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FINAL TECHNICAL REPORT

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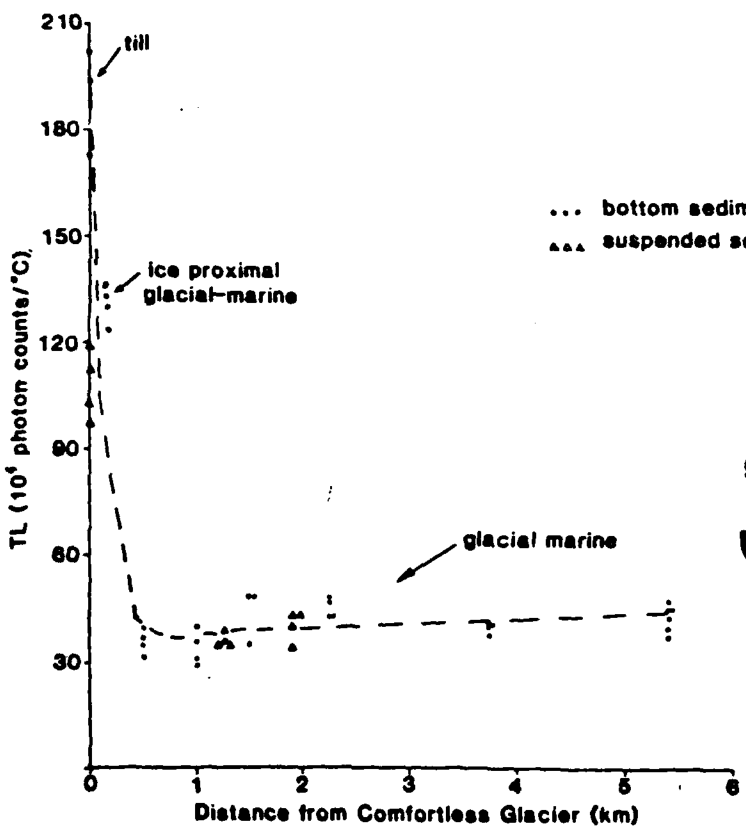
Entitled:

CHARACTERIZATION OF SEDIMENT AND SEDIMENTARY PROCESSES BY THERMOLUMINESCENCE LEVEL IN THE FJORD AND SHELF ENVIRONMENT OF WESTERN SPITSBERGEN, SVALBARD

Principal Investigator: Steven L. Forman
Institute of Arctic and Alpine Research
University of Colorado, Boulder CO 80309-0450

November 15, 1988

Engelskbukta Modern Sediments at 230°C



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This study explored the relationship between high Arctic depositional environments and the natural thermoluminescence (TL) signal of sediments. The energy and duration of light during deposition controls the TL level of silicate mineral grains in the sediment. The results indicate that the TL signal of sediments is proportional to the distance from a glacier sediment-source and to water depth in the littoral/sublittoral zone. The highest TL levels are from tills or ice-shelf sediments, which receive little or no light exposure with deposition. Intermediate TL levels are associated with ice-proximal environments; lower and consistent TL levels are recorded for glacial-marine muds collected from fiord and shelf areas. The TL of sediments decreases away from the glacier sediment source because of longer light exposure with slower rates of deposition. The lowest TL levels are for littoral and sublittoral sediments which receive extended light exposure with shoaling. The relative TL signal of sediments is a new tool for deciphering the source of sediment, particularly in environments proximal to a glacier terminus and in shallow water, less than 15 m deep.

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ABSTRACT

This study explored the relationsip between high Arctic depositional environments and the natural thermoluminescence (TL) signal of sediments. The energy and duration of light exposure during deposition controls the TL level of silicate mineral grains in the sediment. The results indicate that the TL signal of sediments is proportional to the distance from a glacier sediment-source and to water depth in the littoral/sublittoral zone. The highest TL levels are from tills or ice-shelf sediments, which receive little or no light exposure with deposition. Intermediate TL levels are associated with ice-proximal environments; lower and consistent TL levels are recorded for glacial-marine muds collected from fiord and shelf areas. The TL of sediments decreases away from the glacier sediment source because of longer light exposure with slower rates of deposition. The lowest TL levels are for littoral and sublittoral sediments which receive extended light exposure with shoaling. The relative TL signal of sediments is a new tool for deciphering the source of sediment, particularly in environments proximal to a glacier terminus and in shallow water, less than 15 m deep.

