they have a major influence on thicknesses, extent or development of the sequences. The legend to the maps is shown in Fig. 25. Although lithological data from the well Kangâmiut-1 is quoted, greater weight is given to the information represented by these maps when making the geological interpretation. Lithostratigraphy is from Rolle (1985); ages referred to are in part from Toxwenius (1986) and in part from correlation to the global sea level chart of Haq, Hardenbol & Vail (1987). On Fig. 2 correlations to the well Kangâmiut-1 and to the sea level chart are shown.

Sequence S1
(Figs 4 and 24)

Comments to map: Area (1): Onlap occurs in the eastern part of the area only. The sequence is not traced westwards from the fault zone and is generally poorly defined.
Well data: Is not present in Kangâmiut-1. Age is Paleocene.
Interpretation
Vertical aggradation is the main depositional process throughout the sequence. As the base of the sequence - at least in the well Kangâmiut-1 - marks a hiatus, resumed deposition indicates a rise in base level or an opening to a north-western basin. The extent of the sequence is to a high degree controlled by the northern high. Onlap onto and uplift with this high show that uplift took place both prior to and subsequent to deposition of S1. A reliable interpretation in terms of depositional systems and predicted lithology is not considered possible at present.

Sequence S2
(Figs 5 and 21-24)

Comments to map: Area (2): Configuration at right angles to the prograding clinoforms is mounded or subparallel.
Well data: Is not present in Kangâmiut-1, but forms part of the Ikermiut Formation in the Ikermiut-1 well: light to medium grey clay, interbedded with pyritic shale, locally very rich in organic matter. Age is Paleocene.
Interpretation
Thickness and facies information point to the central east-west striking area (2)-(3) as the key to understanding this sequence. It is interpreted as

a channel feeding sediment to the western part of the basin. The "mouth" is situated where western progradation takes place and thickness starts to increase. Laterally/distally to the north and south vertical aggradation is the primary process and thinning occurs. It is tempting to suggest submarine fan sedimentation, with infill of the channel (and eastwards onlap) occurring as a consequence of a rise in base level.

Predicted lithology: Though very shaly in the Ikermiut-1 well (shaliness exaggerated by diapirism?) coarser sediments are likely to occur more proximally in the system and farther east in the channel. Sediments were derived from the east, possibly in part from the exposed south-eastern high. The channel axis ran parallel, about E-W, to this high, which quite evidently was a strong controlling feature in S2-time. From a hydrocarbon point of view the potential occurrence of sand at depths where pyritic shales, rich in organic matter, are evidently present deserves further study. Present depth of burial ranges from >4000 metres in the shaly west to less than 1000 m in the (sandy?) east.

No correlation to changes in eustatic sea level is attempted due to presumed strong tectonic influence.

Sequence S3
(Figs 6 and 24)

Comments to maps: The sequence is not everywhere very well defined.

Well data: Is not present in Kangâmiut-1. Age is Paleocene.

Interpretation

Southwards progradation took place on the flanks of a spur of the northern uplifted high suggesting that this high had some influence on the development of the sequence. Sediments were presumably derived from the north-east and from this high, which probably existed as a positive topographic feature exerting control on the extent of the sequence. Thicknesses seem to indicate that the main part of the sequence is outside the studied area, where strong updoming has occurred and indications of primary deposition patterns may not have been preserved. If the sequence reaches the well Ikermiut-1 it forms part of the shaly and clayey Ikermiut Formation.

Sequence S4
(Figs 7 and 21-24)

Comments to map: Area (1): Hummocky clinoforms are present locally, mainly in the western part of the area. Area (2): The progradation is often associated with mounds. Area (3): Internal terminations, westwards onlap or downlap onto a well-defined level is observed. The boundary to area (4) is somewhat uncertain. The sequence has not been traced north-westwards beyond the fault zone.

Well data: In Kangâmiut-1 the thickness is 427 m. S4 forms the lower part of the Ikermiut Formation. Dark grey to brown shale and soft light brown silty clay. Presence of silty limestone streaks. Age is Late Paleocene. The sequence overlies Campanian sediments.

Interpretation

The thicknesses and eastwards downlap of area (3) are considered to be caused by updoming to the west and do not reflect primary depositional features. The sediments of area (3) (and part of the updoming) seem to predate those of area (2) judging from the westwards onlap and downlap. Area (3) constitutes the eastern part of the domal Ikermiut structure generally interpreted to be shale diapirs (Henderson *et al.*, 1981).

In area (1) vertical aggradation was the main process, onlap towards the east and south possibly indicates deposition during a rise in base level, probably caused by local or regional tectonics rather than eustatic changes in sea level. In area (2) progradation, commonly associated with mounds, and onlapped mounds indicate a higher energy regime, probably submarine channel deposition. Facies shifts from base to top reflect lateral migration of depositional systems. The complex configuration of area (4) is presumed to be caused by volcanics flanking the south-eastern high. Judging from their location the volcanics were probably associated with incipient faulting/fissuring of this high, which may have happened during S4-time. In addition, basement uplift in the north and faulting in the north-west were probably contemporaneous to the deposition of this sequence, though younger sequences are also affected. Thus the general impression is that the development of the sequence at least to some degree was controlled by local tectonics.

Predicted lithology: Marine shales and clays are probably widespread as is evident from well lithology, though coarser sediments are likely to occur associated with the presumed channelization. Well-lithology may, however, reflect rather distal conditions if the sediments were derived from the north-east, as considered highly probable. Thus coarser-grained sediments are expected to occur in area (1) (and in part area (2)).

No correlation to the eustatic sea level curve of Haq *et al.* (1987) is attempted due to presumed tectonic influence.

Sequence S5
(Figs 8 and 21-24)

Comments to map: Area (1): Truncation is by the late (Pleistocene glacial; Henderson *et al.*, 1981) erosional event. Area (1) is otherwise similar to area (2). Area (3): Rapid changes in seismic facies occur. Very local progradation is associated with mounds. Area (4): Downlap is associated with rapid thickening. Internal terminations of reflections are widespread. Area (6): Poorly defined boundary to area (5), internal terminations of reflections. The sequence has not been traced north-westwards beyond the fault zone.
Well data: In Kangâmiut-1 thickness is 142 m. S5 forms part of the Ikermiut Formation: dark grey to brown shale and soft light brown silty clay. Presence of silty limestone streaks. Age is Late Paleocene or very Early Eocene.
Interpretation
The highs continued to control the extent and geometry of the sequences in S5 time. Configurations diverging away from the northern high indicate uplift contemporaneous with deposition of S5. Area (5) is likely to continue northwards along the boundary between (3) and (4) reaching line BG-19 (Fig. 24). Volcanics are presumed to cause the strong reflections showing complex configurations and were probably to some degree related to faulting/fissuring of the south-eastern high. It is uncertain whether the sediments of area (6) belong to the same sequence as those of area (1)-(4). The tie across area (5) is based on boundaries between separate (presumed) volcanic episodes which do not necessarily coincide with the boundaries of the depositional sequence.

The subparallel configuration and high continuity of reflections of area (1) and (2) indicate that vertical aggradation in a rather low-energy regime was the main depositional process. Directions of downlap show a slight westwards and southwards development. The rapid facies change of area (3) suggests a higher energy regime; channels may be present. The eastwards downlap of area (4) does not reflect primary deposition patterns, but is due to the updoming shown by the rapid increase of thickness. The thickened part borders to the west on the Ikermiut structure (shale diapir; Henderson *et al.*, 1981). While thicknesses of area (5) reflect the presumed volcanics, rapid westwards thickening of area (6) is determined by pre-existing topography. Internal terminations may suggest that S5 actually comprises two or more sequences. Not shown on the map is the thinning onto the Kangâmiut High resulting in the thickness of 142 m in the well.

Predicted lithology: The easternmost part of the Ikermiut structure, area (4), is probably shaly, while the bordering region is expected to be enriched in coarser material if shale movement has occurred. The inferred higher energy regime of area (3) compared to (2) and (1) suggests a large degree of winnowing and presumably locally coarser sediments. Rather fine-grained marine sediments are however expected to form the bulk of the sequence.

No interpretation in terms of systems/system tracts and change in eustatic sea level has been attempted.

Sequence S6
(Figs 9 and 21-24)

Comments to map: Area (1): Truncation to the east is by the late erosional event (Pleistocene glacial; Henderson *et al.*, 1981). In the southern part of the area the sequence is considered too thin to allow detailed description. Area (2): Seems to underlie the deposits of area (1) and disappears onto the western "Ikermiut Structure". Area (3): It is not clear whether this area is related to area (2) or (1). Area (4): Seems to underlie the deposits of area (2).

Well data: In Kangâmiut-1 thickness is 158 m. S6 forms part of the Ikermiut Formation: grey to light brown, soft, montmorillonitic clay. Age is close to the Paleocene-Eocene boundary.

Interpretation

The complex configuration of area (2) is interpreted to be a consequence of widespread occurrence of volcanics as in the previous sequences. Volcanism seems to be related to fissuring of the south-eastern high and to local volcanic mounds (Fig. 24). The occurrence reached its maximum areal extent in this sequence and seems to have exerted topographic control on the sediments of area (1). Downlap and local progradation indicate southwards and westwards development in this area and the high continuity possibly reflects deposition in a marine low-energy regime, where only restricted circulation occurred. The westwards progradation in area (3) either reflects an opening to a wider basin or the northernmost extension of the volcanics. The sediments of area (4) may underlie the volcanics thus separated in time and origin from those representing the sequence in area (1).

Predicted lithology: The fairly marine origin indicated by the well lithology is probably representative for area (4) only. In area (1) the sediments are predicted to be of mixed grain size, possibly coarser grained in the eastern part.

Sequence 7
(Figs 10 and 22-24)

12 separate units are recognized in this sequence. Originally more have probably existed, prior to the truncation by the late erosional event (Pleistocene glaciation; Henderson *et al.*, 1981). These units have been shown by seismic facies mapping to be similar in appearance. A similar origin is thus inferred. A well developed unit has been chosen to represent them all in the facies description, while thicknesses are those of the whole sequence.

Comments to map: Area (1): It is unclear whether the unit terminates eastwards by onlap or continues below seismic resolution. Area (2): Configuration at right angles to the prograding clinoforms is mainly subparallel or mounded, but hummocky clinoforms are widespread. The unit thins westwards by downlap but possibly continues below seismic resolution. Isobath mapping of the top of the older sequence S6 (= Level B) shows a depression coinciding with the maximum thickness of S7. This depression is probably an artefact considered to be due to overestimated thicknesses and conversion velocities of sequence S7.

Well data: Is not present in Kangâmiut-1. Age is Early Eocene.

Interpretation

The episodic and highly progradational appearance plus the external lens-shaped geometry indicate sedimentation by a laterally shifting delta system. The migration of the system was towards the north-west. The direction of progradation within each individual unit was consistently south-westwards. Migration of the delta-system was probably dictated by the eastern fluviatile system. Indications of fluvial influence on the delta plain sediments of area (1) are rather scarce; local hummocky clinoforms are a possible candidate. Estimated rates of deposition are up to 1 metre per 1000 years even when the probable overestimation of thicknesses is taken into consideration.

Systems tracts and sea level: Delta progradation across the shelf is characteristic of Highstand (HS) Systems Tracts. The sequence ties to the Highstand of the 3rd order cycle of global sea level TA2.4 (Haq *et al.*, 1987).

Predicted lithology: Delta deposits are sand-prone in the channels and the proximal parts of the clinoforms. The fine-grained deposits of the delta plain are likely to provide seals for these potential reservoirs as lateral migration and progradation evidently have taken place. The delta plain sediments are potentially rich in organic matter as are the distal ones. Older source rocks in the Ikermiut-1 well, however, have been shown to be immature (Rolle, 1985). Present depth of burial reaches 2500 metres to the north-west; a typical value is 1500 metres.

Sequence S8
(Figs 11 and 21-24)

The sequence is made up by four separate units. The three upper units seem by their appearance to be of similar genetic origin, while the lowermost is poorly defined and not described in detail. (Note (B) below). This older unit constitutes the tie to the Kangâmiut-1 well. Thicknesses include all four units, while facies description is of the middle of the three upper units, representing all three.

Comments to map: Area (1): Truncated to the east by the late erosional event (Pleistocene glacial; Henderson *et al.*, 1981). Area (3): Progradation is associated with the well developed constructional mounds. The mounds of the northern part of area (2) are probably related to those of area (3). Hummocky clinoforms occur locally within the mounds.

Well data: In Kangâmiut-1 the thickness of the older unit is 170 m. It forms part of the Ikermiut Formation: grey to light brown, soft, montmorillonitic clay. Age is Early Eocene.

Interpretation (see also notes below)

Area (3), the constructional mounds and associated progradation, which coincide with the NNW-SSE striking thickness maximum, seem to be the key to understanding this sequence. As is the case for the previous sequence S7 and the following sequences, this strike direction probably parallels the palaeo-coast.

Progradation is inferred to be coastal, though it was not as well developed as in the younger progradational sequences. Direction of progradation appears equally to have been towards the west and towards the south. The areas of the two other upper units corresponding to area (3) show an overall westwards shift. The rather thick accumulation, (2) and (1), of apparently subparallel sediment indicates that considerable vertical aggradation occurred. The high continuity of reflectors probably indicates marine shelf and coastal plain sediments; a possible fluviatile influence, represented by hummocky clinoforms, is very limited. The locally shingled prograding configuration of area (4) is interpreted as progradation under shallow water conditions. Within this framework the mounded area is interpreted in terms of coast-parallel bars, although the exact nature is not clear because seismic data of adequate quality connecting the individual mounds are not available.

Systems tracts and sea level: Widespread occurrence on the shelf and the inferred coastal progradation indicate deposition during a relative highstand of sea level. A less rapid fall in sea level explains the diverging appearance (compared to highstand sequences S7, S11 and S13b): more pronounced vertical aggradation on the shelf, less pronounced progradation and the formation of coast parallel features. The sequence probably ties to the Shelf Margin Wedge (SMW) and Highstand (HS) systems tracts of the 3rd order cycles of global sea level TA 2.5 and TA 2.6 (Haq *et al.*, 1987). The downlapped upper boundary of the lowermost unit may tie to the condensed section of TA 2.5.

Predicted lithology: While the eastern aggraded sediments are probably of mixed grain size dependent on the actual depositional environment, the occurrence of clean sands is quite likely in the mounded area. Winnowing of the sediments is presumed to have been carried out by wave or tidal action. A seal is probably provided by area (2) sediments of the westwards shifted subsequent unit. The clayey lithology in Kangâmiut-1 is possibly representative of the lower unit only.

Note A: A hypothesis that the mounded configuration represents cross-sections of fan or channel deposits (channel axis striking NNW-SSE) associated with episodic submarine gravity flows has been abandoned. In that context, sediments of areas (1) and (2) would represent lateral sheet flows.

This, however, would require a palaeo-slope oriented NNW-SSE, at right angles to the palaeo-slope inferred from sequence S7 and the following sequences. An additional requirement is a base level high enough to allow uninhibited deposition by submarine sheet flows. Neither seems to be suggested by the seismic data.

Note B: Mounds and associated progradation seem to be the predominant feature of the lower unit. Poor data quality and a suspected occurrence of intrusions or extrusions marked by reflectors of complex configuration hamper a reliable interpretation. The rather marginal (basinwards) location suggests a lowstand or transgressive origin, sandwiched between S7 and the remaining units of S8.

Sequence S9
(Figs 12, 21 and 23)

Comments to map: The alternating facies distribution covers the whole sequence. Distinction between mounds and hummocky clinoforms is a matter of size only. Onlap onto underlying topography common.

Well data: In Kangâmiut-1 the thickness is 152 metres. S9 forms the upper part of the Ikermiut Formation: grey to light brown, soft, montmorillonitic clay. Age is Early Eocene.

Interpretation

Alternation between subparallel reflectors and hummocky clinoforms suggests a complex system of channel and inter-channel sedimentation. Frequently occurring onlap indicates that palaeo-topography probably was a controlling factor in association with a rather low base level. Prograding clinoforms show that the general direction of transport was southwards. It is not unlikely that (part of) the sediment was derived from the west.

Systems tracts and sea level: The basinwards location relative to the previous sequence S8 and the eastern onlap limit indicate a relative lowstand origin of the sequence. Since no extensive erosion seems to have occurred subsequent to deposition of sequence S8 the fall in sea level probably was fairly slow. Sequence S9 (with S10) ties to the Lowstand (and Transgressive?) Systems Tract of the 3rd order cycle of global sea level TA 2.7 (Haq *et al.*, 1987).

Predicted lithology: The clays of the Kangâmiut-1 well are probably quite widespread, though coarser sediment may occur in the (hummocky) channels, dependent on the nature of the sediment source area. Potential reservoirs are geometrically complex, but quite likely sealed.

Sequence S10
(Figs 13, 23 and 24)

Comments to map: Area (2): The distinction between mounds and hummocky clinoforms is a matter of size only. Mounds may show retrogradational development.
Well data: Is not present in Kangâmiut-1. Age is Early Eocene.
Interpretation
Though the pattern shown by the isopachs resembles fan deposits with a western source in the vicinity of line BG-20, thicknesses are probably controlled by trough formation associated with updoming and faulting in the west. The westwards prograding clinoforms showing an eastern source of sediment are probably rather local and mark the mouth(s) of channels feeding sediment into the area. While aggradation and sheet deposition was predominant in area (1), area (2) is similar to sequence S9: alternating channel and sheet-like interchannel deposits.
Systems tracts and sea level: The location basinwards of S8 and the eastwards onlap plus the close resemblance to sequence S9 indicate deposition during the same lowstand of sea level as S9 (and a tie to 3rd order cycle TA 2.7 (Haq *et al.*, 1987)). Retrogradational mounds may represent an incipient transgressive phase.
Predicted lithology: Coarse sediments are likely to be associated with the channels and retrogradational mounds. Coarsening-upwards sequences are expected in the prograding clinoforms. Finer grained sediments are predicted where the configuration is subparallel. If the clayey lithology of the Ikermiut Formation is representative of the sediment source area, the derived sediments are presumably clayey as well.

Sequence S11
(Figs 14 and 22-24)

Comments to map: Area (1): Truncation is by the late erosional event (Pleistocene glacial; Henderson *et al.*, 1981). Area (3): Facies-shift from base to top common in the southern part. Progradation occurs across hummocky clinoforms and retrogradational(?) mounds. Configuration perpendicular to the prograding clinoforms is mainly subparallel.

Well data: Not present in Kangâmiut-1. Age is Early Eocene.

Interpretation

Coastal progradation is considered the main process of deposition in area (3). There is some uncertainty as to whether delta systems are involved. There is no obvious signs of an episodic development as in the case of (delta) sequence S7, though the two thickness maxima are clearly of different character. The south-eastern maximum of area (2) shows that considerable vertical aggradation took place. The sediments of areas (2) and (1) are probably of nearshore or coastal plain origin. Area (4) represents the distal parts of the prograding system. Lobe formation could be suggested by the flat constructional mound of line BG-24.

Systems tracts and sea level: Subaerial exposure and erosion subsequent to distinct coastal progradation indicate that deposition took place during Highstand (HS) conditions. Possible retrogradational development in the south prior to progradation may represent a Transgressive (TR) Systems Tract. The sequence ties to one or more of the 3rd order cycles of global sea level TA 2.7, TA 2.8 and TA 2.9 (Haq *et al.*, 1987). The details of these cycles are not expected to be detectable by the seismic method.

