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Age and extent of the Yermak Slide north of Spitsbergen, Arctic Ocean

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[1] The extent of the Yermak Slide has been revised on the basis of new acoustic and detailed bathymetric data. The true geometry, with an affected area of at least 10,000 km^2 and more than 2400 km^3 of involved sedimentary material, puts the Yermak Slide among the largest exposed submarine slides worldwide, comparable to the Storegga Slide off central Norway. Details from the side's internal structure give evidence for one main slide event during MIS 3 followed by repeated minor events. The timing coincides with the transition of the Kapp Ekholm Interstadial into Glaciation G of Svalbard (Mangerud et al., 1998) and the buildup phase of the Svalbard-Barents Sea Ice Sheet. Thus the slide occurred during a period of falling sea level, increasing ice volume, and, presumably, increasing glaciotectonic activity. The side's geometry and internal physical appearance point to a tectonically induced partial shelf collapse.

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1. Introduction

[2] Submarine slides (or submarine landslides) play a significant role among the variety of sediment transport processes from continental margins to deep sea environments. By moving large amounts of sediment masses, they are not only an effective mechanism to transport sediment to the abyssal plains, but they are also a substantial hazard to seafloor infrastructure and are able to create tsunamis that have far-reaching consequences. On Europe's continental margins, a number of slides have been discovered by side-scan sonar imaging and detailed bathymetric mapping, ranging from small-scale features to megascale events like the Storegga Slide off Norway, which affected some 95,000 km^2 of the seafloor and involved about 2,400–3,200 km^3 of sediment [e.g., *Vogt et al.*, 1999c; *Mienert and Weaver*, 2002, and references therein; *Haflidason et al.*, 2004]. Three of these slides have been chosen to be studied in more detail within the ESF EUROMARGIN project "Slope Stabilities on Europe's passive continental Margin" to shed light on the preconditions, trigger mechanisms and geometrical relations of these events. The COSTA project [*Canals et al.*, 2004] has shown that submarine slides are highly variable in size, position and setting, exhibit relations between their geometrical parameters such as headwall height, drop height, run-out distance or total area, and that a trend from carbonate river-fed to glacier-fed continental margins might exist. Geometrical parameters are not yet available for Europe's northernmost identified slide, situated on the glacier-fed, siliciclastic continental margin north of Spitsbergen (Figure 1). This slide was first described by *Cherkis et al.* [1999] and is situated at

the termination of the Hinløpen Strait cross-shelf trough, which hosted an ice stream during glacial times [*Ottesen et al.*, 2005]. The slide has been referred to as the Yermak Slide, according to its position adjacent to the Yermak Plateau, or sometimes as Malene Bukta or Malene Slide according to the submarine embayment of its evacuation area [*Vogt et al.*, 1999b, 1999c; *Haflidason et al.*, 2004]. *Cherkis et al.* [1999] used side-scan sonar images and bathymetric data to determine some of its structures (Figure 2).

2. Physiographic Setting

[3] The surface water circulation around Spitsbergen is characterized by the northward flowing West Spitsbergen Current (WSC) transporting warm and saline Atlantic water into the Arctic Ocean via Fram Strait. Branches of the WSC flush the outer shelf west and northwest of Spitsbergen (North Svalbard Current, NSC) and the Yermak Plateau (Yermak Slope Current, YSC; Yermak Plateau Current, YPC) [*Schlichtholz and Houssais*, 1999a, 1999b]. A counterpart to the WSC, the East Greenland Current (EGC), transports less saline and colder Arctic water into the Greenland Sea (Figure 1).

[4] The archipelago was repeatedly and heavily glaciated during the Weichselian Glacial [*Mangerud et al.*, 1998; *Svendsen et al.*, 2004]. Our investigation area is situated on and close to the shelf north of Spitsbergen and Nordaustlandet. These two present-day islands are separated by a deep geologic structure that has been exploited by glacial erosion to form a cross shelf trough. This Hinløpen cross shelf trough hosted an ice stream during glacial times, and probably also during late Weichselian full glacial conditions [*Ottesen et al.*, 2005]. The termination of the Hinløpen trough is characterized by a number of submarine embayments and slope escarpments [*Cherkis et al.*, 1999; *Vanneste et al.*, 2004]. In contrast to other cross shelf troughs, a trough mouth fan (TMF) is missing. A number of submarine escarpments and headwalls characterize the evacuation area of the Yermak Slide, giving evidence for multiple slope failure events [*Cherkis et al.*, 1999; *Vanneste et al.*, 2004].

[5] In this paper we present new acoustic and detailed bathymetric data that show the first details of the Yermak Slide's internal structure, a much larger extent than previously thought (Figure 2) and the first evidence for a pre-LGM stage of sliding.