OBJECTIVE OF RESEARCH

This research focussed on testing the hypothesis that thermoluminescence (TL) properties of glacial-marine sediments in the fiord and shelf environments of western Spitsbergen, Svalbard and possibly other glaciated coastlines is a sensitive indicator of sedimentary environment. The TL signal of mineral grains is acquired from the exposure to ionizing radiation from the radioactive decay of the uranium and thorium series and potassium-40. The thermoluminescence signal of buried minerals increases with age. Thus, bedrock and Quaternary sediment eroded and transported by glaciers, without exposing the mineral grains to light, has a relatively high TL signal. This acquired TL signal is substantially reduced with exposure to sunlight. This reduction in the TL level of silicate mineral grains is primarily controlled by the duration, intensity and spectrum of light exposure during transport and deposition of sediment.

Turbid water condition in the glacial-marine environment substantially reduces the penetrating light intensity and attenuates wavelengths (Jerlov, 1976). This reduced spectra is only capable of partially bleaching sediments (cf. Berger et al, 1984; Forman et al, 1987). Therefor, it is hypothesized that tills and ice proximal sediments that are rapidly deposited and are exposed to little (<1 hr) or no light and thus have relatively high TL levels. Fiord muds (ice distal deposits) receive longer light exposure albeit attenuated by turbidity and exhibit intermediate to low TL levels. Near-shore sediments, receive extended light exposure during re-suspension by tidal currents and thus have the lowest TL levels. The reported results generally support the above hypotheses, but the TL properties of sediments has less resolution at deeper water depths than originally speculated.

SAMPLING FOR SEDIMENTS

Sediment from two different areas were sampled for TL studies: 1) Modern sediments from two fiords on western, Spitsbergen. 2) A core from the outer shelf of Cumerland Sound, off of southern Baffin Island. Analysis of the the modern sediments provides key data to ascertain the relationship between depositional environments and sediment TL level. The preliminary analysis of core material gives new insight into the utility of TL in core studies.

The two fiords on western Spitsbergen, Engelskbukta and part of Kongsjorden have been sampled for TL analysis. Sediments were sampled with an Eckman bottom grab sampler, from a 20 ft launch. We also attempted to retrieve undisiturbed sediments by coring with a 10 cm diameter gravity core. Core recovery was poor because of high pore water content of the sediment. Suspended sediment samples were also collected from a number of grab stations. Core tops from 2 or

3 cores from deeper shelf environments have recently become available for TL analyses. The bottom grab and coring epuipment was provided by Woods Hole Oceanographic Institute at no cost to this project.

After the sediment was brought to the surface it was immediately placed in light tight containers. The sediment received approximately <5 seconds light exposure during containment, which has neglible effect on TL properties. A total of 59 samples were collected for TL analysis (Table 1).

The un-x-rayed half of core HU85 029 was sampled for TL analysis. This core was retrieved from 814 m water depth from the mouth of Cumberland Sound, Baffin Island, Canada (65° 02.57′ N, 64° 59.51′ W). Approximately 1.5 cm cubes of material were removed from the core at various levels (Figure 1). An internal unlight exposeded sediment was used in the TL analysis.

SEDIMENTOLOGIC CONTEXT OF ANALYZED SAMPLES

Samples from Engelskbukta were collected from sedimentary environments characteristic of high Arctic glaciated coasts (Figure 2). Specifically, till and ice-proximal sediments associated with Comfortless glacier were sampled as well as glacial-marine muds deposited up to 6 km beyond the ice margin. In addition the littoral and sublittoral zone sediments were collected for TL analyses.

Table 1: **TL Samples from Svalbard 1988**

Blomstrandbreen, Kongsfjorden MODERN

Sample #	Water Depth M
FL88-30	0 beach
FL88-31	21 mud
FL88-32	4 sublit.
FL88-33	17 mud
FL88-34	14 peb. mud
FL88-35	34 mud
FL88-36	27 mud
FL88-38	37 mud
FL88-39	49 peb. mud
FL88-40	71 mud

Sample #	Water Depth M
FL88-41	22 mud
FL88-42	11 mud
FL88-43	22 mud
FL88-44	5 mud
FL88-45	13 mud
FL88-46	11 mud
FL88-47	0 till

Engelskbukta MODERN

Sample #	Water Depth M
FL88-300	37 mud
FL88-301	60 mud*
FL88-302	55 mud
FL88-303	34 mud
FL88-304	62 mud
FL88-305	68 mud*
FL88-306	88 mud*
FL88-307	78 mud
FL88-308	0 susp.
FL88-309	0 beach
FL88-310	0 beach
FL88-311	1 sublit
FL88-312	1 sublit*
FL88-313	3 sublit
FL88-314	6 mud
FL88-315	22 mud
FL88-316	8 mud
FL88-317	6 mud
FL88-318	21 mud
FL88-319	15 mud