Predicted lithology: Coarsening-upwards sequences are probably associated with the prograding clinoforms with finer grained deposits in the distal area (4). Lithofacies units in areas (1) and (2) are generally predicted to strike NW-SE, but the lithologies are less predictable due to the unknown relative influence of fluvial and marine processes. Possible lithologies range from lagoonal mud to well winnowed beach sand.

Sequence S12 (cf. S13a)

(Figs 15, 23 and 24)

Comments to map: Area (1): Truncated by the erosional event inferred to have occurred subsequent to deposition of S13b. Area (4): The E-W orientated constructional mounds locally show internal hummocky configuration.

Well data: Is not present in Kangâmiut-1. Age is close to the Early-Middle Eocene boundary.

Interpretation

The mounded configuration showing southwards progradation represents channel or fan deposits; hummocky clinoforms within and flanking the mounds represent smaller scale channels. The appearance of the sequence is generally similar to sequence S13a indicating a genetically similar origin, probably as separate depositional episodes. The two sequences are considered to be pene-contemporary and slight overlap/interfingering may occur. The peculiar, rather abrupt southern termination may be explained by updip abandonment of this particular channel.

Systems tracts and sea level: While the channel deposits probably reflect Lowstand gravity flows, the onlap-downlap configuration of area (3) may signify Lowstand Wedge (LSW) sedimentation turning into a Transgressive (TR) Systems Tract further east. This interpretation, however, is rather uncertain due to the very small thicknesses and the presumed erosion of area (1) and around line BG-20. Corresponds to the lower portions of the 3rd order cycle TA3.1 on the global sea level curve (Haq *et al.*, 1987), possibly including part of TA3.2

Predicted lithology: Depending on the sediment source area, coarse sediments are likely to occur centrally in the mounded area (4) and as deposits in the smaller channels. The subparallel sheet deposits may be fine-grained and impermeable. Clean sands are known to be often associated with Transgressive Systems Tracts, if such is present.

Sequence S13

The division of this sequence into S13a and S13b is due to a rather late realization that sequence S12 seemed to have a western equivalent on line BG-18 (Fig. 23). Tracing of its boundary round the seismic grid led to the identification of the two separate sequences S13a and S13b. Sequences S13a and S13b were digitized and depth-converted as one sequence so in the zone of overlap between the two, thickness calculations were made directly from the seismic sections.

Sequence S13a (cf. S12)
(Figs 16, 21 and 23)

Comments to map: In the zone of overlap thickness-calculations were adjusted by hand. Area (2): Progradation is clearly associated with the mounds of area (1). Area (4): Onlap is most evident in the south.

Well data: In Kangâmiut-1 the thickness is 65 m. S13a is equivalent to the Nukik Formation in this well. Four facies were recognized: a) Fine-grained, shaly, feldspathic and slightly glauconitic sandstone, 2) Red coloured very micaceous siltstone, 3) Brown montmorillonitic shale, and 4) Sandy limestone levels. Age is close to the Early-Middle Eocene boundary.

Interpretation

The sequence is interpreted as being the southern equivalent of sequence S12, having the same facies distribution characteristics: mounds mainly orientated E-W with associated southwards (and westwards) progradation. The wide channel deposits considered to be represented by this distribution give way to the smaller-scale channel and sheet deposits of area (3). The change is probably gradual and reflects a transition to a generally more distal regime. Presumed erosion of sequence S11 may point to a north-eastern source of sediment, but a major western contribution is not unlikely.

Systems tracts and sea level: Eastwards onlap, the seismic facies distribution and the location basinwards of the previous sequence S11 all indicate a lowstand origin of the sequence. On the global sea level curve, (Haq *et al.*, 1987) S13a with S12 probably ties to the Lowstand Fan and Lowstand Wedge (LSW) of the 3rd order cycle TA3.1. Alternatively the upper boundary ties to the condensation/downlap surface of TA3.2, the included systems tracts being unresolvable by the seismics. The eastwards onlap may to some extent signify a Transgressive (TR) phase.

Predicted lithology: Though mainly shaly lithological facies are recognized in Kangâmiut-1, coarser sediments quite likely occur elsewhere. Particularly the hummocky and mounded channel deposits are likely to be sand-prone. Distal (southern) sands may occur if the system is sand efficient. A possible seal is provided by finer-grained sheet deposits, though updip closure is a problem.

Note: The Nukik Formation is interpreted by Rolle (1985) as a westward prograding turbidite unit. The westward direction of progradation was probably inferred from the decrease in thickness from 286 m in the well Nukik-2 to 65 m in Kangâmiut-1. Since the formation in Kangâmiut-1 apparently ties to the generally southwards developing sequence S13a, this inference is considered questionable. The two sections of the Nukik Formation may actually represent separate (turbiditic) episodes with sediment derived from different areas. The submarine gravity flows considered responsible for the deposition of S12 and S13a were quite likely turbidity currents, though this does not appear from the seismic data alone.

Sequence S13b

(Figs 17, 23 and 14)

Comments to map: In the zone of overlap thickness calculations were adjusted by hand. Area (1): Thicknesses are marked by erosion.

Well data: Is not represented in well Kangâmiut-1. Age is probably Middle Eocene.

Interpretation

The predominant feature is obviously the prograding seismic facies, though it is not clear whether it represents a delta, or another sort of coastal progradation. As the sequence lacks the episodic development characteristic of (delta-)sequence S7, conditions must have been somewhat different during deposition of S13b. Influence from waves and currents was probably more pronounced, blurring the effect of possible migration of the depositional systems. Information on the original northern and eastern part of the sequence is scarce. Hummocky elements may indicate fluvial channel deposits.

Systems tracts and sea level: The extensive progradation across the shelf is a main characteristic of Highstand (HS) deposits. Though it is uncertain to what degree the sequence was eroded, widespread indications of erosion suggest a Type-I unconformity in consequence of a rapid fall in base level subsequent to deposition of S13b. On the global sea level chart (Haq *et al.*, 1987) the sequence probably ties to the Highstand (HS) of the 3rd order cycle TA3.2 or TA3.3. Incipient hinterland uplift may account for the uncertainty of the tie.

Predicted lithology: The progradation probably led to upward coarsening sequences. A coast parallel (NW-SE) occurrence of clean sands in the upper part of the clinoforms may have been the consequence of winnowing carried out by possible wave action. Landwards sandy channel and finer-grained interchannel sediments may have been deposited. Lateral migration of these facies perhaps resulted in the formation of sealed reservoirs, though of complex geometry. The coast-parallel sands could be sealed as a consequence of the progradation of the fine interchannel facies. The presumed final erosion, however, most likely removed this possible seal. As always the actual lithology depends on the material then available in the source area.

Sequence S14
(Figs 18 and 21)

Comments to map: Area (1): Progradation is mainly associated with or across mounds. Area (2): The alternating facies distribution has a mounded external shape in the northern part.

Well data: In Kangâmiut-1 the thickness is 235 m. S14 forms the lowermost part of the Kangâmiut Formation. In its lower half the lithology alternates between two different sandy facies: 1) Coarse-grained arkosic sandstone, and 2) Fine-grained, shaly and feldspathic sandstone with abundant heavy minerals and micas, all very altered. Layers rich in organic matter and pyrite are present. In the upper half the main lithologic facies is a coarse-grained arkosic sandstone with abundant feldspars, heavy minerals and ferruginous micas. Age is Middle or Late Eocene.

Interpretation

The widespread occurrence of mounds with associated progradation in area (1) may indicate channel and/or fan sedimentation. The westwards progradation generally seems to reflect a lateral migration of the depositional systems. Though the preferred apparent southwards and westwards directions of progradation point towards a north-eastern source of sediment, a (partly) western source cannot be excluded. In area (2) sedimentation was predominantly sheet-like as witnessed by the subparallel configuration. Flat mounds and hummocky clinoforms suggest that channel deposits are quite frequent. This facies-distribution probably represents more distal conditions. Westwards and southwards progradation/migration across older mounds, and the change in lithology from base to top of the sequence in the Kangâmiut-1 well possibly indicate that incipient tectonic uplift to the east and north became an established controlling feature during deposition of sequence S14.

Systems tracts and sea level: The fall in base level prior to deposition of sequence S14 indicated by erosion of S13b could point towards a Lowstand origin of S14. The location basinwards of S13b and the eastwards onlap supports this view, though a Transgressive Systems Tract (TR) followed by the progradation of a Highstand (HS) or Shelf Margin Wedge (SMW) cannot be excluded. The tie to the global sea level curve (Haq *et al.*, 1987) is not clear and is probably blurred by the tectonism presumed to have started during S14 time. In addition a hiatus may occur in the time between S13b and S14, though no such break is reported from biostratigraphical studies (Toxwenius, 1986).

Predicted lithology: The coarse immature sandstones, presumably related to the uplift in the east and north, are expected to have become increasingly common as deposition proceeded. The fine grained, shaly sandstones are probably of submarine channel/interchannel origin. Though layers rich in organic matter and pyrite are evidently present, shale and organic content probably decrease towards the more proximal north-east. Reservoir properties of the coarse sandstones are expected to be quite good, but a seal is probably lacking.

Sequence S15
(Figs 19, 21, 23 and 24)

Comments to map: Area (1): In many areas the sequence is too thin to allow further description. Area (2): Several episodes may be present. Configuration at right angles to the prograding clinoforms is mounded or subparallel. Area (3): Facies shifts from base to top are common as is onlap onto underlying topography. Areas (2), (3) and (4) seem to be eroded (Figs 21 and 23). Area (6): Truncated by the late erosional event (Pleistocene glacial; Henderson *et al.*, 1987).
Well data: In Kangâmiut-1 the thickness is 133 m. S15 forms part of the Kangâmiut Formation; lithology is coarse-grained arkosic sandstones with abundant feldspars, heavy minerals and ferruginous mica. Age is Middle or Late Eocene.
Interpretation
Central erosion and channel cuts indicate deposition prior to a fall in base level. This sequence, however, differs from the previous highstand sequences in several respects. A N-S subdivision of seismic facies is marked in the north, and southwards progradation was more predominant. Except in area (2) vertical aggradation was the prevailing depositional process. The sequence being thinner in the north (1) is probably due to the restriction exerted by base level. Not being allowed to aggrade vertically, northerly derived sediment preferentially bypassed this area to be deposited in southwards coastal progradation patterns in the central area (2). The northern sediment input was probably caused by uplift to the north-north-east. Hummocks in area (1) may represent channel deposits. The westwards prograding elements in area (2) are possibly delta progradation associated with eastern fluviatile systems. The facies distribution in the south (3) does not express the distal parts of a delta system. Rapid facies shifts and

several episodes, younger onlapping older, indicate a rather high energy regime. Northwards retrograding mounds may express an incipient rise in base level subsequent to deposition of S14. Progressive eastwards onlap in the south (4) may express a further rise. The N-S striking area of mounds, roughly coincident with the thickness maximum, could represent coast-parallel bars. The final erosion marked a fall in base level.
Systems tracts and sea level: Though the presence of both Transgressive (TR) and Highstand (HS) systems tracts seems to be evident, there is some difficulty in tying to the eustatic sea level curve of Haq *et al.* (1987) Interfingering of sediments derived from the north and the east reduces the chances of explaining the sedimentological development of the sequence. In addition changes in base level were probably to a high degree controlled by tectonic uplift, also in the east. The lithological information - coarse, immature sandstones - supports this view.
Predicted lithology: Coarse sandstones are probably widespread since they appear to be so distally. More muddy sediments may be present associated with the presumed eastern delta system, but are probably not interesting from a hydrocarbon point of view.

Sequence S16
(Figs 20 and 21-24)

Comments to map: Area (1): Thicknesses in the western part are controlled by underlying structures. Area (2): Several episodes may be present, but crossing multiples disturb. Area (3): The mound situated centrally on line BG-14 may show retrogradational (eastwards) development. Hummocky clinoforms occur mainly in the central part of the area. Area (5): Truncation is by the late erosional event (Pleistocene glacial; Henderson *et al.*, 1981).
Well data: In Kangâmiut-1 the thickness is 223 m. S16 forms part of the Kangâmiut Formation. Coarse-grained arkosic sandstones, locally cyclic sedimentation with series of coarsening-upwards sequences. Age is Late Eocene (-Early Oligocene).
Interpretation
This sequence is in many respects similar to the previous sequence S15. The N-S division in facies distribution is evident, while the westwards progradational element in area (2) is more pronounced. In the north (1) shelf/coastal plain sedimentation with possible channel deposits is indicated by generally continuous subparallel reflectors locally interrupted

by hummocky clinoforms. In area (2) the westwards progradation was possibly associated with fluviatile systems to the east, while the southwards progradation was possibly a continuation of the coastal progradation of sequence S15. Alternating hummocky clinoforms and subparallel configuration in area (3) indicate that vertical aggradation was the primary process with widespread channel deposition occurring. A high noise level makes detailed interpretation difficult.

Systems tracts and sea level: The progressive eastwards onlap (4) indicates a resumed rise in base level subsequent to the fall witnessed by erosion of sequence S15. In addition to this Transgressive (TR) Systems Tract the progradation probably formed part of a Highstand (HS) Systems Tract. However, changes in the pattern of sedimentation are considered to be mainly controlled by tectonics, i.e. hinterland uplift. The strongly downlapped top of S16 (Fig. 21) may tie to the well-defined Early Oligocene condensed section on the global sea level chart (Haq *et al.*, 1987).

Predicted lithology: The coarse sandstones of the Kangâmiut Formation are probably quite widespread. Finer-grained sediments, often associated with the distal parts of prograding systems, interchannel deposits and delta plains/delta fronts are not expected to be abundant.

Well ties

In the well Kangâmiut-1 (cf. Fig. 2) the Ikermiut Formation comprises the sequences S4, S5, S6, the lower unit of S8, and S9 (with S10). The Nukik Formation comprises the sequence S13a (with S12) and the Kangâmiut Formation the sequences S14, S15, S16 plus 400 metres of uninterpreted section.

(1) As the sequences S1, S2, S3, S7, S8 (upper three units), S11 and S13b apparently do not reach the well, it can be concluded that the stratigraphic record of Kangâmiut-1 well includes several hiatuses or condensed sections not previously recognized.

(2) Likewise it is evident that the lithostratigraphical subdivision carried out by Rolle (1985) insufficiently represents the actual variations in the basin (as Rolle also predicted).

(3) Sequences S7, S11, S13b and the three upper units of S8 are all interpreted to be progradational, deposited during highstands and incipient falls of relative sea level. Combined with the fact that these

sequences are either absent from the well or are represented only by condensed sections, this leads to an overrepresentation of lowstand fairly-marine sediments in Kangâmiut-1 well.

(4) The rather homogeneous, shaly Ikermiut Formation as found in the wells thus may consist of a much more varied lithology in more central areas and could include reservoir sands.

The effects mentioned are mainly due to the rather marginal location of Kangâmiut-1. Ikermiut-1 suffers from the same weakness because the diapirism in this area (Henderson *et al.*, 1981) is likely to overrepresent shales at the well location. There is some uncertainty as to which sequences form part of the updoming Ikermiut formation and which are covered by the hiatus comprising the greater part of the Middle and Upper Eocene in Ikermiut-1. In this well the only sequence included in the overlying Kangâmiut formation is S16, which forms the lowermost <100 m of the *c.* 600 m thick formation.

The Late Paleocene - Early Eocene age of the Hellefisk Formation (Toxwenius, 1986), represented in well Hellefisk-1 only, indicates that it is contemporary with sequences S4-S13, though only a few of these seem to reach this well.

Correlation to the Global Sea Level Curve (Haq, Hardenbol & Vail, 1987)

The correlation, based on interpretation of the individual sequences and the succession of sequences combined with ages obtained from the Kangâmiut-1 well (Toxwenius, 1986), contains the following 'fix-points' which are considered very reliable (Fig. 2):

(a) Top of sequence S16 which is a strongly downlapped surface shown by all three wells to be close to the Eocene-Oligocene boundary.

(b) The lowstand sequence S13a (with S12) whose age is close to the Early Eocene - Middle Eocene boundary and which has a strongly downlapped top.

(c) The top of sequence S6, a strongly downlapped surface dated as Early Eocene by Toxwenius (1986). The Paleocene to very Early Eocene age given by the sea level chart differs slightly from Toxwenius' dating, though in both cases the base of Dinoflagellate Zone D6 defines the Paleocene-Eocene boundary (S. Piasecki, pers. comm. 1990).

The reliability of the two latter fix-points is greatly supported by the convincing agreement between the interpretation of the Lower Eocene sequences S7-S13a and what is predicted from the sea level curve. Uncertainty however rests with the correlation of sequences S14, S15 and of S16 itself, though its top is considered certain.

Thus the Early Eocene obviously represented a tectonically quiet period of (thermal) subsidence, when fluctuations in eustatic sea level controlled the sedimentological development in the area. The lack of correlation of the Middle-Upper Eocene sequences with the Haq *et al.* (1987) curves indicates increased tectonic influence or an incomplete stratigraphic record, or probably both. The Paleocene sequences have not been connected unambiguously to systems tracts and sea level changes, so no tie to the sea level curve has been attempted for this interval. In addition Paleocene rifting may possibly have occurred in the region, in which case the stratigraphic record will be less likely to reflect eustatic changes of sea level.

The biostratigraphic dating (Toxwenius, 1986) and the independent dating provided by correlation to the global sea level chart (Haq, Hardenbol & Vail, 1987) concur on the Early Eocene age of sequences S7-S13a and the Late Eocene - Early Oligocene age of sequence S16. There is however some uncertainty concerning the Middle-Upper Eocene sequences. Several observations combine to suggest that a major change of conditions occured in the area at this time.

(1) Deposition of the coarse-grained Kangâmiut Formation where previously shales were predominant.

(2) Rates of deposition at the Kangâmiut-1 well location show a distinct fall from Early Eocene to Middle-Late Eocene times. That the large thicknesses of the Lower Eocene sequences S7 and S8 do not reach the well accentuates this point. This fall in deposition rate contrasts with the expected rapid rate of deposition conventionally considered to be associated with the mineralogically immature sediments of the type found in the Kangâmiut Formation (Rolle, 1985).

(3) Non-correlation of sequences S14-S16 to the global sea level chart of Haq *et al.* (1987) may suggest major tectonic influence, possibly as hinterland uplift.

(4) Likewise dip values of Levels A, B, C and O may indicate the onset of differential subsidence/uplift during the Eocene.

On this basis the existence of a major Middle or Late Eocene hiatus is suggested, possibly in connection with the erosion event subsequent to sequence S13b. It should be noted however that Toxwenius (1976) presents no biostratigraphical evidence of such a hiatus.

Tectonic Setting

Combining the structural and stratigraphic features mentioned previously with what is known about the spreading history of the Labrador Sea to Baffin Bay area reveals some interesting relations:

The very Early Eocene (Anomaly 24) opening of Baffin Bay and Davis Strait (Srivastava, 1978) corresponds to the age obtained for Level B (Fig. 2). Absence of Anomaly 13 in the Labrador Sea area (Srivastava, 1978; Srivastava *et al.*, 1981) indicates that ocean spreading may have ended in latest Eocene or Early Oligocene, the age obtained for Level C. Thus the sediments below Level B were deposited before and during the period of rifting in Baffin Bay, while those between Level B and C are "syn-drift" sediments and those above Level C are "post-drift". In addition it is noted that Level B marked the end of strong structural influence in the west, i.e. faulting in the north-west (d) and updoming in the central west (f) (Fig. 3). Basement uplift in the north (b) and volcanism presumably related to the south-east high (a) were contemporaneous to deposition of the sediments below Level B. Volcanics of presumed Paleocene age (Hald & Larsen, 1987) encountered in the wells Nukik-2 and Hellefisk-1 were shown by the same authors to be geochemically more closely related to the volcanics of Baffin Island on the other side of Davis Strait than to those onshore West Greenland. Seismic stratigraphic studies (J.A. Chalmers, pers. comm. 1989) have tied the volcanics of Nukik-2 to those flanking the south-east high. This high remained topographically positive until Level B time, while the Kangâmiut Ridge became submerged somewhat earlier.