3. Material and Methods

[6] Detailed bathymetric data and high-resolution ground-penetrating echo sounding data were acquired by the HYDROSWEEP DS2 and the PARASOUND Hydromap Control systems, respectively, aboard R/V *Polarstern* during cruise ARKXX/3 [*Stein*, 2005]. Additional data from cruise ARKXV/2 of R/V *Polarstern* [*Jokat*, 2000], including marine multichannel seismic profiles (acquired using a 24-liter air gun cluster; see *Geissler and Jokat* [2004] for details), have been compiled to analyze the area of the Yermak Slide. Sediment cores, from carefully selected sites, were retrieved using the gravity or giant gravity corer [*Stein*, 2005]. AMS radiocarbon dating was performed on carbonaceous shells from *Neogloboquadrina pachyderma sin*. at the Leibniz-Laboratory for Radiometric Dating and Isotope Research in Kiel, Germany.

4. Results

[7] PARASOUND sediment-penetrating acoustic data reveal clear differences in the acoustic facies of slide debris and normal hemipelagic glaciomarine sediments. The latter sediments appear as acoustically layered units that permit deep penetration of acoustic waves. The slide related debris is acoustically opaque, revealing no indication of internal structures and almost no penetration of acoustic energy. The absence of internal structures in the PARASOUND imagery (that is, no systematic contrasts in acoustic impedance) points toward a homogeneous debris. This distinction permits a mapping of the slide area, having an inner part within the Sophia Basin and an outer part toward the Nansen Basin (Figure 2).

[8] The inner part of the slide is characterized by a mass of dense acoustically opaque material (presumably over-consolidated silty clays). A number of large blocks, with extents of up to 4 km and relief of more than 300 m above the surrounding hummocky area, are centered within this debris (Figure 2). A coring attempt on the main megablock (Figure 2) resulted in zero recovery [*Stein*, 2005]. Judging from the rope tension protocol, the gravity core must have jumped back from a presumably hard ground. Therefore, and due to their intact shape, they might represent a second and more solid type of lithology in the slide. Large

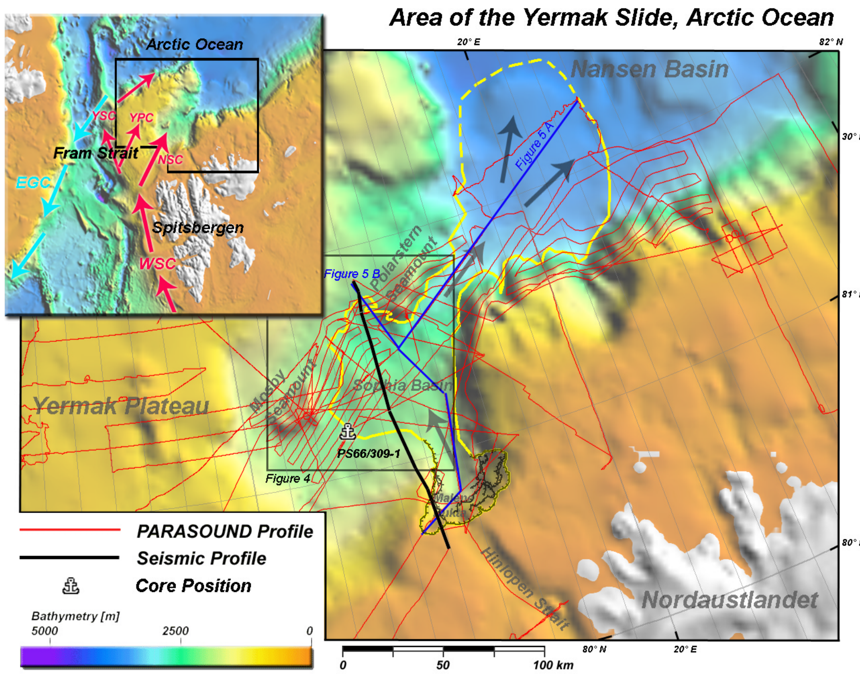

Figure 1. Map of Sophia Basin and the adjacent shelf with position of sediment core PS66/309-1, and PARASOUND and seismic profiles acquired during "Polarstern" Expeditions ARKXV/2 and ARKXX/3. Slide extent according to our study (headwalls partly according to integrated interpretation of *Vanneste et al.* [2004]). Inset map shows surface water circulation in the Fram Strait area (WSC, West Spitsbergen Current; NSC, North Svalbard Current; YPC, Yermak Plateau Current; YSC, Yermak Slope Current; EGC, East Greenland Current). Bathymetry from the International Bathymetric Chart of the Arctic Ocean (IBCAO) [*Jakobsson and IBCAO Editorial Board Members*, 2001].

ridges in front of the blocks suggest that they ploughed up the surrounding debris while traveling, which might point to them having a higher density. Younger debris flows, visible as acoustically transparent units, have been identified in PARASOUND data from some of the topographic depressions in this inner part of the slide (Figure 3). These flows occasionally overlie each other and are likely to correspond to the younger slide scars in the head wall area.