Sample #	Water Depth M
FL88-320	10 mud
FL88-321	1 susp.
FL88-322	41 mud
FL88-355	till
FL88-356	3 mud*
FL88-357	3 mud*
FL88-358	3 susp.
FL88-359	27 susp.
FL88-360	27 mud*
FL88-361	18 mud
FL88-362	26 mud
FL88-363	26 susp.
FL88-364	82 mud*
FL88-365	1 susp.
FL88-366	80 mud
FL88-367	30 mud
FL88-368	51 mud
FL88-369	6 mud
FL88-370	6 mud
FL88-371	2 mud
FL88-372	5 mud
FL88-373	2 mud

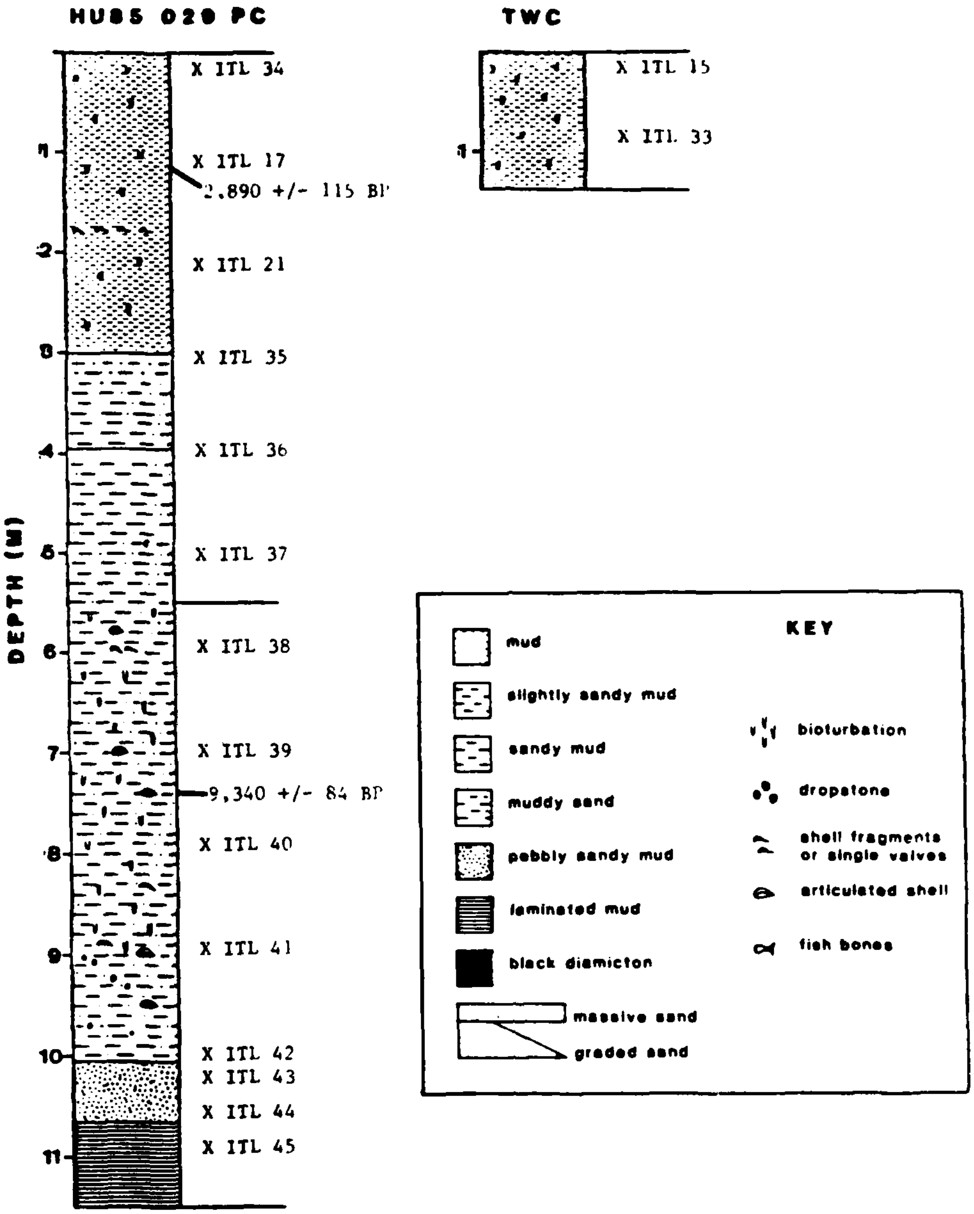

Figure 1: Log of core HU85 029 with location of sediment sampled for TL analyses.