Though no proper structural analysis has been carried out, it is suggested that Levels A, B and C represent periods of change in the regional tectonic setting.

Initial rifting, lithosphere extension, thinning and flexure formed the basin in which the sediments below Level A were deposited. The horst and graben structures (rifts) of Fig. 3 (e) are probably related to this phase.

Between Level A and Level B time, rifting continued. The volcanism, basement uplift, faulting and shale movement ((a), (b), (d) and (f) of Fig. 3) are all associated with this phase. The topographic highs existing or coming into existence during this period caused a probably restricted marine circulation with rather anoxic conditions as a consequence. Improved circulation as witnessed by decreasing organic content and less pyrite in the sediments of the Ikermiut Formation (Rolle, 1985) resulted from widening of the sea and/or submergence of the Kangâmiut Ridge (and Davis Strait

High). At Level B time, between chrons 24 and 25, a drastic change in the direction of motion of Greenland relative to North America and Eurasia took place, resulting in lateral shearing motion through Davis Strait rather than 'conventional' sea floor spreading (Roest & Srivastava, 1989). It remains a possibility that Level B reflects this change rather than onset of spreading in the area, as it has lately been suggested that spreading in Baffin Bay may have commenced as early as anomaly 31 time (Roest & Srivastava, 1989), although initial spreading as early as this is disputed in the inner Labrador Sea (Chalmers, in review).

The sediments between Levels B and C were deposited during active sea floor spreading (or shearing motion) seaward of the study area. Tectonically quieter conditions prevailed during this period with thermal (differential) subsidence of the continental shelf. It is considered likely that hinterland uplift started during this thermal phase.

The "post-drift" sediments above Level C were deposited during continued thermal subsidence. It is not clear for how long hinterland uplift persisted.

It is still a matter of dispute whether active sea floor spreading took place in the Davis Strait-Baffin Bay region at all. Though it is argued that active spreading and formation of oceanic crust did take place (e.g. Srivastava *et al.*, 1981), this and several other issues concerning the structural development of the area have not yet been settled. One issue is the nature and origin of the Davis Strait High, immediately west of the area studied in the present report. Srivastava & Arthur (1989) favour a (Paleocene) hot spot origin of this high, similar to that of Iceland. At present one can only guess to what extent this would influence the thermal and subsidence history on the adjacent West Greenland shelf. With several important issues still unsettled, it is advised that certain reservations concerning the development described above should be made.

SUMMARY

A regional seismic stratigraphic study of the Paleocene-Eocene section covering 20 000 km^2 offshore southern West Greenland has been carried out. The method used was the seismic sequence and facies analysis described by Vail *et al.* (1977), Vail (1987) and Macurda (1986). Correlation to lithostratigraphic formations (Rolle, 1985) and information on lithology was obtained from tie to the well Kangâmiut-1. Age of the identified sequences was provided by the biostratigraphic study of Toxwenius (1986) and by correlation to the global sea level chart of Haq, Hardenbol & Vail, 1987. Depth conversion was carried out using velocity functions derived from the TWT-depth information given by calibrated sonic logs of the wells Ikermiut-1 (Chevron), Hellefisk-1 (ARCO) and Kangâmiut-1 (Total).

Geological interpretation of the seventeen recognized seismic sequences was attempted in terms of depositional systems, systems tracts and predicted lithology, where it was considered justified by the observations, at least in the case of the Eocene sequences S7-S16. In ascending order the sequences are (Fig. 2):

S1: Poorly defined. Reflects resumed sedimentation subsequent to the possible hiatus represented by Level A.

S2: Tentatively interpreted as submarine fan sediments and transgressive channel infill.

S3: Poorly defined. Some westwards and southwards progradation. Possibly controlled by the northern uplifted high.

S4: Probably contemporaneous to northern uplift, faulting to the north-west and incipient volcanism to the south-east. Laterally migrating submarine channel systems are suggested. Contributes to the western shale diapirs of Henderson *et al.* (1981).

S5: Probably contemporaneous to structuring and volcanism initiated during deposition of S4. Contributes to the "Ikermiut shale diapirs" (Henderson *et al.*, 1981). Vertical aggradation in a low-energy marine regime was the predominant process, though limited occurrence of channel deposits is suggested.

S6: Occurrence of volcanics reached its maximum areal extent in S6 time and probably exerted topographic control on the sediments. A shallow marine origin with only limited water circulation is inferred for the sediments.

S7: Sedimentation by laterally shifting delta systems. Progradation and lateral migration of depositional systems are likely to provide potential possibilities for sealing of sandy deposits within the sequence. The organic matter probably present in the delta plain deposits is not expected to have reached maturity.

S8: Coastal progradation and aggradation. The area of constructional mounds parallelling the palaeo-coast is tentatively interpreted as potentially sand-rich bars. Three units of this nature are underlain by a fourth, which separates the two progradational sequences S7 and S8.

S9: A complex system of submarine channel and interchannel sedimentation during a lowstand of relative sea level is inferred. Palaeo-topography seems to have played a controlling role. Sediment was probably (in part) derived from the west.

S10: Considered similar and (pene-)contemporary to S9. Local westwards progradation suggests an eastern source of sediment.

S11: Coastal progradation; not similar to delta sequence S7 as no lateral migration of depositional systems is evident. Sandy deposits are very likely. Probably subjected to subsequent subaerial exposure and erosion.

S12: Submarine channel and/or fan sedimentation during a lowstand of relative sea level is inferred.

S13a: Considered similar and (pene-)contemporary to S12. Sheet deposits are more predominant in the southern (distal) parts compared to the mounded channel deposits in the north.

S13b: Coastal progradation, similar to S11. Probably more wave- and current-dominated than delta sequence S7 and subjected to subsequent erosion in large areas.

S14: Submarine channel and sheet deposition. Progradation and lateral migration is partly considered a result of incipient eastern uplift as is the preceding/contemporaneous erosion on the shelf.

S15: Coastal progradation from north and east (? south-westwards delta progradation) associated with tectonic uplift. Generally shallow water sedimentation in a rather high energy regime sensitive to small variations in base level. Coast-parallel bars are possible in the south, where also transgression seems to have taken place in the lower parts.

S16: Continuation of coastal progradation from the north, westwards progradation more pronounced than in S15. Vertically aggrading sheet sediments were predominant in the south with widespread channel deposits. Still eastern and northern uplift is considered the controlling factor on the development.

The tie to Kangâmiut-1 shows the sequences S4, S5, S6, S8 (lower unit) and S9 (with S10) to constitute the Ikermiut Formation there. Sequences S1, S2 and S3 are covered by the hiatus represented by Level A. Two condensed sections, respectively representing sequences S7 and S8 (3 upper units) are present within the Ikermiut Formation. The Nukik Formation is here equivalent to sequence S13a (with S12). A condensed section corresponding to S11 is represented by the boundary to the Ikermiut Formation. The Kangâmiut Formation includes the sequences S14, S15 and S16 plus 400 metres of uninterpreted section and is separated from the Nukik Formation by a condensed section corresponding to sequence S13b. None of the mentioned condensed sections have previously been recognized. The 26 metres of Narssarmiut Formation below the unconformity is the poor representative of the generally 1000-1500 metres of uninterpreted pre-Paleocene (-Lower Paleocene?) section.

The correlation to the sea level chart of Haq *et al.* (1987) shows a good agreement for the Lower Eocene sequences S7-S13a indicating a period of stable, uniform subsidence (thermal?) with the eustatic sea level controlling the sedimentological development in the area. Correlation of the older Paleocene sequences has not been attempted. The lack of correlation of the younger Middle-Upper Eocene sequences is considered the effect of increased tectonic influence and possibly represents an incomplete record.

In addition presumed onset of differential subsidence/uplift during the Eocene and the change to deposition of the Kangâmiut Formation in the Middle Eocene indicate markedly altered conditions in the area. The inferred hiatus subsequent to deposition of sequence S13b is tentatively suggested to mark a (regional) unconformity and to be the cause of apparently slow rates of deposition observed in the Middle-Late Eocene.

On the Labrador Shelf, Balkwill (1987) reports an Upper Eocene boundary separating his "Drift-phase" and "Post-drift" megasequences. The associated change from pelite-dominated to coarse, immature sediments is considered a result of uplift and erosion of coastal highlands. Further south on the West Greenland continental shelf, Chalmers (1989) has proposed the existence of four megasequences, M1-M4, with M3 and M4 possibly corresponding to the two mentioned Labrador Shelf megasequences of Balkwill (1987). Chalmers mentions the possibility that this M3/M4 megasequence boundary could be put either at the base of or low within Rolle's Kangâmiut Formation, suggesting a Middle or Late Eocene age for this boundary.

CONCLUSIONS

The work presented in this report should be considered a forerunner of the more detailed and complete studies on the West Greenland shelf planned by the Geological Survey of Greenland (Chalmers, 1990). The main conclusions of the study are:

1) 17 Paleocene-Eocene seismic sequences occur the area. Correlation to the Sea Level Chart of Haq *et al.* (1987) suggests a period of thermal subsidence during the Early Eocene, with the eustatic sea level controlling the sedimentological development. The Paleocene and Middle-Upper Eocene development is probably tectonically controlled.
2) Existence of 17(+) sequences in the section defined by the lithostratigraphic formations Ikermiut, Nukik, Kangâmiut (and Hellefisk) of Rolle (1985) indicates a more complex stratigraphy than recognized hitherto.
3) The lack of reservoir rocks in the deeper part of the section is likely to be a local phenomenon, in part determined by the distal location of the wells relative to the inferred sediment source area. In the well Kangâmiut-1 the shaly and organic rich Ikermiut Formation is shown to contain the condensed sections of sequences considered sand-prone elsewhere.
4) The best existing seismic data are of adequate quality to allow regional seismic stratigraphic interpretation. An improved database through reprocessing of old data and acquisition of new supplementary data, however, is needed to carry out more detailed identification of possible prospects.
5) The evaluation of the West Greenland shelf on the basis of the 5 existing exploratory wells must be considered inadequate, and the abandonment of the area by industry premature.

Acknowledgements: Permission to use unpublished results from his seismic stratigraphic study was kindly given by J. A. Chalmers. J. A. Chalmers and H. C. Larsen offered much good advice and valuable criticism for which I am very grateful.

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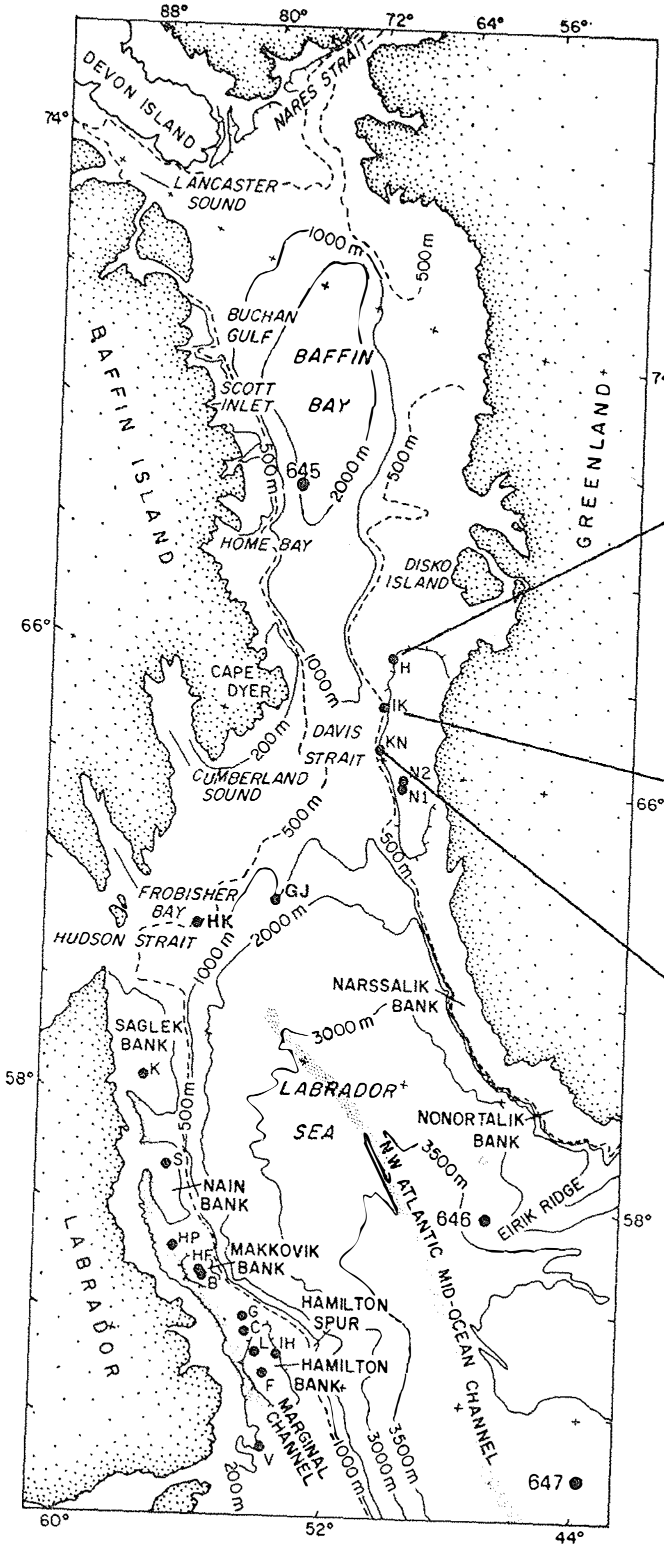


FIG. 1A. GENERALIZED BATHYMETRY OF BAFFIN BAY- LABRADOR SEA REGION SHOWING EXPLORATORY WELLS AND OCEAN DRILLING PROGRAM SITES 645, 646 AND 647. (FROM PROCEEDINGS OF THE ODP, VOL 105, 1989)