[9] Toward its western margin within the Sophia Basin, the Yermak Slide develops a consistent facies (Figures 3 and 4). Starting from the hummocky slide debris of the inner part of the slide, which appears acoustically opaque and with rough topography, the acoustic character of the slide becomes increasingly transparent, suggestive of debris flows. The marginal debris flows and, presumably, associated turbidites overlie and pinch out into "normal" glaciomarine hemipelagic sediments which appear as acoustically layered sequences (Figure 4). The same hemipelagic glaciomarine silty clay can be found on top of the debris flows/turbidites (Figures 4 and 5). Thus our interpretation is that the slide developed into a debris flow with associated turbidites toward its western margin, in accordance with both theory and lithologic evidence from our cores. According to the PARASOUND data, the marginal debris flows did not develop an erosional character. This points toward hydroplaning at the base of the debris flow which may be a common feature for debris flows [e.g., *De Blasio et al.*, 2004]. In our interpretation, the western margin of the slide debris lies farther west in the Sophia Basin than depicted by *Cherkis et al.* [1999] (Figure 2).

[10] Originating at the trough mouth of Hinløpen Strait and flowing into Sophia Basin, the slide funneled out between the shelf and a seamount discovered in 1999 (Polarstern Peak [*Daschner et al.*, 2000] (Figure 3) toward the continental slope north of Nordaustlandet and into the Nansen Basin. The slide keeps its hummocky appearance toward its distal part, although in general the surface seems to become smoother with distance. At the northeasternmost station of cruise ARK XX/3 (82°18'N

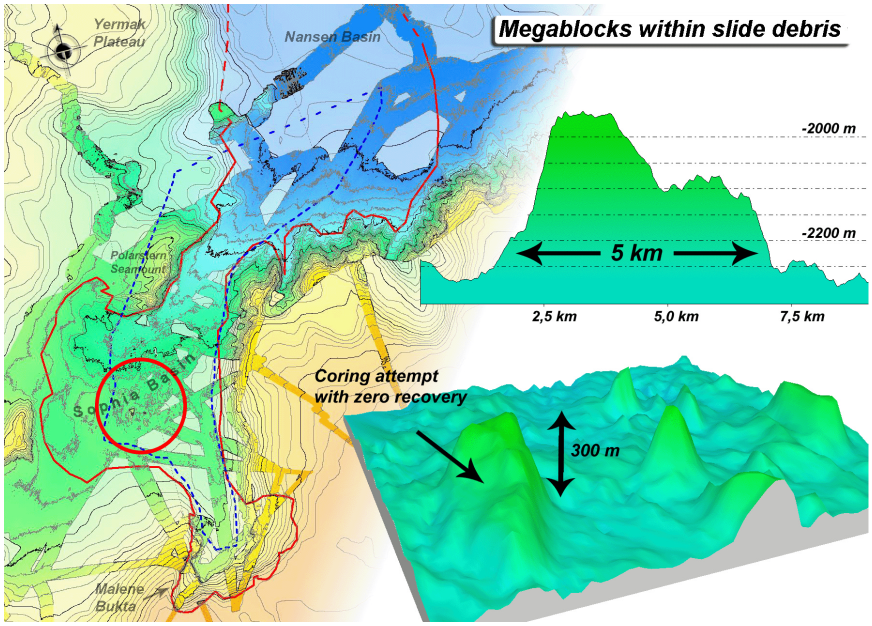

Figure 2. Map with new detailed bathymetry showing offsets to the underlying older IBCAO, slide extent according to *Cherkis et al.* [1999] (dashed blue line) as well as new slide extent (red line; headwall area according to *Vanneste et al.* [2004]) and close-up of megablocks reaching up to 5 km long and with 300 m relief above the surrounding debris (red encircled area). A coring attempt on the main megablock, with zero recovery [see *Stein*, 2005], probably points toward a more solid lithology of these blocks.

and 23°E) [*Stein*, 2005] the slide develops a debris flow-like appearance, and beyond this most likely extends farther into the Nansen Basin. However, due to heavy sea ice conditions, resulting in poor quality and coverage of the acoustic data, this remote part of the slide remains poorly constrained. In general, the eastern margins of the slide did not develop a pronounced and characteristic acoustic appearance. Consequently, the distinction of the side's margins from slumps and debris flows from the shelf break north of Nordaustlandet remains difficult. Thus the actual margin may lie farther east, and the slide may be even larger than shown here. However, the probable margin has partly been based on bathymetric information and represents the most likely extent. Neglecting the debris flows into the Nansen Basin, the Yermak Slide has affected an area of at least 10,000 km^2.