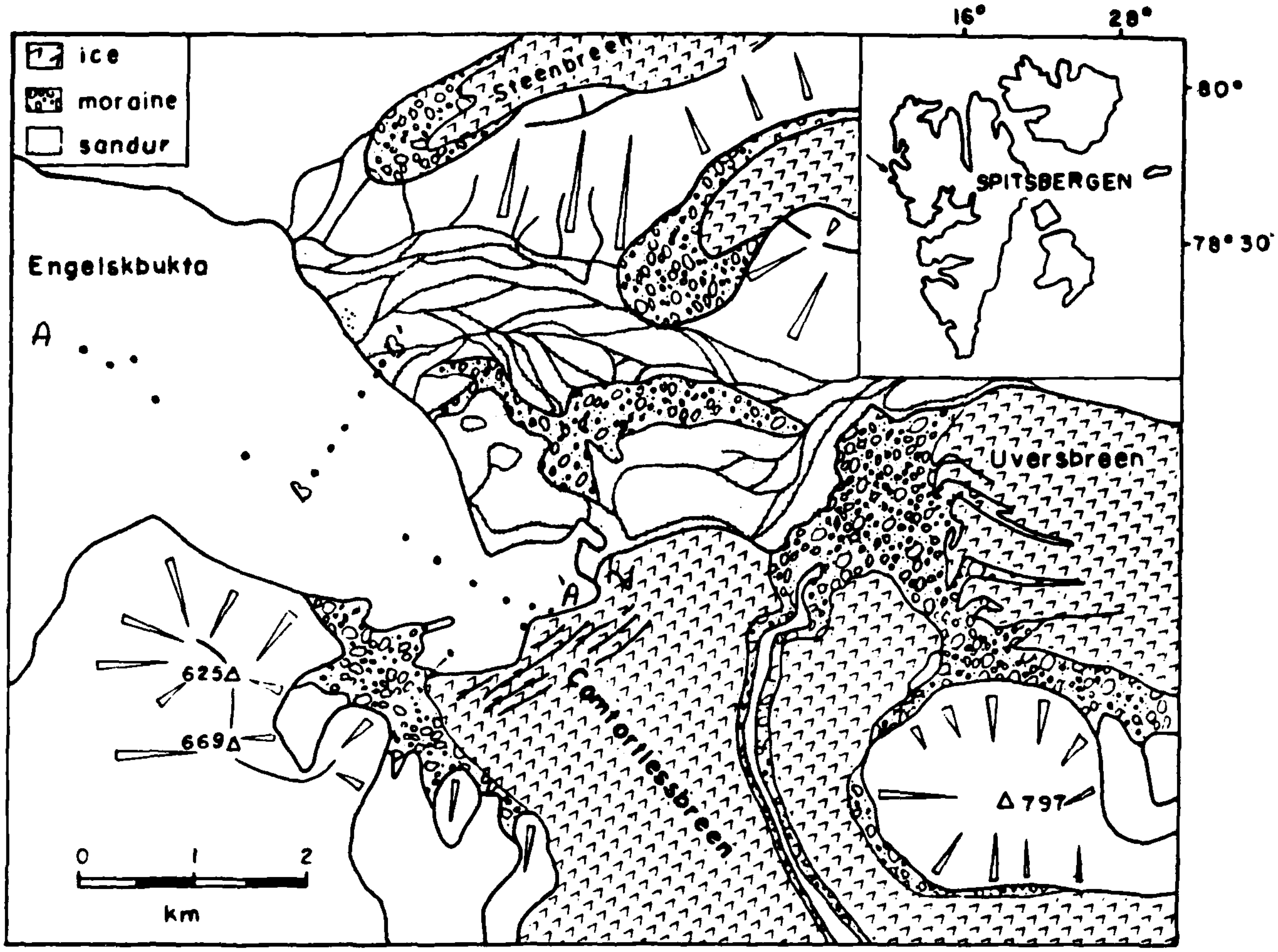

Figure 2: Map of the fiord, Engelskbukta with approximate location of sampling stations.

Samples analyzed from core HU85 029 span a deglacial sequences deposited in the last ca. 15 ka (Jennings, unpublished data). The base of the core penetrates a laminated clay-mud devoid of microfauna which is interpreted as sediment deposited beneath an ice shelf. The overlying unit is a sandy-pebbly mud, and is inferred to be an ice-proximal glacial-marine mud. Above this ice proximal unit the sediment fines upward and exhibits typical "glacial" fauna. This relatively homogenous and thick middle-unit of the core is a ice-distal glacial marine mud deposited during the deglacial phase 10 to 8 ka ago. The core is capped by 3 meters of post-glacial diatomaceous mud.

LABORATORY PROCEDURES

The samples were washed in 10% HCl to remove carbonate and regent grade hydrogen peroxide to oxidize out all organics. The 5-11 μm silicate minieral fraction was separated and deposited onto clean aluminum discs. The TL of samples was measured by a "Daybreak" reader using an EMI 9635A photomultiplier tube fitted with a Chance-Pilkington HA-3 heat absorbing filter and a Corning 5-58 filter. The dominant blue emissions were selected for TL analyses. Samples were heated at a rate of 5°C/second in an argon environment after initial evacuation of the glow oven.