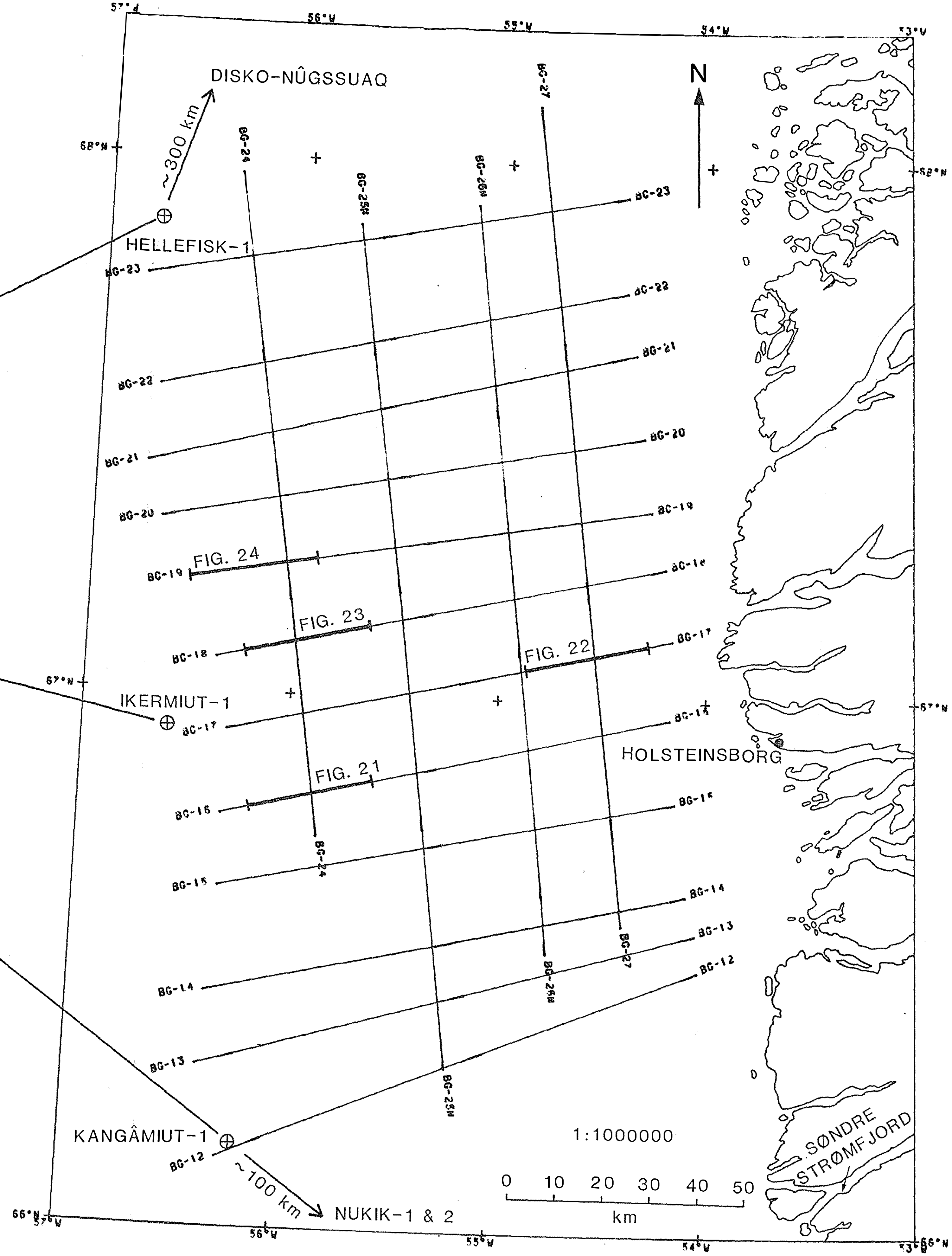


FIG. 1B WELLS AND MAIN SEISMIC LINES OFFSHORE SOUTHERN WEST GREENLAND

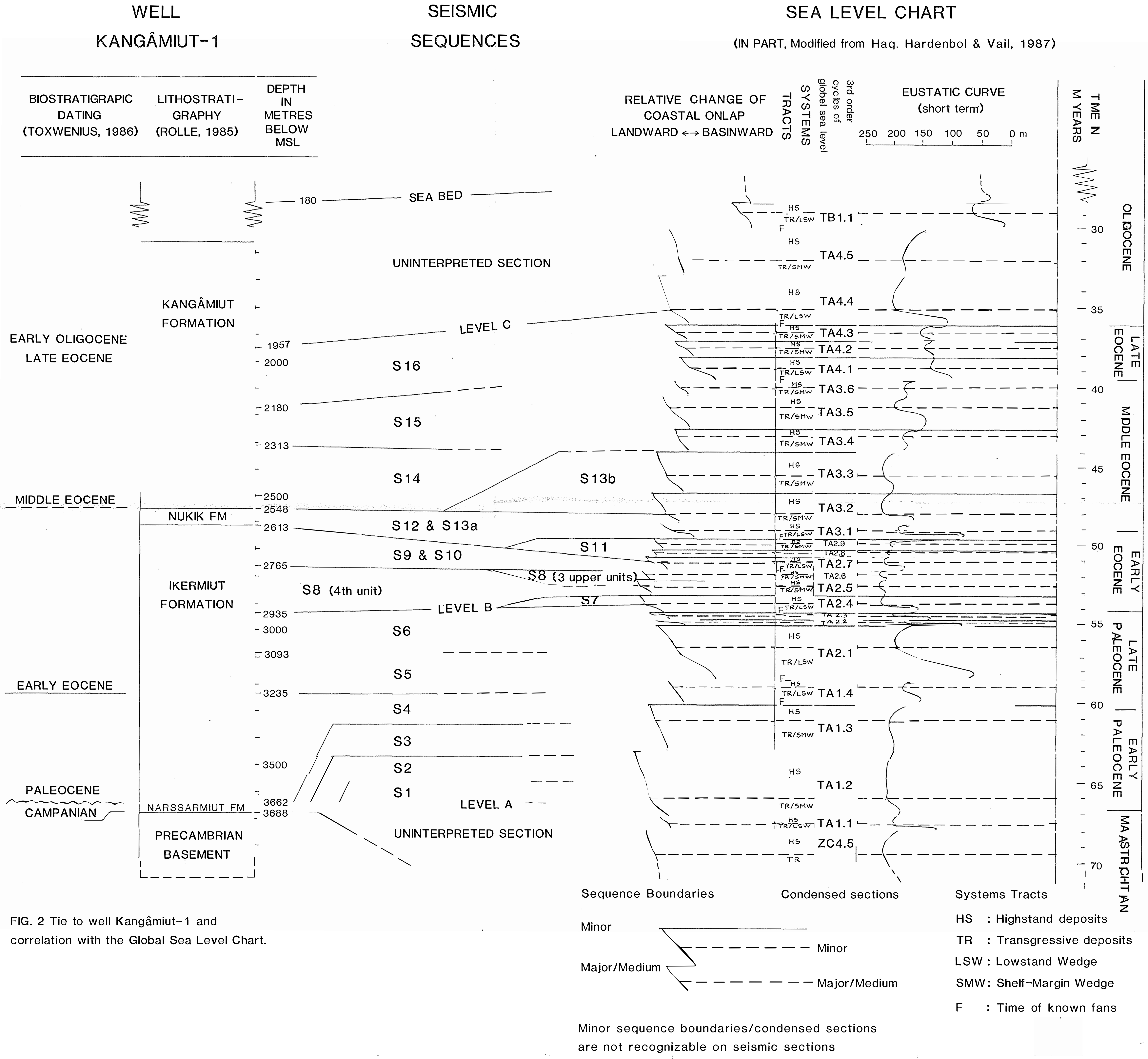
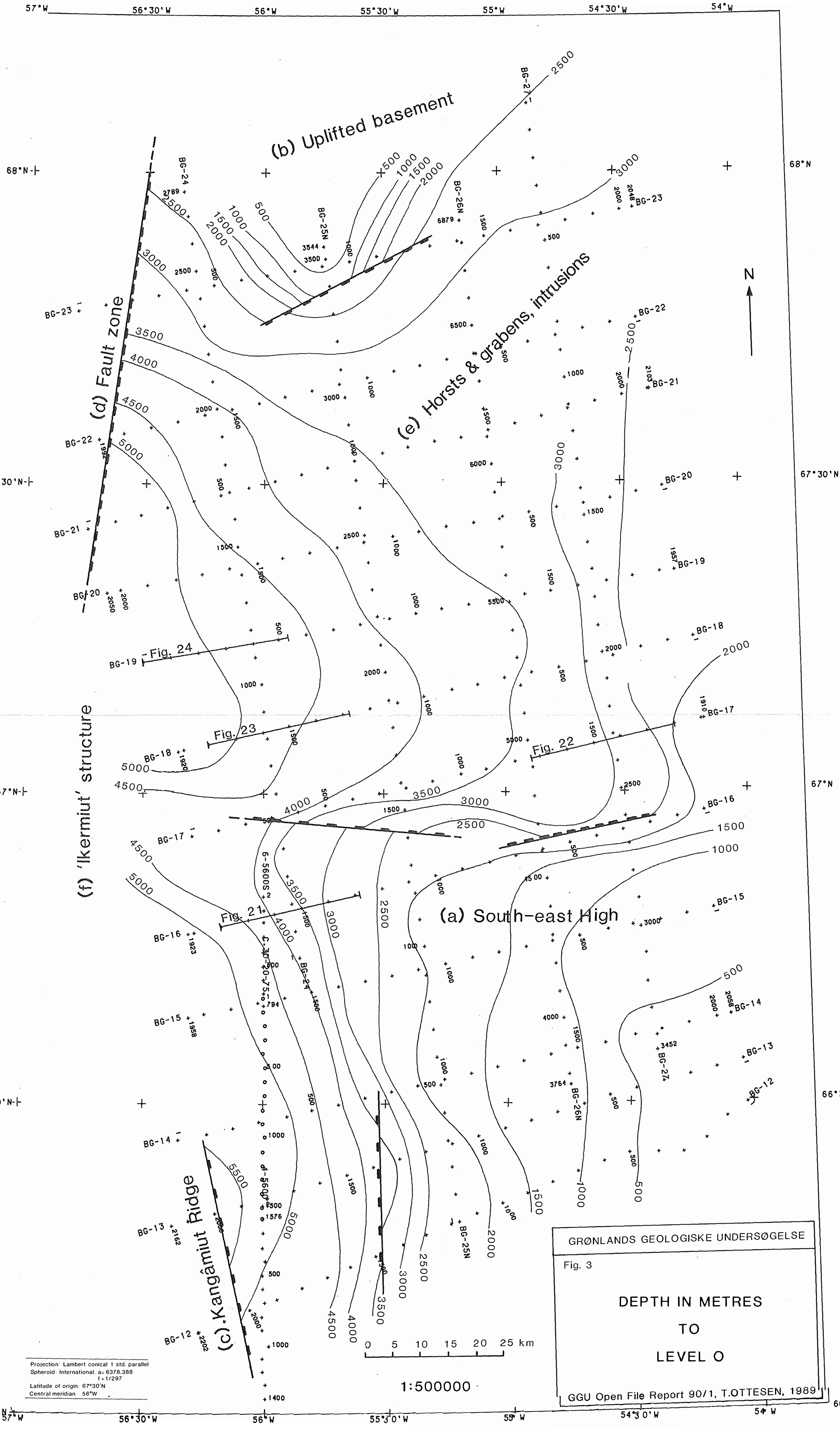


FIG. 2 Tie to well Kangâmiut-1 and correlation with the Global Sea Level Chart.

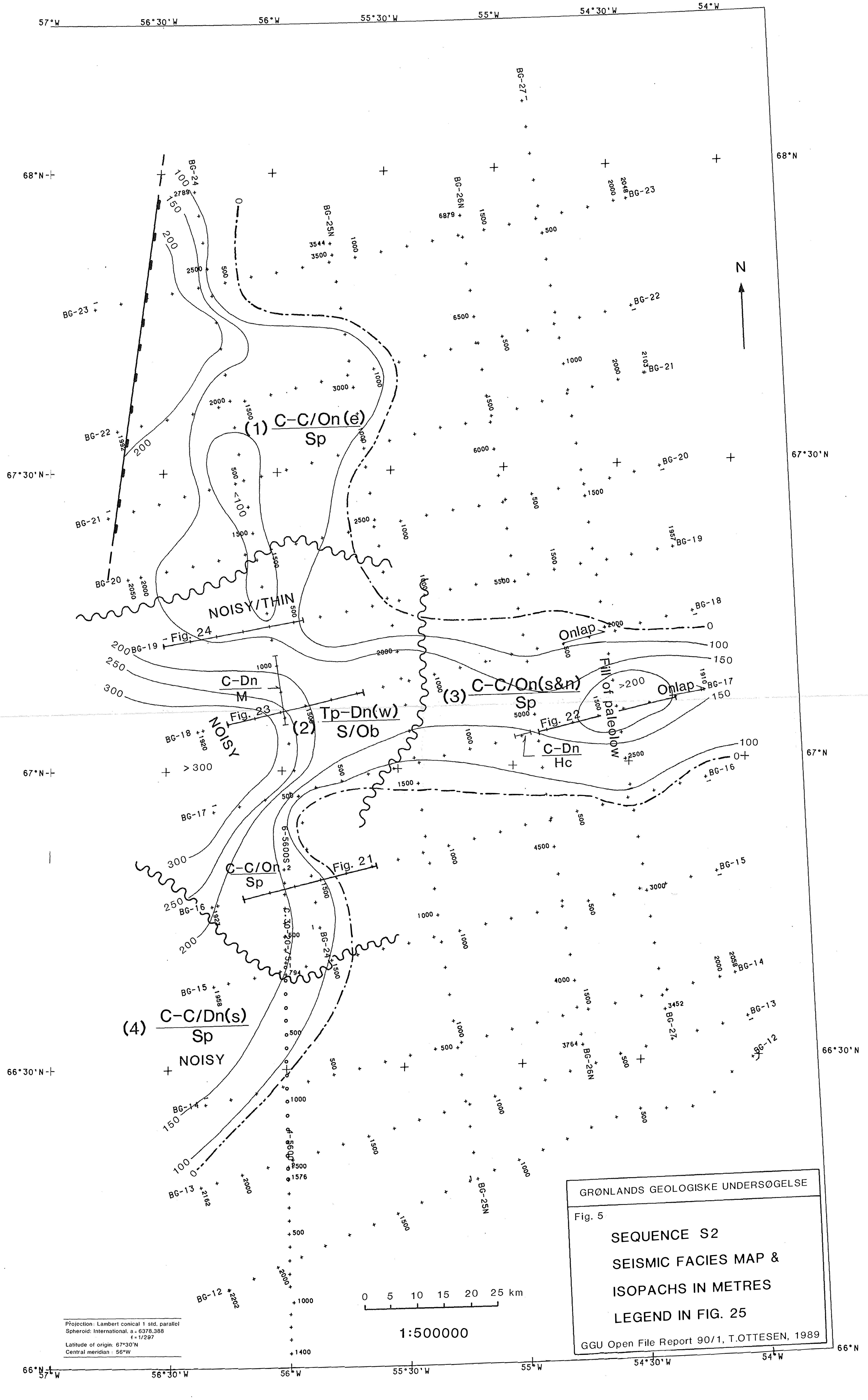

57°W
56°30'W
56°W
55°30'W
55°W
54°30'W
54°W
68°N
67°30'N
67°N
66°30'N
66°N
N
(a) South-east High
(b) Uplifted basement
(c) Kangâmiut Ridge
(d) Fault zone
(e) Horsts & grabens, intrusions
(f) 'Ikermiut' structure
Fig. 21
Fig. 22
Fig. 23
Fig. 24
0 5 10 15 20 25 km
1:500000
Projection: Lambert conical 1 std. parallel
Spheroid: International, a= 6378,388
f = 1/297
Latitude of origin: 67°30'N
Central meridian: 56°W
GRØNLANDS GEOLOGISKE UNDERSØGELSE
Fig. 3
DEPTH IN METRES
TO
LEVEL O
GGU Open File Report 90/1, T.OTTESEN, 1989

GRØNLANDS GEOLOGISKE UNDERSØGELSE

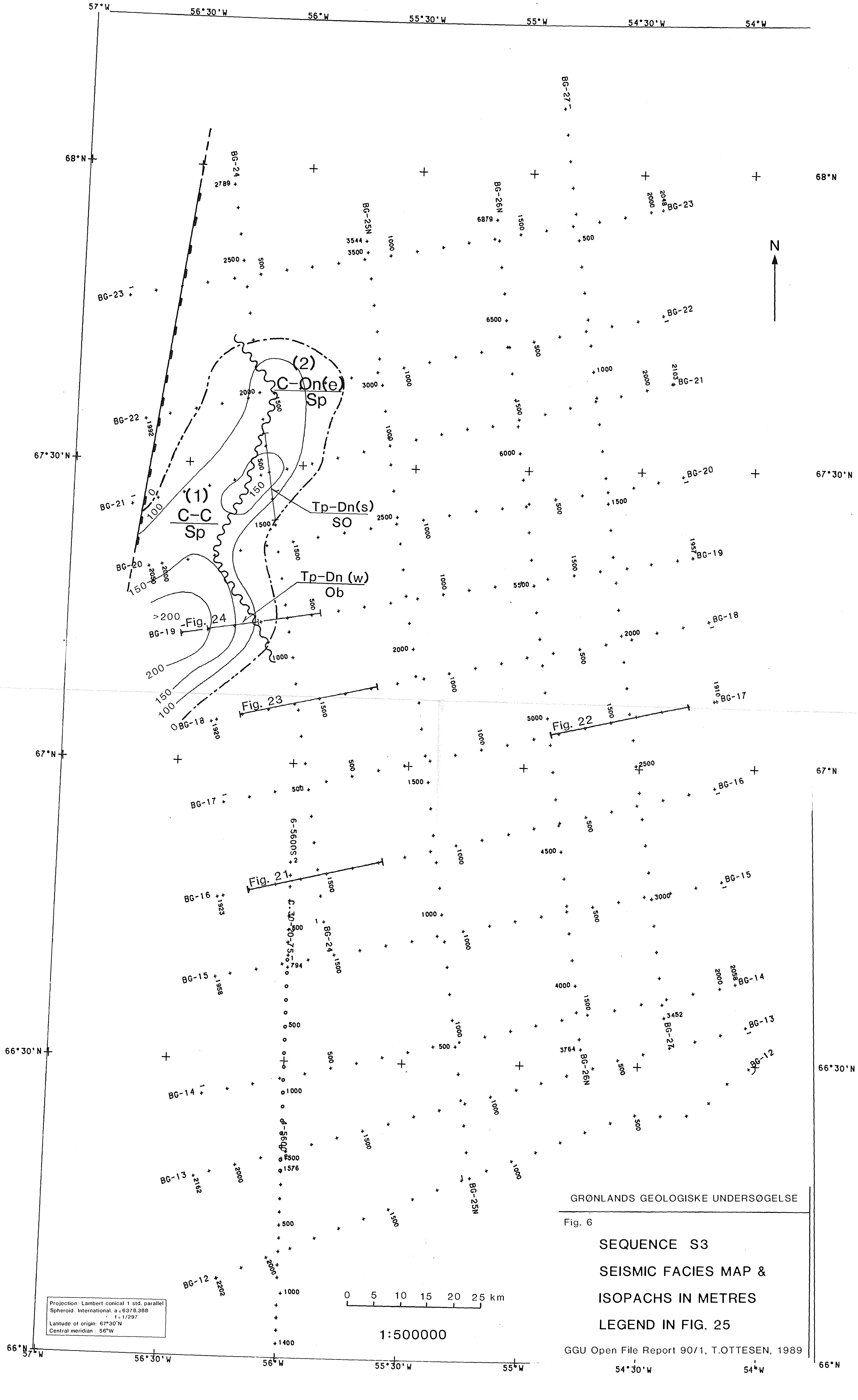
Fig. 4

SEQUENCE S1
SEISMIC FACIES MAP &
ISOPACHS IN METRES
LEGEND IN FIG. 25

GGU Open File Report 90/1, T.OTTESEN, 1989



57°W
56°30'W
56°W
55°30'W
55°W
54°30'W
54°W
68°N
67°30'N
67°N
66°30'N
66°N
N
BG-27
BG-26N
BG-25N
BG-24
BG-23
BG-22
BG-21
BG-20
BG-19
BG-18
BG-17
BG-16
BG-15
BG-14
BG-13
BG-12
(1) C-C/On(e) / Sp
<100
NOISY/THIN
Fig. 24
C-Dn / M
Fig. 23
NOISY
(2) Tp-Dn(w) / S/Ob
>300
(3) C-C/On(s&n) / Sp
Onlap
Fill of paleolow
>200
Fig. 22
C-Dn / Hc
C-C/On / Sp
Fig. 21
(4) C-C/Dn(s) / Sp
NOISY
0 5 10 15 20 25 km
1:500000
Projection: Lambert conical 1 std. parallel
Spheroid: International, a = 6378,388
f = 1/297
Latitude of origin: 67°30'N
Central meridian: 56°W
GRØNLANDS GEOLOGISKE UNDERSØGELSE
Fig. 5
SEQUENCE S2
SEISMIC FACIES MAP &
ISOPACHS IN METRES
LEGEND IN FIG. 25
GGU Open File Report 90/1, T.OTTESEN, 1989



GRØNLANDS GEOLOGISKE UNDERSØGELSE

Fig. 6

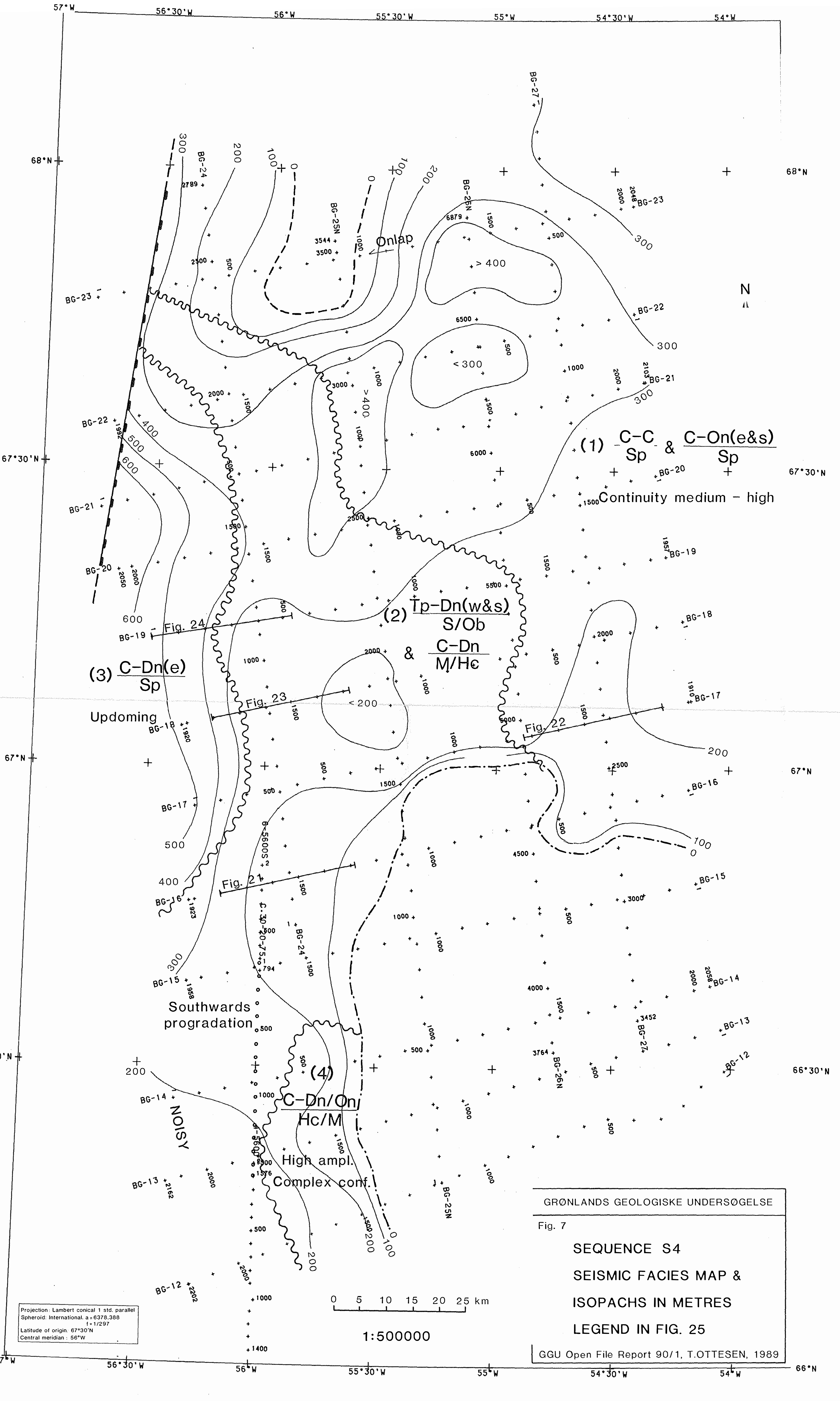
SEQUENCE S3

SEISMIC FACIES MAP &

ISOPACHS IN METRES

LEGEND IN FIG. 25

GGU Open File Report 90/1, T.OTTESEN, 1989



GRØNLANDS GEOLOGISKE UNDERSØGELSE

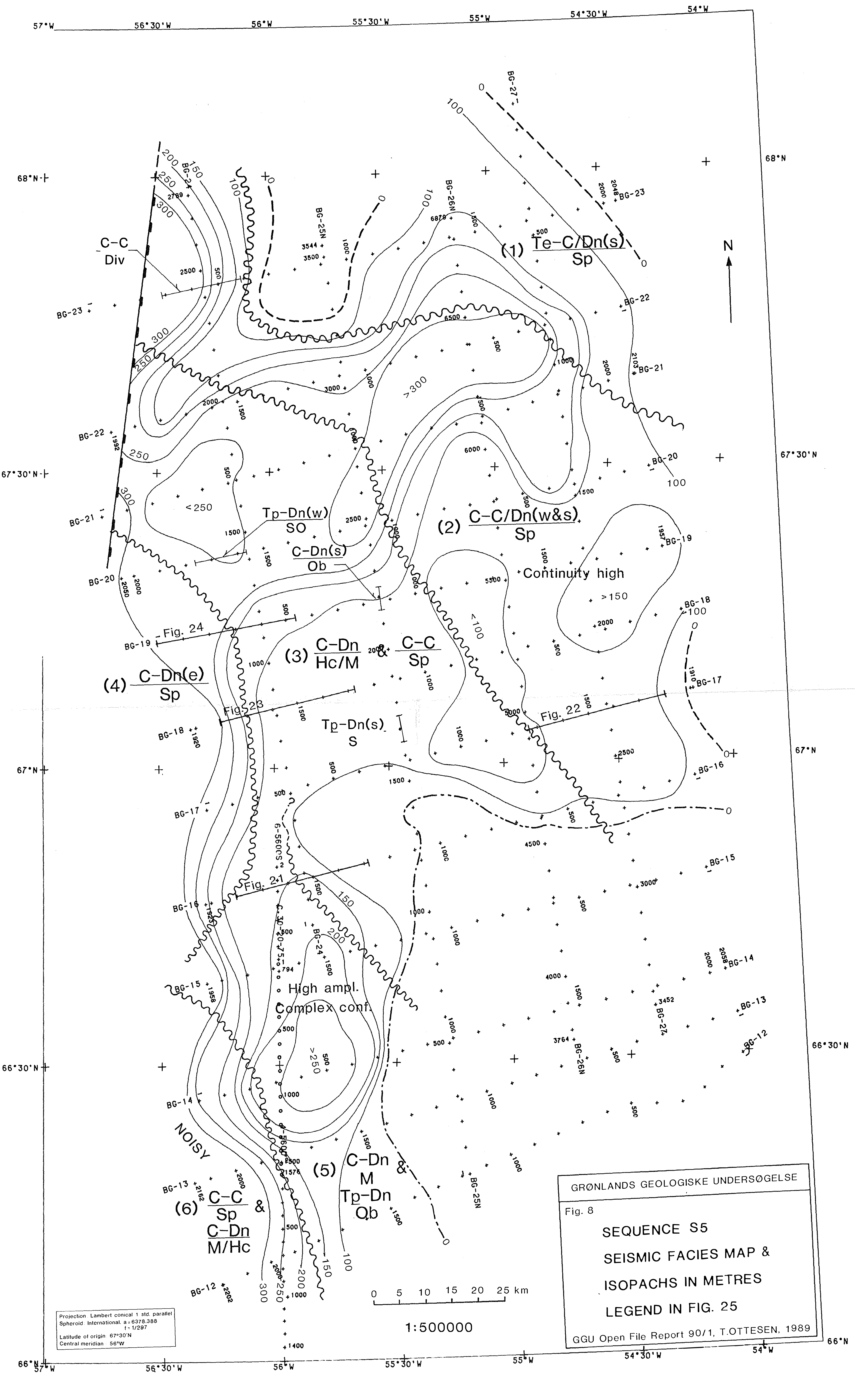
Fig. 7

SEQUENCE S4

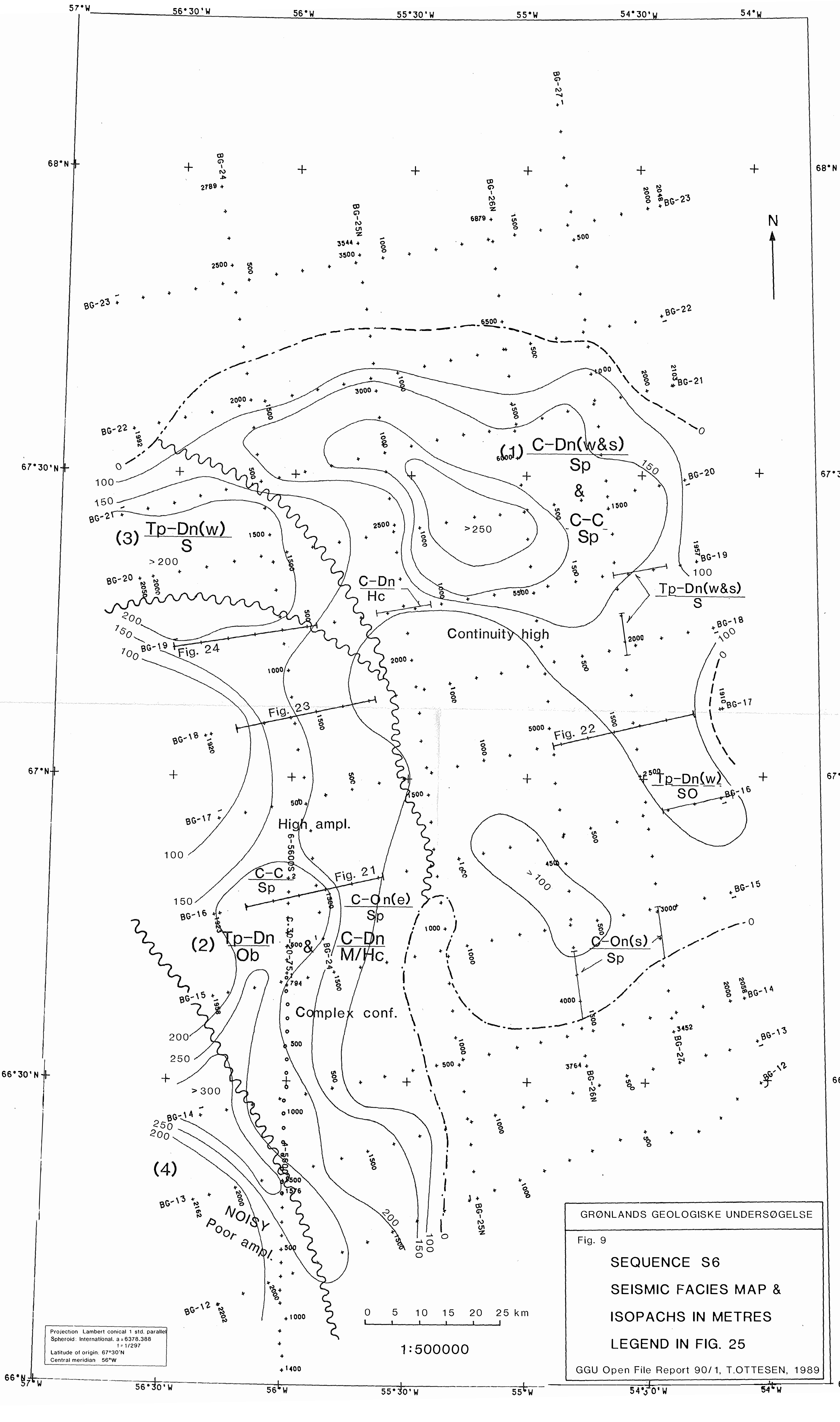
SEISMIC FACIES MAP & ISOPACHS IN METRES

LEGEND IN FIG. 25

GGU Open File Report 90/1, T.OTTESEN, 1989



57°W
56°30'W
56°W
55°30'W
55°W
54°30'W
54°W
68°N
67°30'N
67°N
66°30'N
66°N
N
(1) Te-C/Dn(s) / Sp
(2) C-C/Dn(w&s) / Sp
Continuity high
(3) C-Dn / Hc/M & C-C / Sp
(4) C-Dn(e) / Sp
(5) C-Dn & M / Tp-Dn / Qb
(6) C-C / Sp & C-Dn / M/Hc
C-C / Div
Tp-Dn(w) / SO
C-Dn(s) / Ob
Tp-Dn(s) / S
High ampl.
Complex conf.
NOISY
Fig. 21
Fig. 22
Fig. 23
Fig. 24
0 5 10 15 20 25 km
1:500000
Projection Lambert conical 1 std. parallel
Spheroid International, a = 6378.388
f = 1/297
Latitude of origin 67°30'N
Central meridian 56°W
GRØNLANDS GEOLOGISKE UNDERSØGELSE
Fig. 8
SEQUENCE S5
SEISMIC FACIES MAP &
ISOPACHS IN METRES
LEGEND IN FIG. 25
GGU Open File Report 90/1, T.OTTESEN, 1989