In order to compare the thermoluminescence response of difference samples, discs were normalized to each other by the following procedure: (1) after initial glowing all discs received a second beta dose of 2.2 Gy (gray = 100 rads); (2) glowing of discs was delayed >2 hrs; and (3) the area between 15C and 300 °C of second dose glow curve was used to normalize the TL signal of the initial glow.

Uranium and thorium content was determined by thick-source alpha counting with the Th content estimated by counting slow-pairs (Huntley and Wintle, 1981). Comparison of sealed and unsealed alpha counts indicates that most samples exhibited little or no radon loss. Atomic absorption spectrophotometry provided %K for K-40 concentrations.

RESULTS: MODERN FIORD SEDIMENTS

The TL values of the collected sediments vary systematically from the glacier to the outer fiord (Figure 3). The till from the basal zone of Comfortless glacier yielded the highest TL level, nearly 6 times that of a glacial-marine mud. Ice-proximal sediments within a few 100 meters of the glacier front have relatively high TL levels approximately midway between values for the till and glacial-marine silt. A similar TL level were obtained on suspended sediment from a meltwater stream on the margin of Comfortless glacier. These relatively elevated TL values from the till, ice-proximal sediments and meltwater sediments indicate that sediment deposited at or near

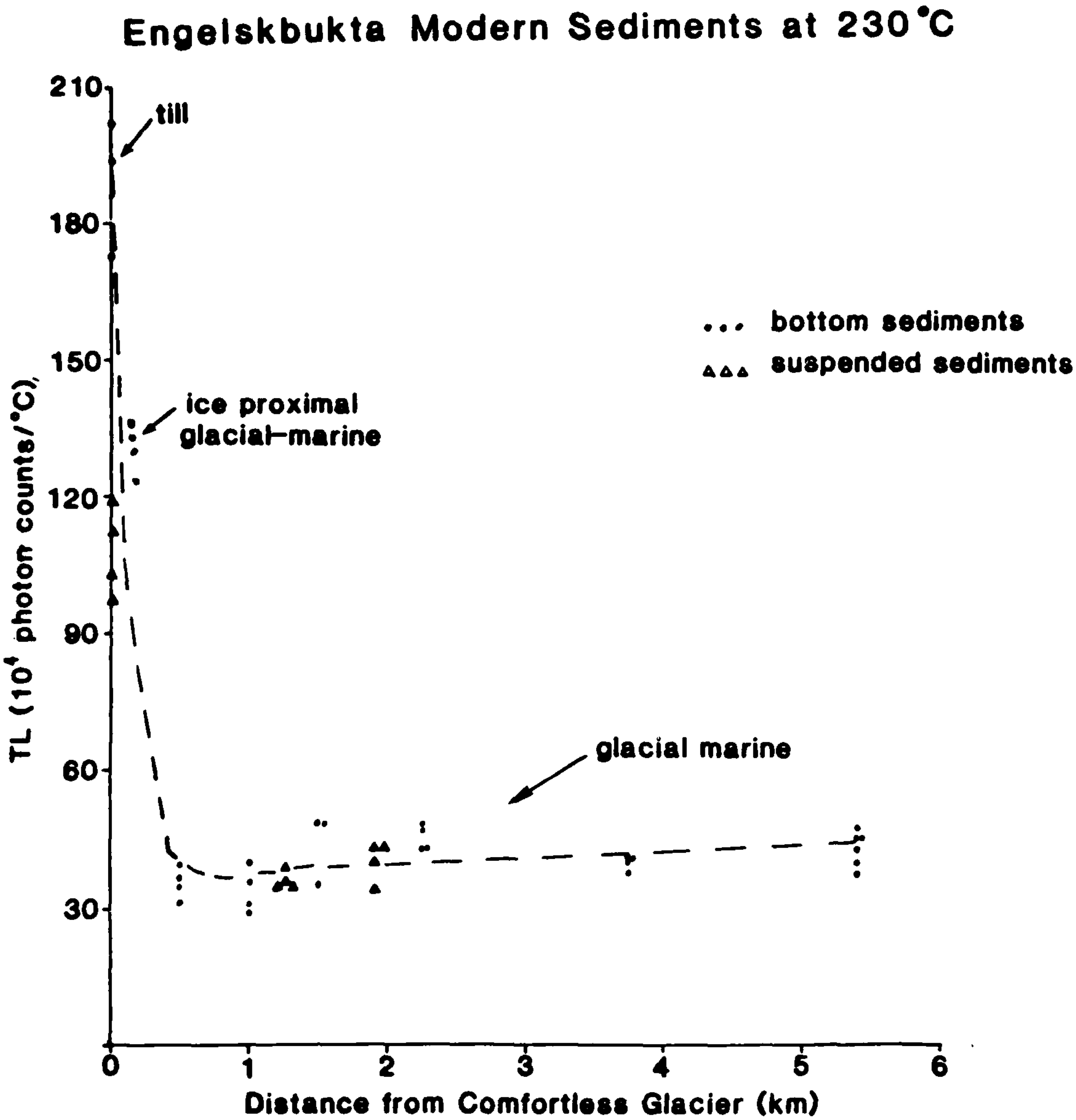

Figure 3: Natural TL reponse of samples collected along Transect A-A' of Figure 2. Shows decrease of TL signal of sediment from a glacier sediment source to the fiord/shelf environment.

a glacier front receives brief if any, light exposure. However, the ice proximal deposit and meltwater sediment have lower TL levels than the till suggesting that some reduction in TL signal does occur during short term aqueous transport.

Glacial-marine sediment from 0.5 to 5 km beyond the ice margin, as well as corresponding suspended sediment samples exhibited similar TL values. The TL of sediment is reduced to a moderate level and maintains that level out-fiord and on to the shelf. The spectra penetrating surface turbid water can only reduce the TL of the suspended sediment to a certain level irregardless of the length of exposure. This data suggest that the turbid water conditions in Engelskbukta are at a threshold for reducing the TL signal in sediments.

The lowest TL levels are for sediment collected from the littoral and sublittoral zones (Figure 4). The TL level of sediments increase at water depths >15 m, beyond the influence of shoaling. Similar results were reported by Forman (1988). Resuspension of sediment in the littoral and sublittoral zone gives additional light exposure of the sediment high in the water column, further reducing the TL signal. These sediments probably receive higher intensity and shorter wavelength light exposure than deeper fiord sediments.

RESULTS: BAFFIN SHELF CORE

This core exhibits changes in TL intensity related to

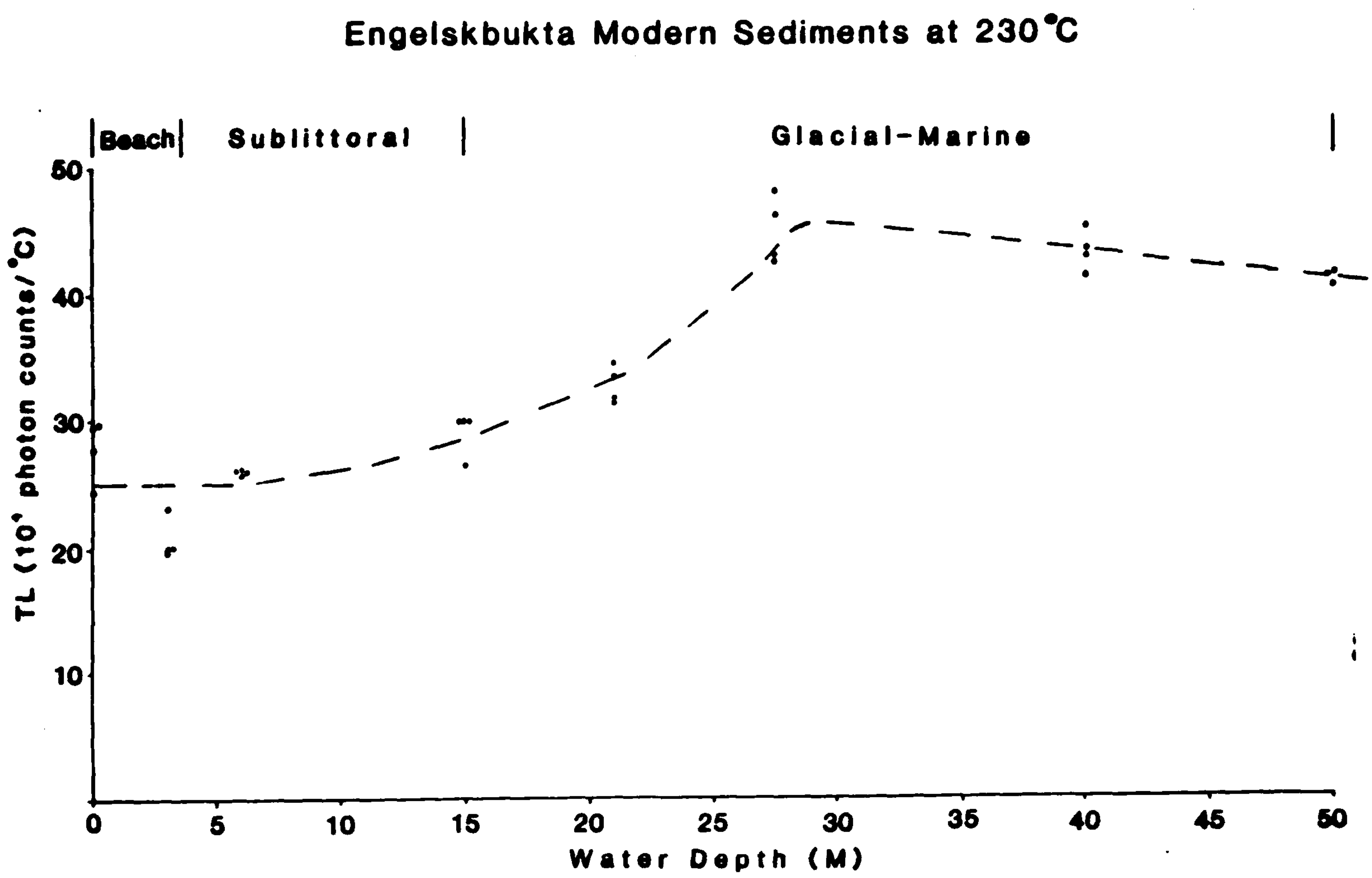

Figure 4: Natural TL response of samples collected from Transect B-B′ of Figure 2. Documents the decrease in TL signal in the sublittoral and littoral zone.

inferred changes in depositional environments (Figure 5). The highest TL values are for a laminated mud unit at the base of the core, tentatively interpreted as sediment deposited beneath an ice shelf. This unit has elevated TL levels because the sediment receives little if any light exposure with ice cover over the site and adjacent areas. Lower but still relatively high TL levels were determined for a pebbly-sandy mud immediately above the laminated unit. The pebbly sand mud unit is interpreted as an ice-proximal deposit; the relatively high TL level is compatable with this interpretation.

The TL of the remainder of core is relatively homogenous and low with values between 3 and 4 x 10^7 photon counts/°C. These low values are associated with deglacial marine and late Holocene diatomaceous muds. The majority of these sediments were probably deposited from hypocynal flows in seasonally ice-free seas.

The radioacitivity (dose rate in Grays/year) of the sediment decreases substantially down core (Figure 6). This reduction in radioactivity excentuates the documented trends.

DISCUSSION AND CONCLUSIONS

These results indicate that the relative TL level of sediments can provide valuable information to infer sedimentary environments. The highest TL levels are associated with tills or ice shelf sediments which receive little or not light