GRØNLANDS GEOLOGISKE UNDERSØGELSE

Fig. 9

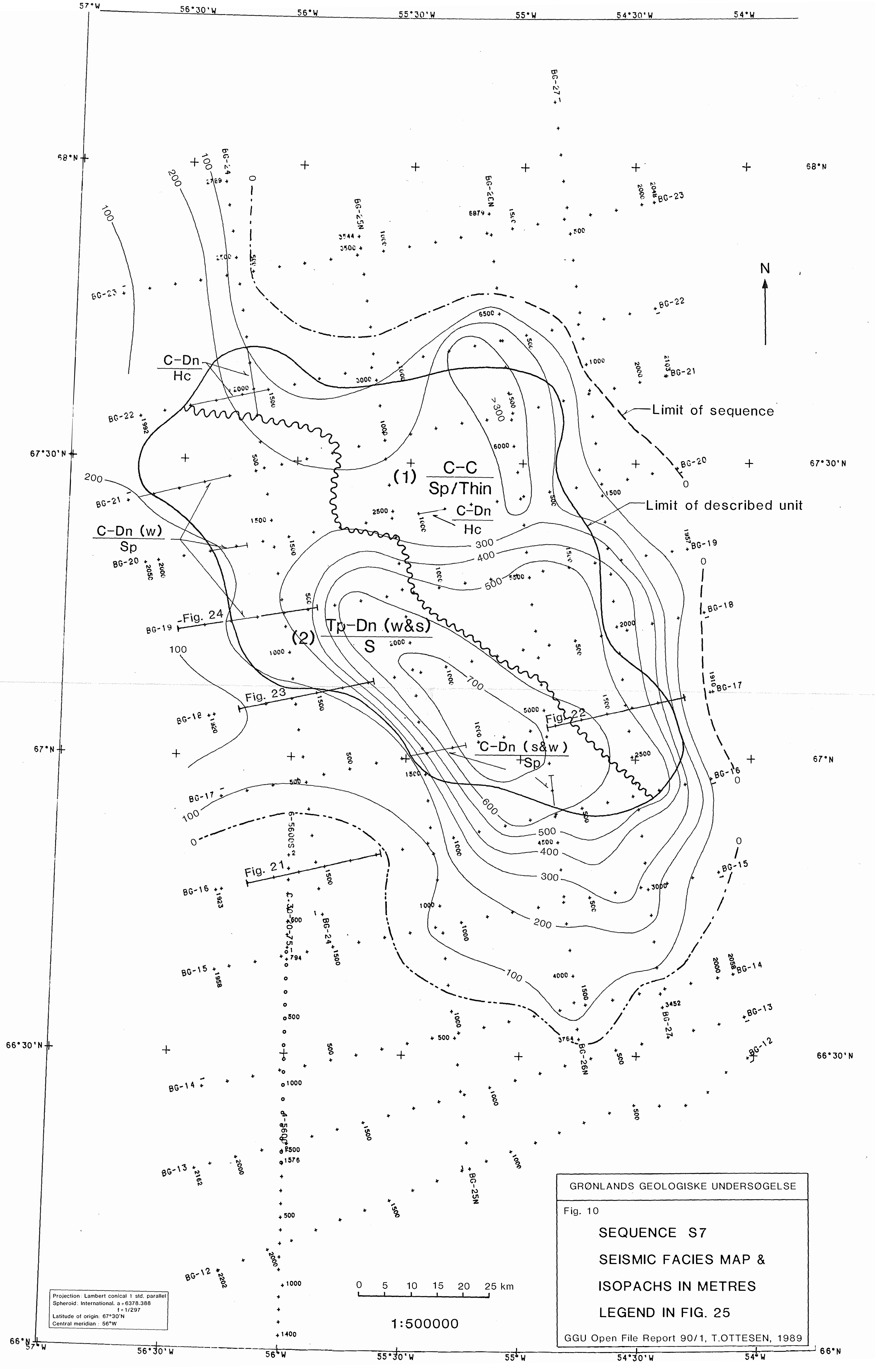
SEQUENCE S6

SEISMIC FACIES MAP &

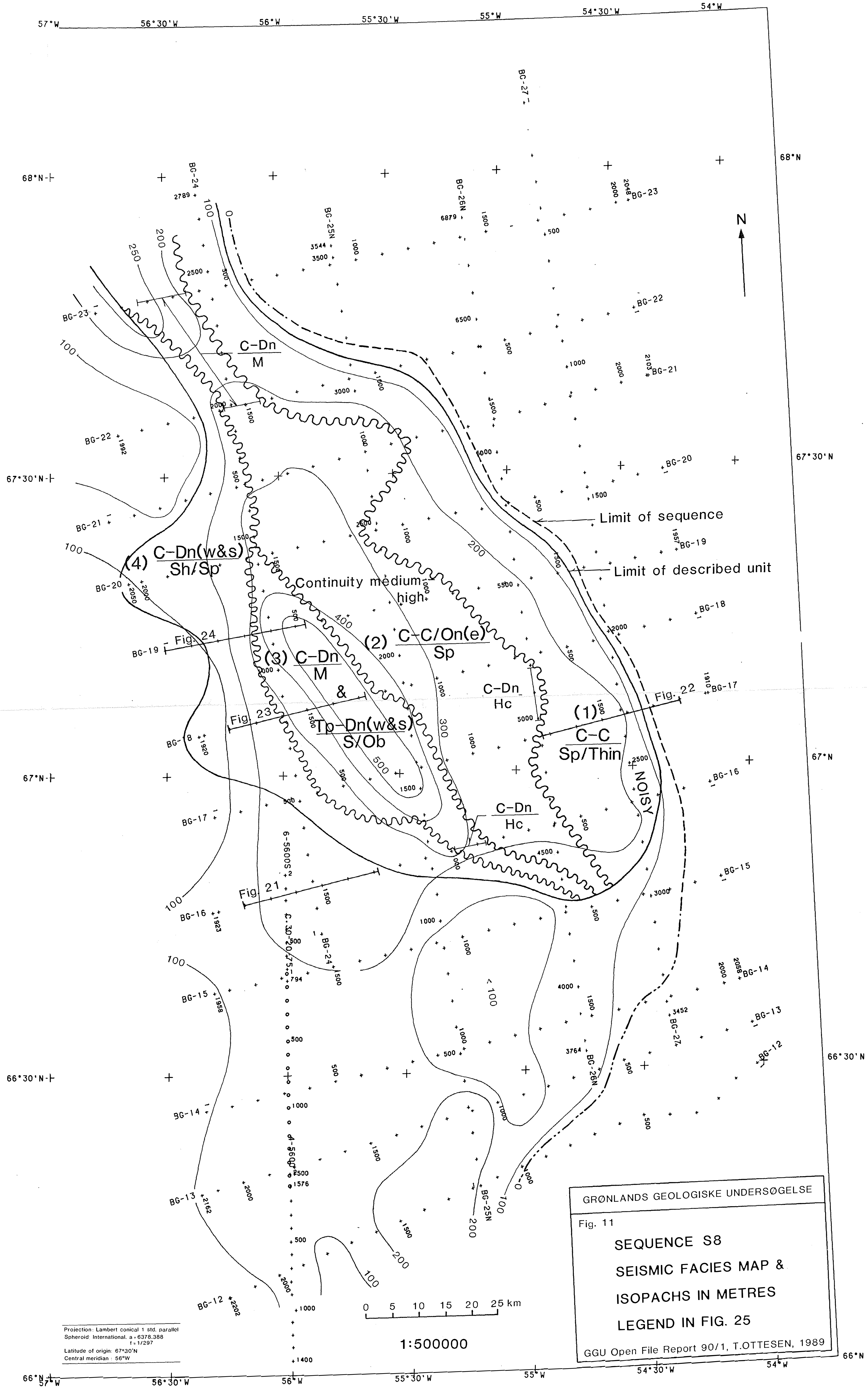
ISOPACHS IN METRES

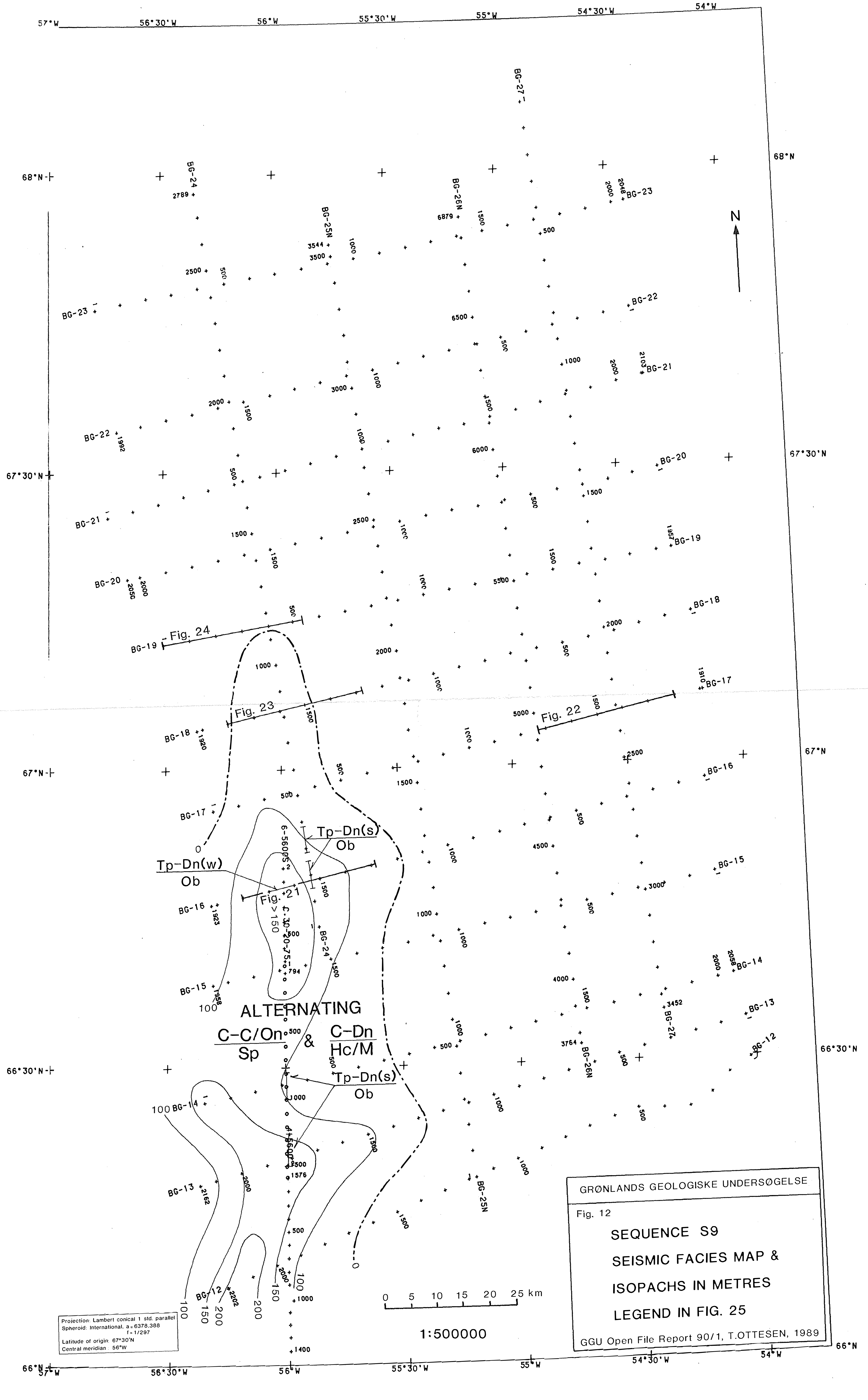
LEGEND IN FIG. 25

GGU Open File Report 90/1, T.OTTESEN, 1989

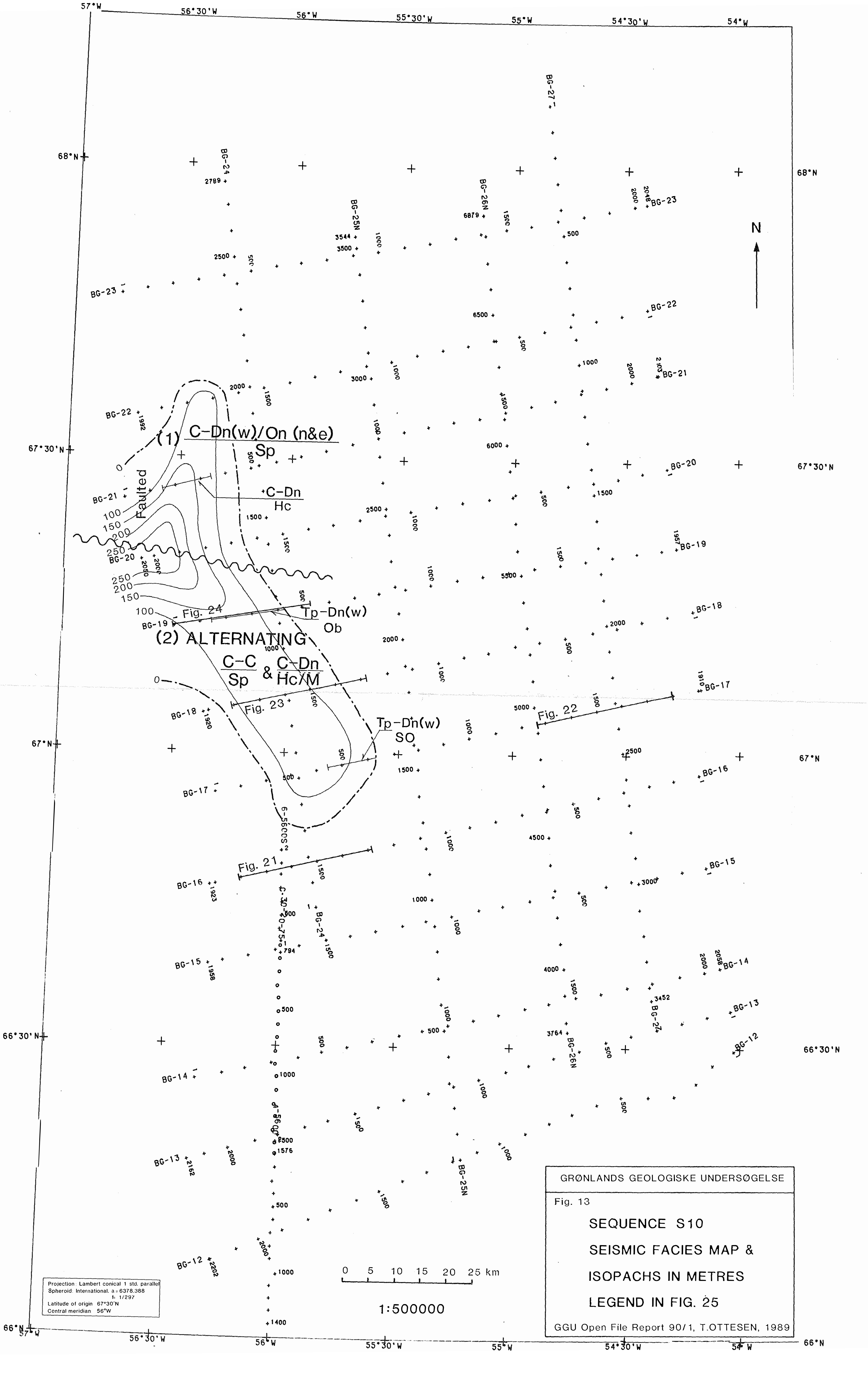


57°W
56°30'W
56°W
55°30'W
55°W
54°30'W
54°W
68°N
67°30'N
67°N
66°30'N
66°N
N
Limit of sequence
Limit of described unit
C-Dn
Hc
(1) C-C
Sp/Thin
C-Dn (w)
Sp
(2) Tp-Dn (w&s)
S
C-Dn (s&w)
Sp
Fig. 21
Fig. 22
Fig. 23
Fig. 24
Projection: Lambert conical 1 std. parallel
Spheroid: International, a = 6378.388
f = 1/297
Latitude of origin: 67°30'N
Central meridian: 56°W
0 5 10 15 20 25 km
1:500000
GRØNLANDS GEOLOGISKE UNDERSØGELSE
Fig. 10
SEQUENCE S7
SEISMIC FACIES MAP &
ISOPACHS IN METRES
LEGEND IN FIG. 25
GGU Open File Report 90/1, T.OTTESEN, 1989


N
Limit of sequence
Limit of described unit
Continuity medium-high
(1) C-C / Sp/Thin
(2) C-C/On(e) / Sp
(3) C-Dn / M & Tp-Dn(w&s) / S/Ob
(4) C-Dn(w&s) / Sh/Sp
C-Dn / M
C-Dn / Hc
NOISY
Fig. 21
Fig. 22
Fig. 23
Fig. 24
0 5 10 15 20 25 km
1:500000
Projection: Lambert conical 1 std. parallel
Spheroid: International, a = 6378,388 f = 1/297
Latitude of origin: 67°30'N
Central meridian: 56°W
GRØNLANDS GEOLOGISKE UNDERSØGELSE
Fig. 11
SEQUENCE S8
SEISMIC FACIES MAP &
ISOPACHS IN METRES
LEGEND IN FIG. 25
GGU Open File Report 90/1, T.OTTESEN, 1989



57°W
56°30'W
56°W
55°30'W
55°W
54°30'W
54°W
68°N
67°30'N
67°N
66°30'N
66°N
N
BG-19
BG-20
BG-21
BG-22
BG-23
BG-24
BG-25N
BG-26N
BG-27
BG-18
BG-17
BG-16
BG-15
BG-14
BG-13
BG-12
Fig. 24
Fig. 23
Fig. 22
Fig. 21
Tp-Dn(s)
Ob
Tp-Dn(w)
Ob
>150
ALTERNATING
C-C/On
Sp
&
C-Dn
Hc/M
Tp-Dn(s)
Ob
0
100
150
200
0 5 10 15 20 25 km
1:500000
Projection: Lambert conical 1 std. parallel
Spheroid: International, a=6378.388 f=1/297
Latitude of origin: 67°30'N
Central meridian: 56°W
GRØNLANDS GEOLOGISKE UNDERSØGELSE
Fig. 12
SEQUENCE S9
SEISMIC FACIES MAP &
ISOPACHS IN METRES
LEGEND IN FIG. 25
GGU Open File Report 90/1, T.OTTESEN, 1989



GRØNLANDS GEOLOGISKE UNDERSØGELSE

Fig. 13

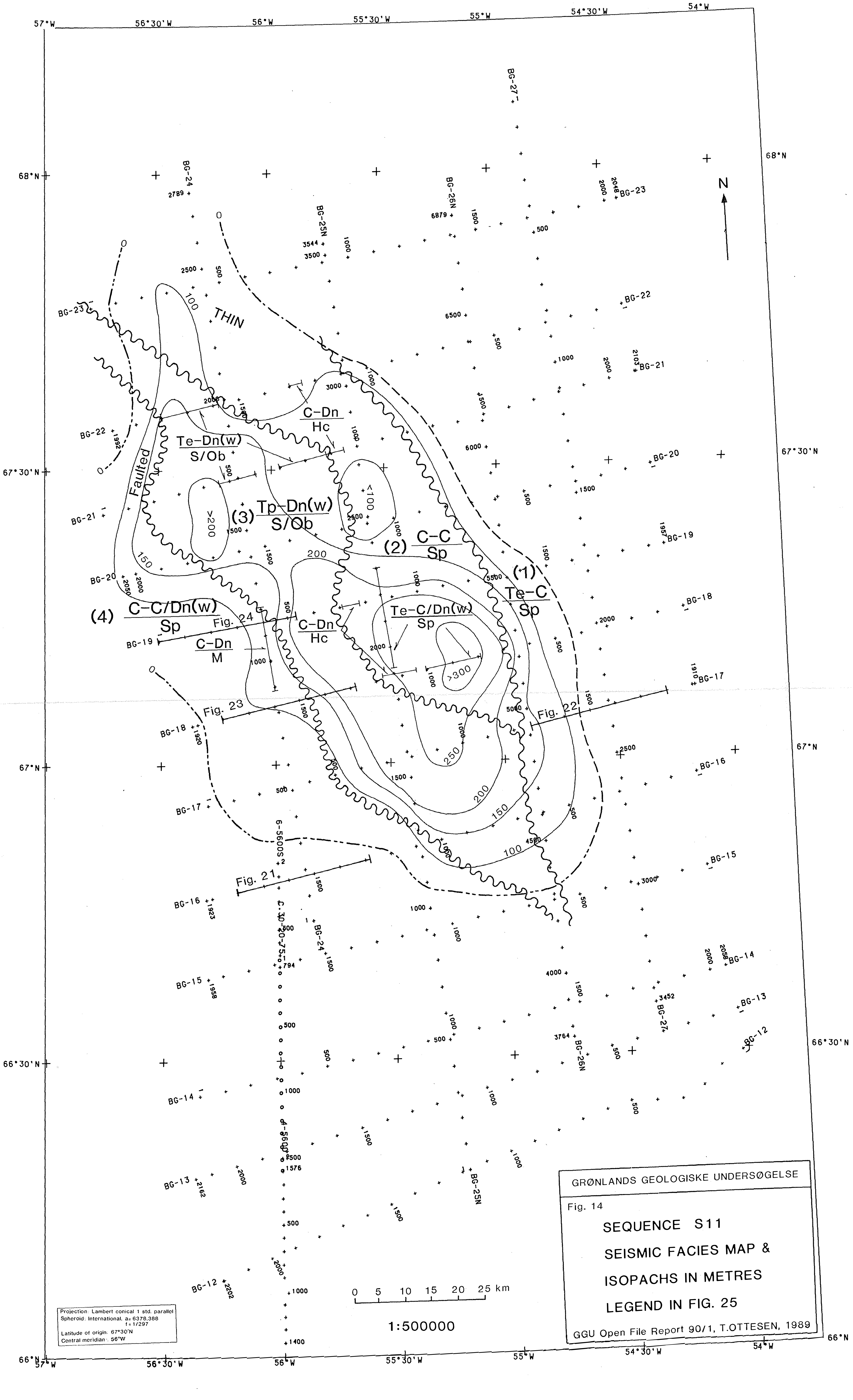
SEQUENCE S10

SEISMIC FACIES MAP &

ISOPACHS IN METRES

LEGEND IN FIG. 25

GGU Open File Report 90/1, T.OTTESEN, 1989



GRØNLANDS GEOLOGISKE UNDERSØGELSE

Fig. 14

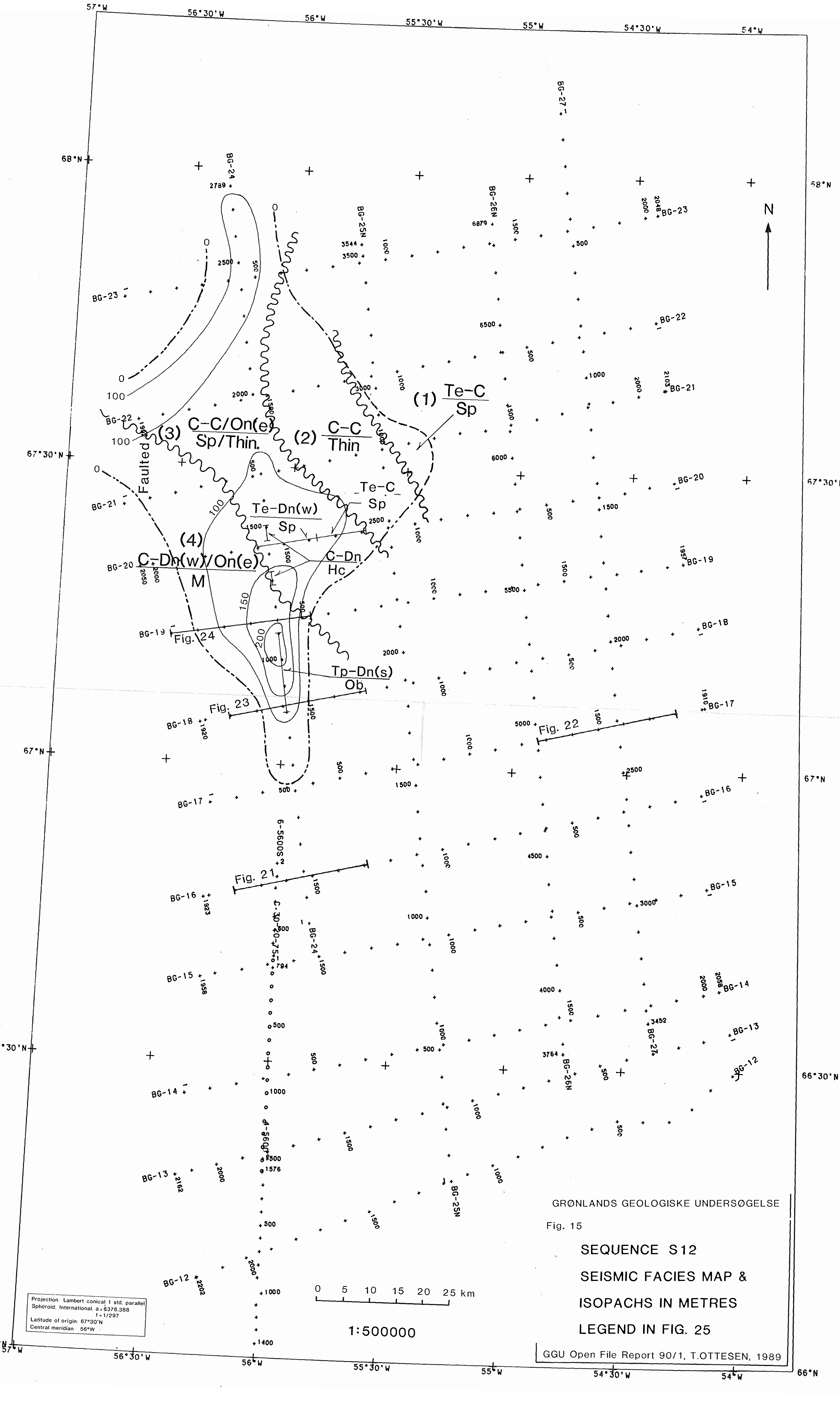
SEQUENCE S11

SEISMIC FACIES MAP &

ISOPACHS IN METRES

LEGEND IN FIG. 25

GGU Open File Report 90/1, T.OTTESEN, 1989



GRØNLANDS GEOLOGISKE UNDERSØGELSE

Fig. 15

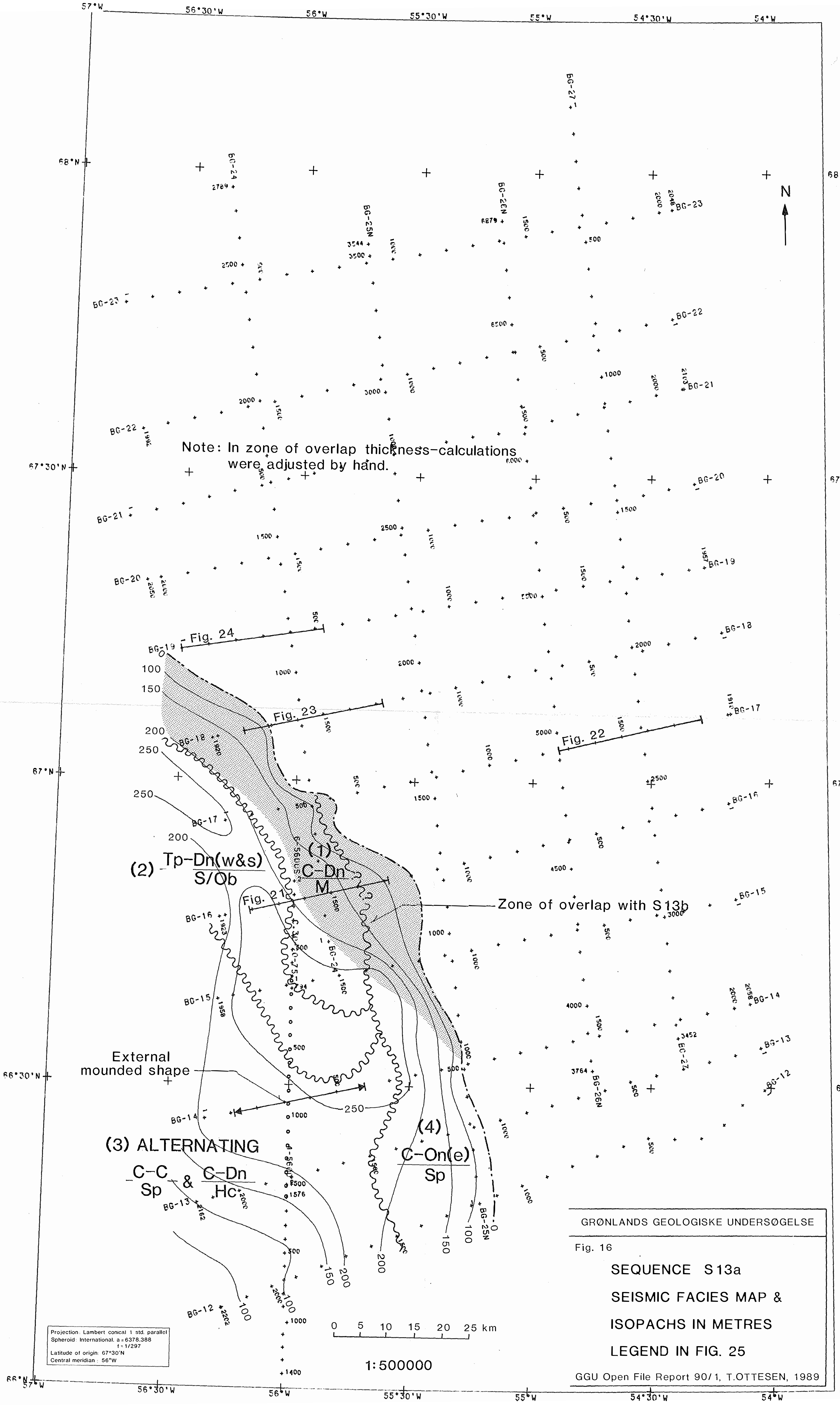
SEQUENCE S12

SEISMIC FACIES MAP &

ISOPACHS IN METRES

LEGEND IN FIG. 25

GGU Open File Report 90/1, T.OTTESEN, 1989

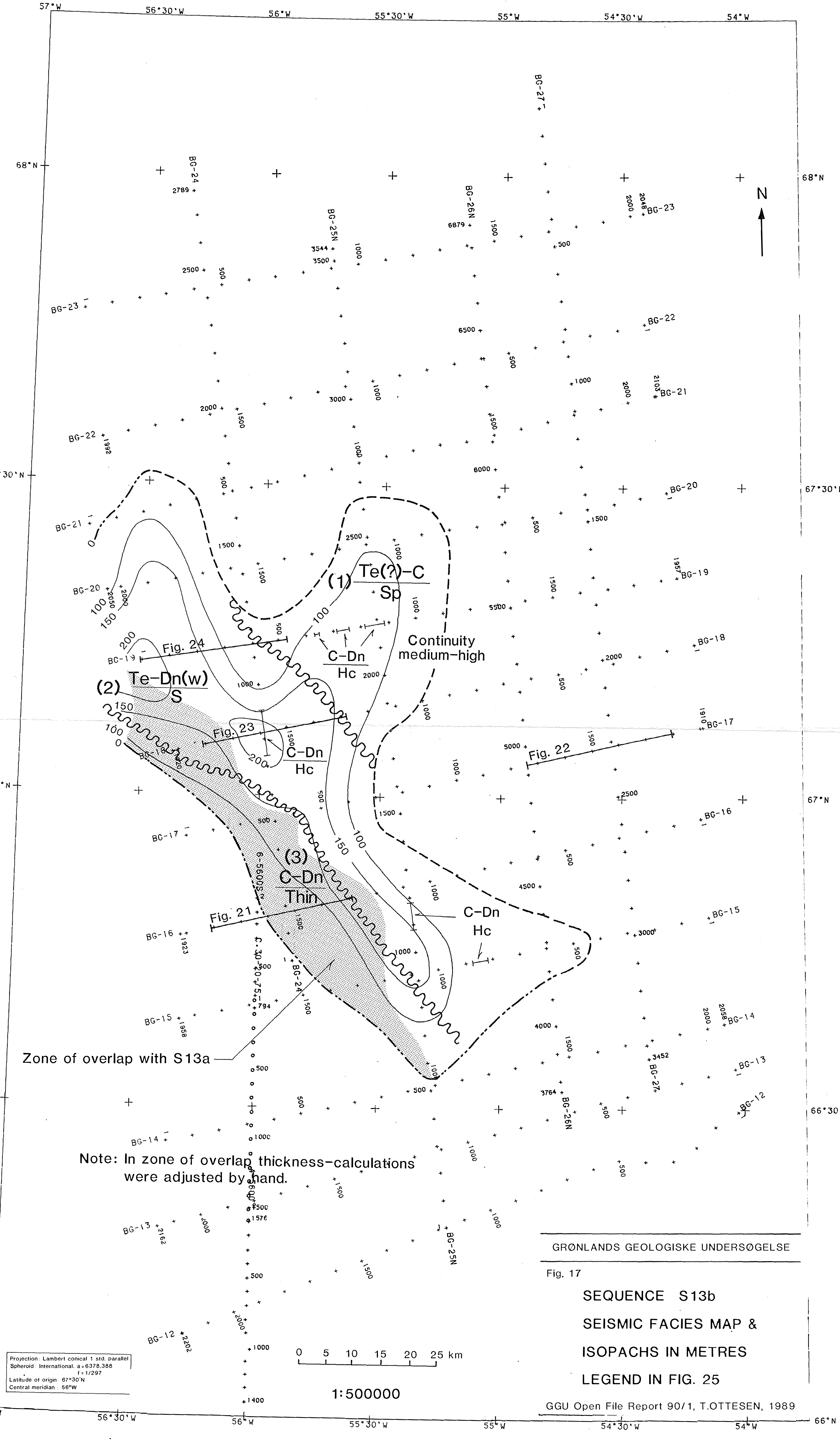


GRØNLANDS GEOLOGISKE UNDERSØGELSE

Fig. 16

SEQUENCE S13a
SEISMIC FACIES MAP & ISOPACHS IN METRES
LEGEND IN FIG. 25

GGU Open File Report 90/1, T.OTTESEN, 1989

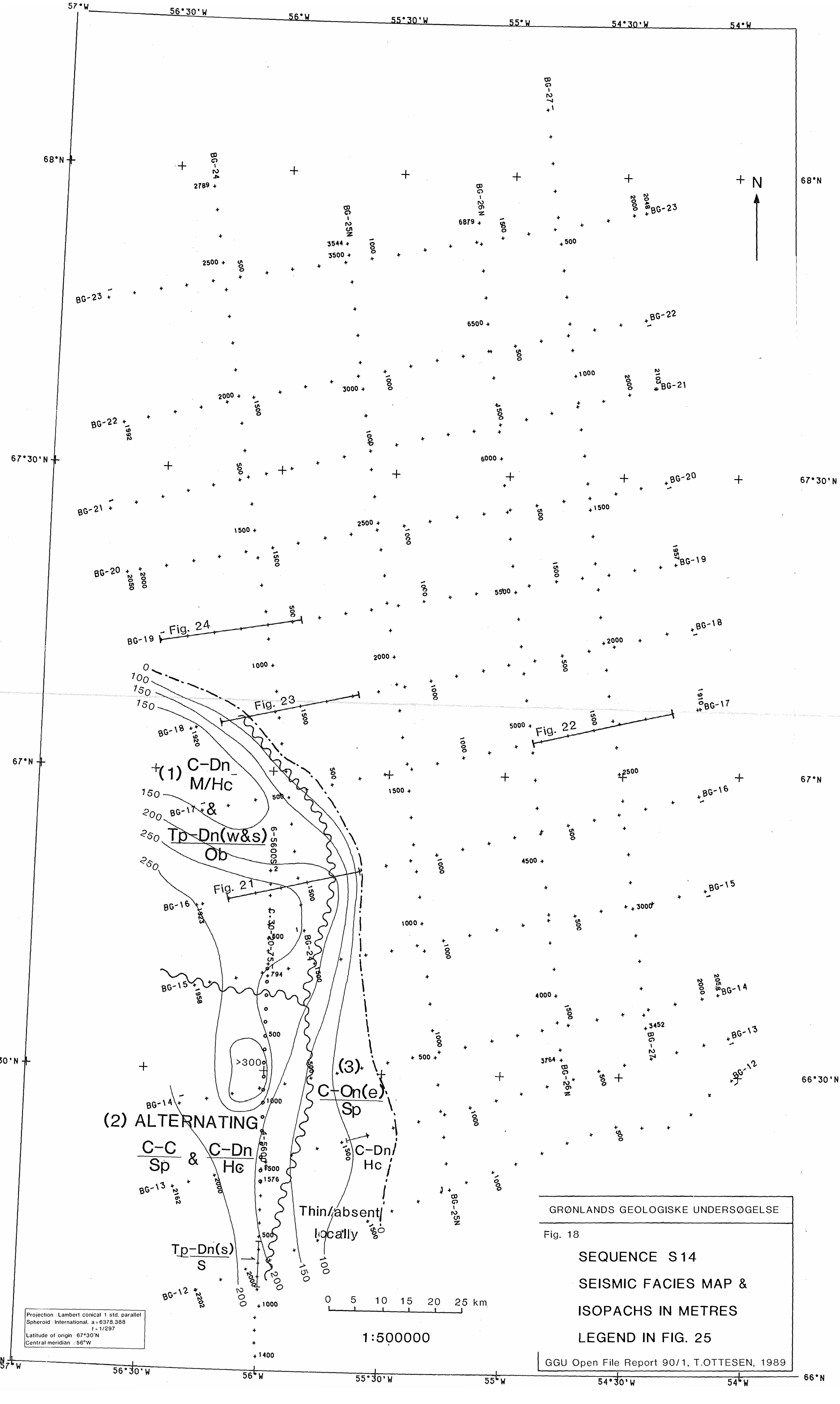


GRØNLANDS GEOLOGISKE UNDERSØGELSE

Fig. 17

SEQUENCE S13b
SEISMIC FACIES MAP &
ISOPACHS IN METRES
LEGEND IN FIG. 25

GGU Open File Report 90/1, T.OTTESEN, 1989



GRØNLANDS GEOLOGISKE UNDERSØGELSE

Fig. 18

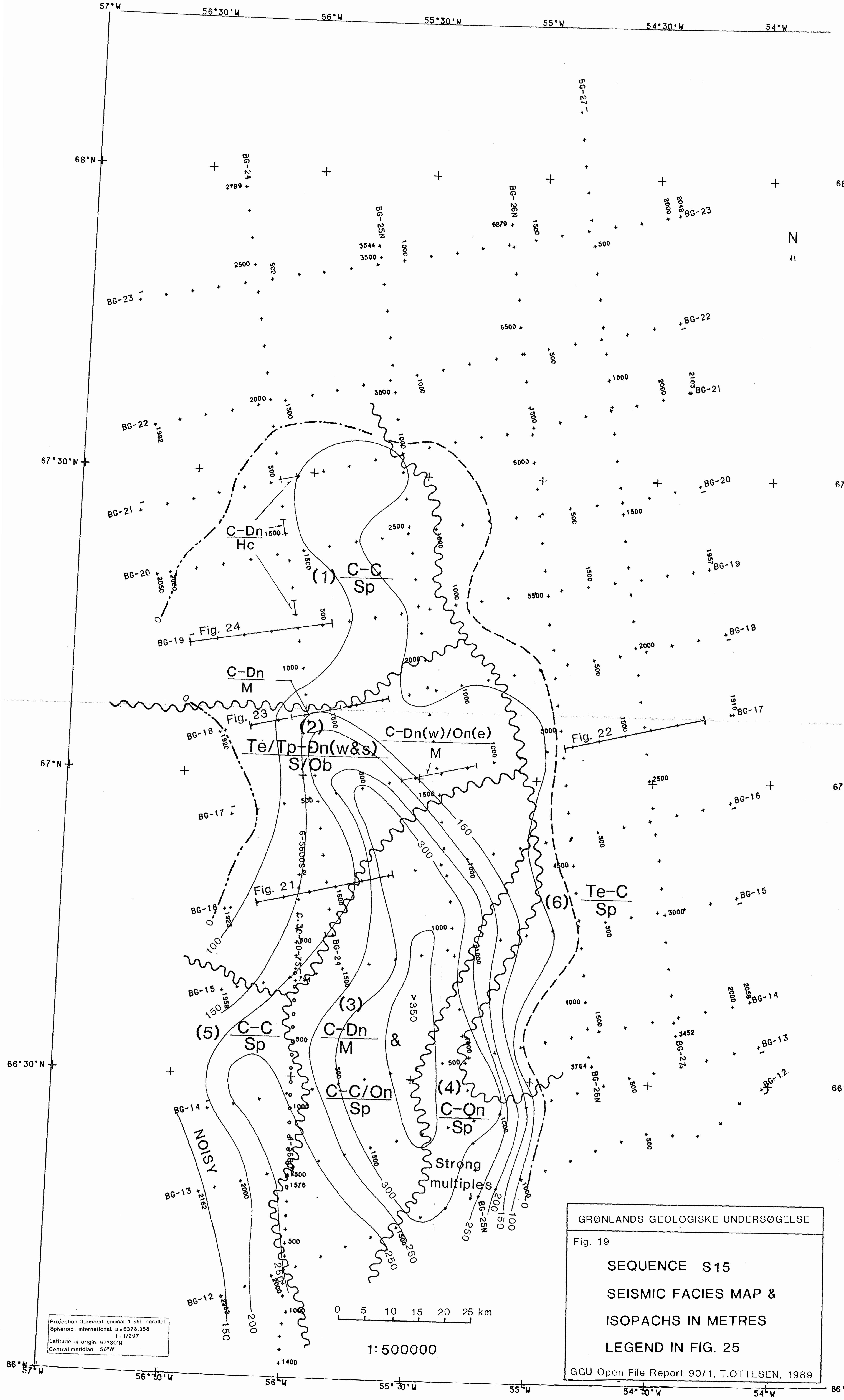
SEQUENCE S14

SEISMIC FACIES MAP &

ISOPACHS IN METRES

LEGEND IN FIG. 25

GGU Open File Report 90/1, T.OTTESEN, 1989



GRØNLANDS GEOLOGISKE UNDERSØGELSE

Fig. 19

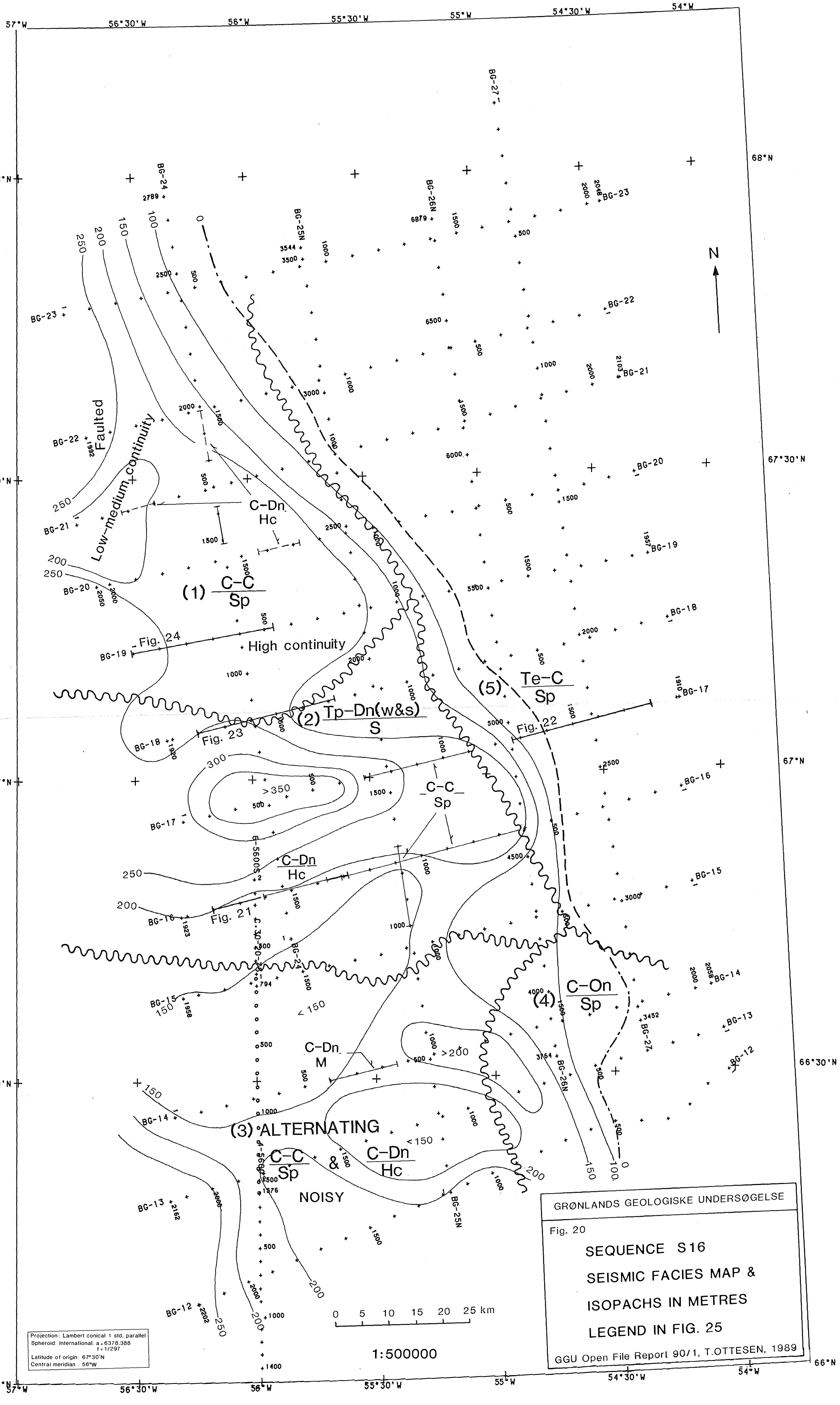
SEQUENCE S15

SEISMIC FACIES MAP &

ISOPACHS IN METRES

LEGEND IN FIG. 25

GGU Open File Report 90/1, T.OTTESEN, 1989



GRØNLANDS GEOLOGISKE UNDERSØGELSE

Fig. 20

SEQUENCE S16

SEISMIC FACIES MAP &

ISOPACHS IN METRES

LEGEND IN FIG. 25

GGU Open File Report 90/1, T.OTTESEN, 1989

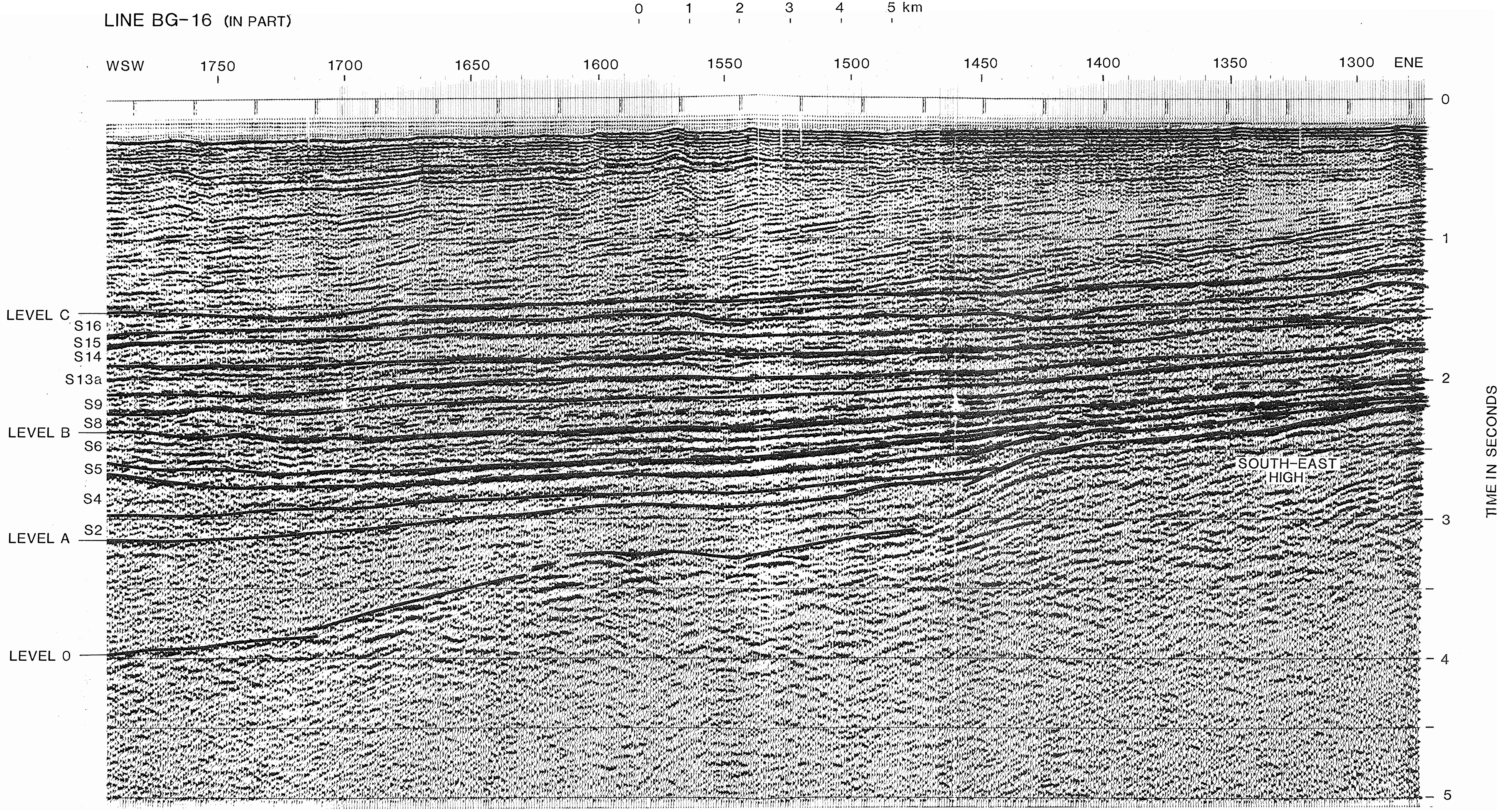


Fig. 21, comments

S16: Strongly downlapped top - Level C. Westwards downlap/progradation interrupted by hummocky clinoforms. Multiples associated with overlying inclined surfaces possibly present.