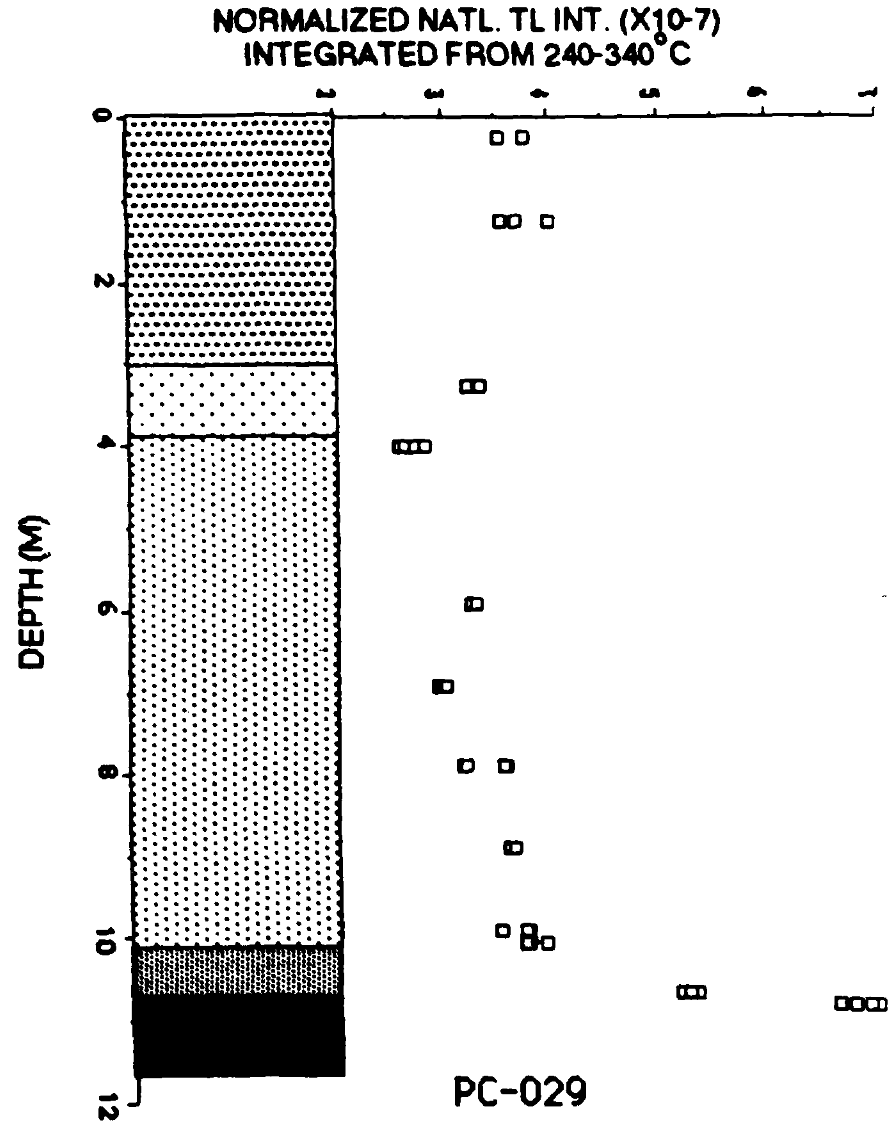

Figure 5: Natural TL signal of sediment from core HU85 029. Highest TL levels are at the base of the core from a sediment probably deposited beneath an ice-shelf.

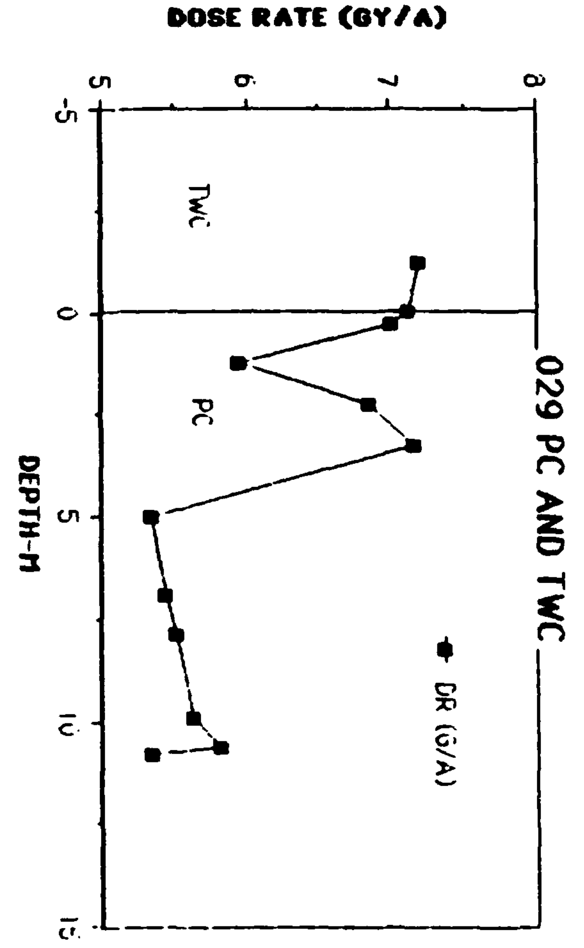

Figure 6: Natural radioactivity (Grays/year) of TL samples from core HU85 029. This trend in radioactivity accentuates the reported TL signal in Figure 5.

exposure during deposition. Intermediate to high TL levels are associated with ice-proximal environments. Sediment in close proximity to a glacier source are rapidly deposited and receive relatively brief (< 1hr) light exposure under turbid water condition. Intermediate and consistent TL signals are characteristic of glacial-marine muds, which are exposured to relatively weak wavelengths in a turbid water environment. The lowest TL signals are associated with shallow water deposits in the littoral and sublittoral zone. Sediment within the zone of shoaling and breaking waves are repeatedly resuspended high in the water column and thus have ample opportunity for the reduction in the TL signal from extended light exposure.

The relative difference between ice proximal/ice-shelf sediments and glacial marine sediments in core HU85 029 is similar to the differences between the modern till/ice-proximal deposits and glacial-marine mud in Engelskbukta. This similarity in relative response suggest that TL analysis may have broad applications in deciphering depositional environments in many other glaciated coastal areas. The TL signal is particularly sensitive indicator for ice-proximal and sublittoral/littoral environments. The relative TL response of sediments provides new information for interpreting the proximity to a glacier sediment source and to the zone of shoaling.

This additional knowledge of the natural variability in the TL signal of glacial and marine sediments provides important insight for the temporal application of the TL technique. This research suggests that glacial-marine sediments in fiord and shelf environments and littoral/ sublittoral sediments are appropriate materials for TL dating. The TL technique can date sediments deposited in the last 200,000 years and is particulary useful for sediments deposited between 40,000 to 100,000 years ago, beyond the range of radiocarbon dating.

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