S15: Westwards downlap/progradation. Channel cut (?), sp. 1400-1450. Hummocky clinoforms and/or noise present. Facies shift from base to top, sp. 1300 and eastwards.

S14: Eastwards onlap, flat climbing mounds (?), sp. 1400-1450. Alternating hummocky clinoforms and subparallel configurations.

S13a: Sp. 1440-1630., separate or stacked constructional mounds with almost transparent interior. S13b constitutes the upper thin part.

S9: Alternating hummocky clinoforms and subparallel configuration; hummocky clinoforms especially clear, sp. 1470-1505. Eastwards thinning by onlap.

S8: Acute angled westwards downlap onto boundary to the 4th (lower) unit, which is marked by a broken line.

S6: Description in terms of complex configuration not very obvious here. Strong reflections.

S5, S4, S2 and section below Level A: Onlap onto South-east High. Rather noisy.

South-east High: Likely to be in part of volcanic origin; volcanism may be associated with upfaulting of this high. It is at present not clear to what extent the pattern within the high represents prograding volcanics and to what extent what we see are reverberating reflections and diffractions associated with faulting.

Below Level 0: Likewise it is not clear whether Precambrian basement is overlain by volcanics or sediments, or whether diffractions and reverberating reflections solely form the apparent reflection pattern.

FIG. 22 GGU Open File Series 90/1

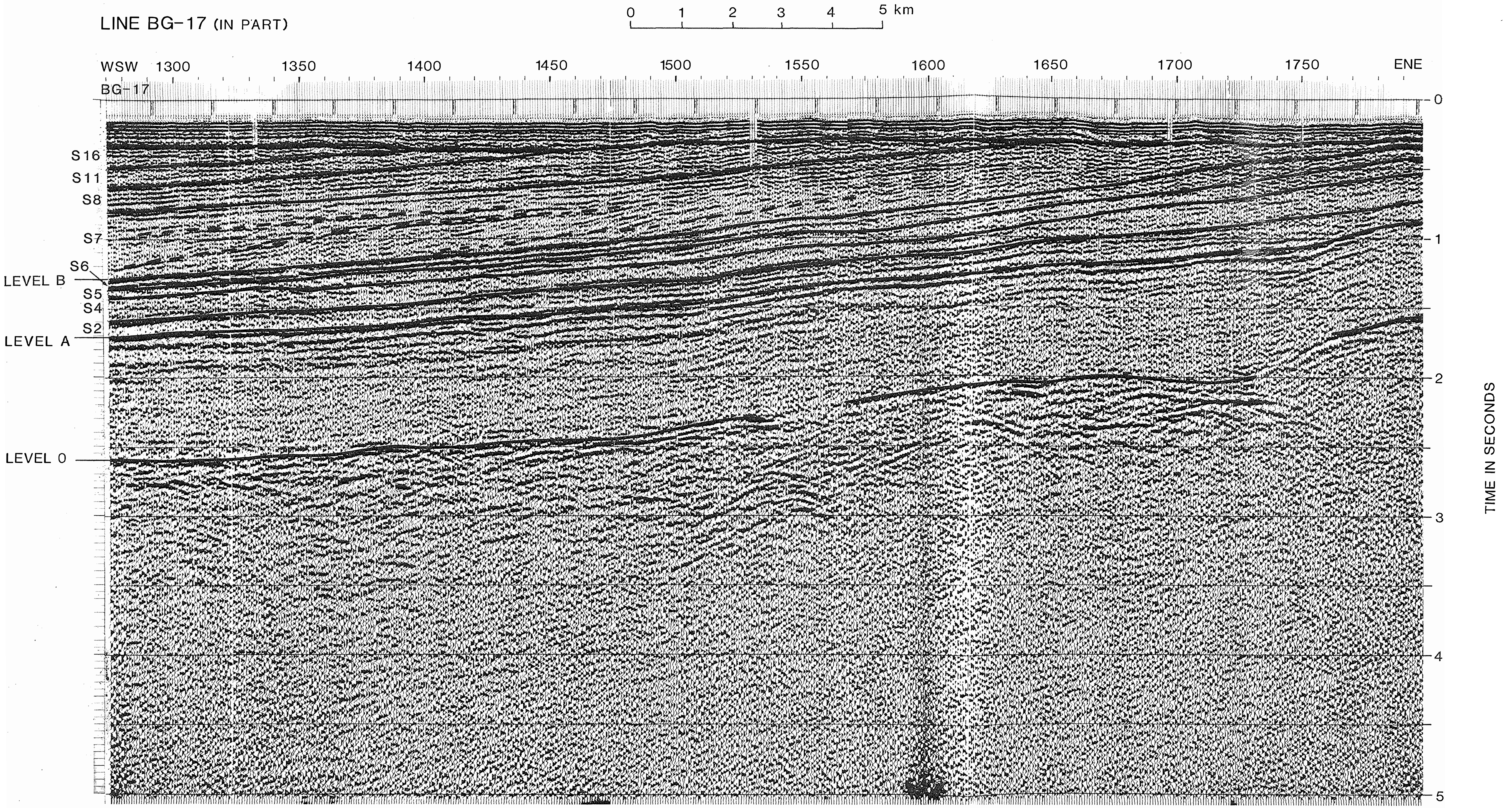


Fig. 22, comments

S16, S11, S8, S7: Erosional truncation at a level close below the present seabed. The exact level is not known due to strong multiples. Farther east S6, S5 and S4 suffer the same fate.

S7: Westwards progradation. Broken lines mark boundaries of separate but mutually similar units forming the sequence.

Level B: Strongly downlapped.

S2: Eastwards onlap, most clear to the east of sp. 1750.

Below Level A: Subdivision into an upper highly reflective part and a lower more transparent part.

Below Level O: Diffractions indicate widespread faulting. Volcanics overlying older sediments or Precambrian basement are a possible additional cause of the complex pattern.

FIG. 23 GGU Open File Series 90/1

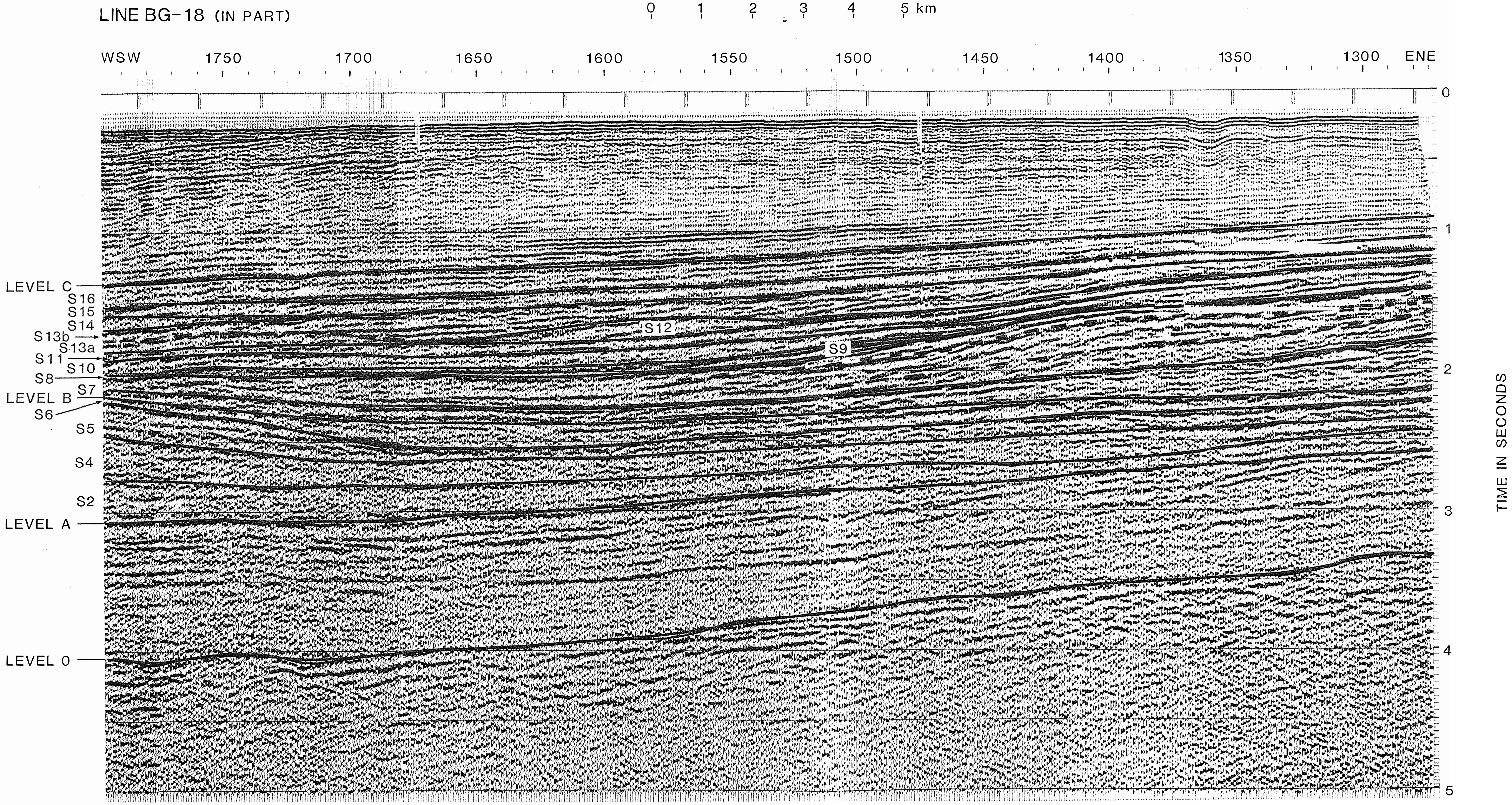


Fig. 23, comments

S15: Channel cut (?), sp. 1330-1360. Flat mounds and westwards progradation

S13b: Strong westwards progradation; prograding clinoforms possibly eroded.

S13a: Mixed hummocky clinoforms and mounded configuration. S13a is possibly contemporary to S12.

S12: Large, single constructional mound. S12 is possibly contemporary to S13a.

S11: Westwards progradation in the east.

S10: Eastwards onlap; local mounds and hummocky clinoforms.

S8: Boundaries between separate units are shown by broken lines. Large constructional mounds with associated westwards progadation in middle unit; less distinct in lower unit.

S7: Westwards progradation in the east.

Level B: Strongly downlapped by reflectors of S7.

S6: Mounds and hummocky clinoforms and/or disrupted reflectors with diffractions.

S5: Hummocky clinoforms and mounds, thickens by updoming to the west, where eastwards downlap occurs.

S4: Broad constructional mound containing smaller mounds, sp. 1360-1510, with associated westwards progradation. Updoming and eastwards downlap in the west.

S2: Westwards progradation, though rather noisy. Updoming not pronounced.

Below Level A: Subdivision into an upper highly reflective part with inclined reflectors and a lower more transparent part.

Below Level O: The apparent presence of reflections suggest volcanics overlying older sediments or Precambrian basement, though diffractions and reverberated reflections are quite probably present.

FIG. 24 GGU Open File Series 90/1

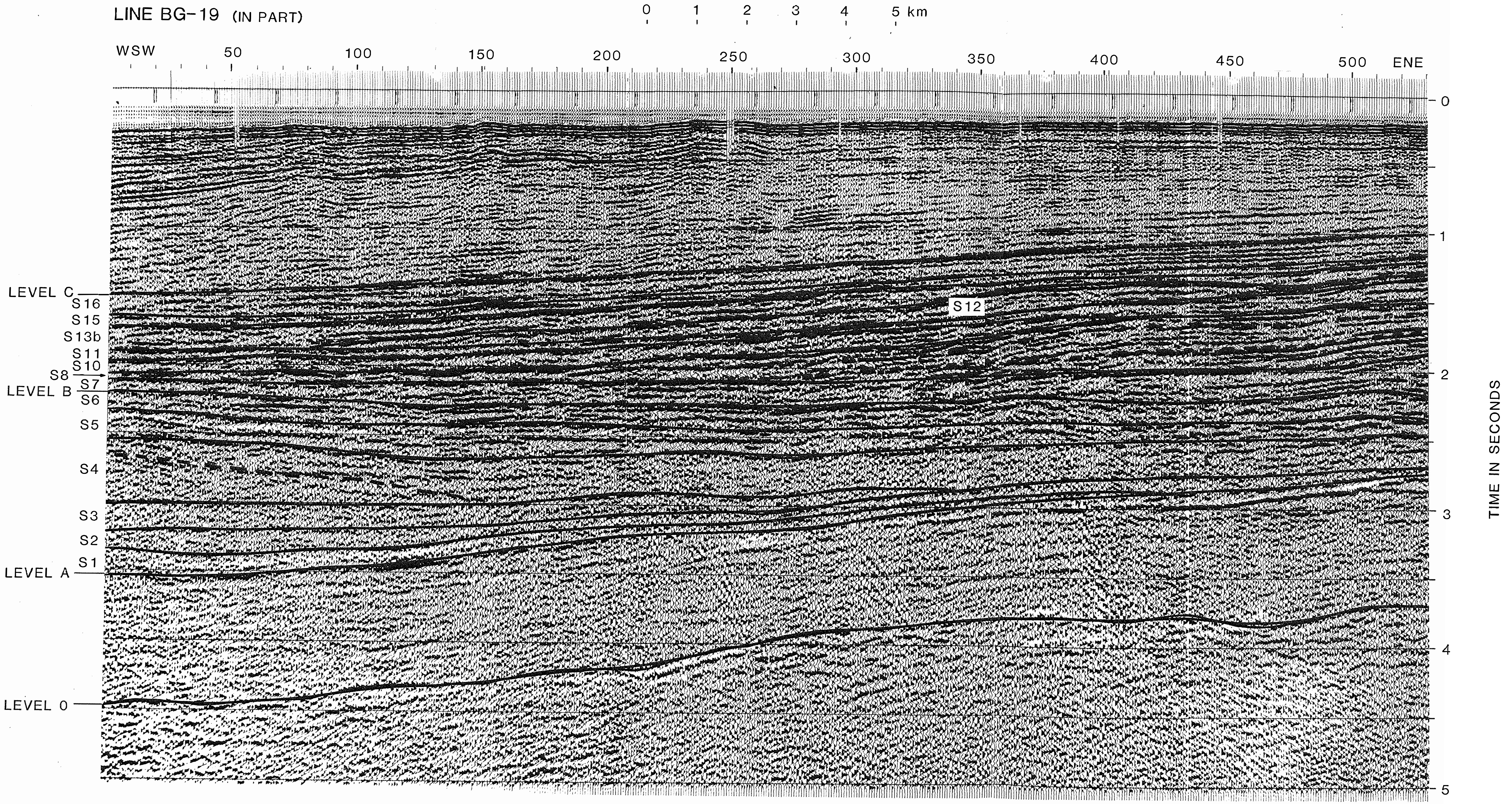


Fig. 24, comments

S13b: Westwards progradation.

S12: Broad constructional mound, sp. 320-460; elsewhere smaller mounds.

S10: Westwards progradation across climbing mounds sp. 300-360.

S8: Boundaries between separate, similar units are shown with broken lines. Constructional mound with associated westwards progradation, most distinct in lower unit sp. 520 and westwards.

S6 and S5: Sp. 330-400, stacked constructional mounds with noisy area below. Possibly a volcanic mound with some associated progradation. Configuration elsewhere is generally a complex blend of mounds, hummocky clinoforms and progradation.

S4: Updoming to the west. Onlap onto internal boundary, which is marked by a broken line; rather noisy.

S3: Westwards progradation, noisy.

S2 and S1: Noisy, boundaries not very well defined.

MAP LEGEND

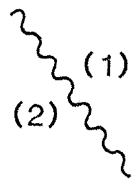
SEQUENCE LIMITS:

Erosion Limit

Onlap Limit

Downlap Limit

AREA LIMIT:



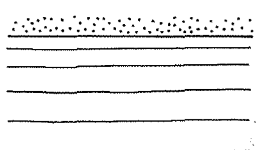
SEISMIC FACIES DESCRIPTION:

The ABC-notation:

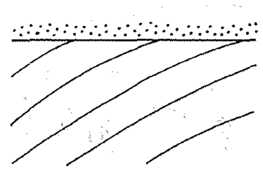
Above – Below
Configuration

A, GEOMETRIC RELATION AT UPPER SEQUENCE BOUNDARY:

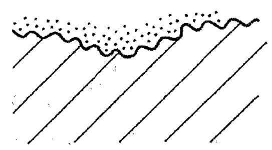
Concordance (C)



Toplap (Tp)

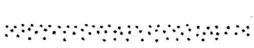


Erosional truncation (Te)

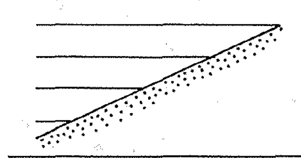


B, GEOMETRIC RELATION AT LOWER BOUNDARY:

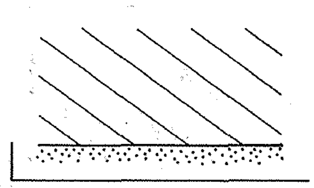
Concordance (C)



Onlap (On)

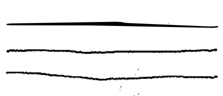


Downlap (Dn)

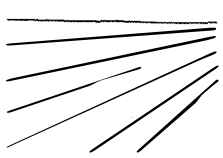


C, INTERNAL REFLECTOR-CONFIGURATION:

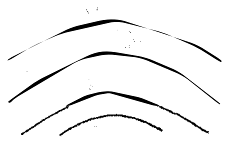
Subparallel (Sp)



Divergent (Div)

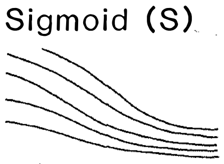


Mounded (M)

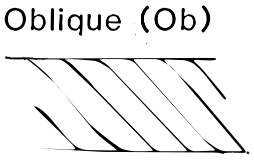


Hummocky clinoforms (Hc)

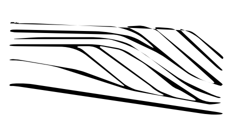
Sigmoid (S)



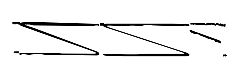
Oblique (Ob)



Sigmoid-Oblique (SO)



Shingled (Sh)



ISSN 0903-7322