[11] Seismic data from lines AWI-99161 and AWI-99140, collected in 1999 [*Geissler and Jokat*, 2004], display some deeper features of the slide. A number of reflectors can be observed within the Yermak Slide deposits despite strong seismic energy scattering at the rough seafloor and a pronounced first reflector (Figure 6). The slide debris should have at least an average thickness of 200 m, based on extrapolation of the dipping hemipelagic strata below the main debris in PARASOUND images. The character of the second reflector on line AWI-99161 (Figure 6, D) seems to be influenced by bathymetric effects. In addition, the reflector does not match with the PARASOUND data (showing no internal reflectors at this level) and the expected depth interval of the lower slide boundary. Thus the lower boundary of the slide is most likely represented by the third strong reflector (Figure 6, B). The southern part of line AWI-99140 (Figure 6, A) shows the same three reflectors, but echoes below the rough topography (including the megablocks) are more scattered. The central part of this line displays a similar sequence, with two reflectors (second and third reflectors, Figure 6, C) dipping northward at about 3.6 and 3.7 s TWT. The reflectors seem not to mimic the seafloor and correspond with the expected depth interval for the lower slide boundary; thus they most likely represent the slide base.

[12] According to the reflector's depths of 275 to 305 m below seafloor, the volume of the sedimentary material from the inner slide can be estimated at between 1100 and 1250 km^3. A volume calculation for the outer part of the slide remains more difficult because seismic information on the slide plane is confined to its southern part, close to the

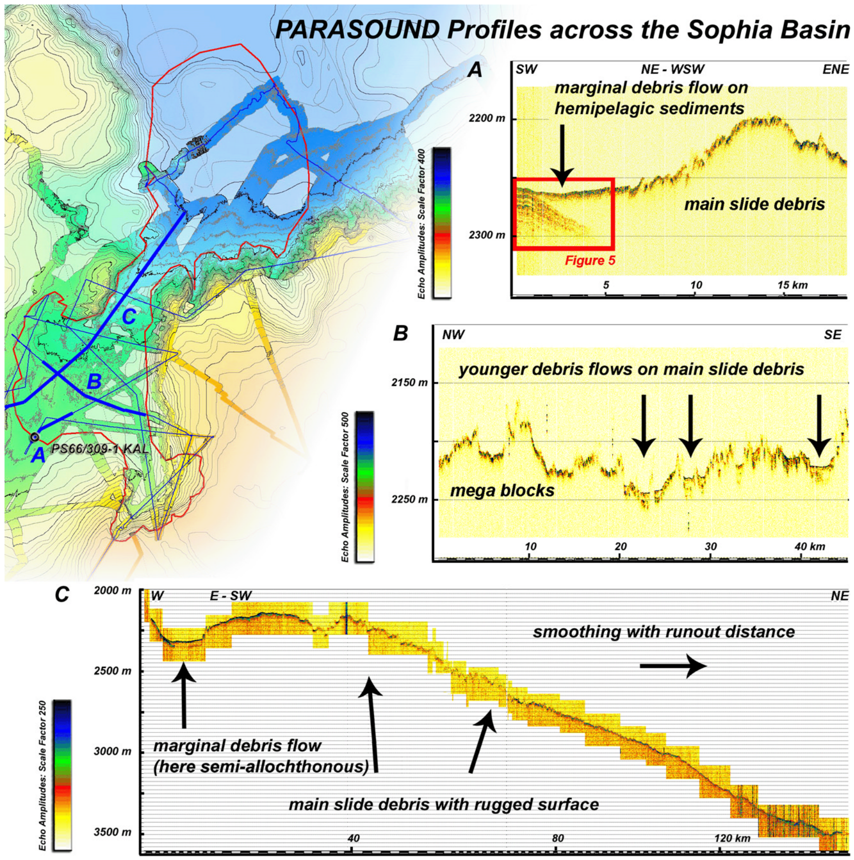

Figure 3. Typical PARASOUND profiles across the western margin of the Yermak Slide within the Sophia Basin, showing the transition from main slide debris into the marginal debris flow (A), the inner slide area with hummocky relief, megablocks, and indication of younger debris flows within distinct local depressions (B), and along runout displaying the slide's broad geometric features, as well as smoothing of the surface toward the distal part (C). Note that the marginal debris flow developed a semiallochthonous appearance in profile C.

shelf rise north of Nordaustlandet. According to seismic lines AWI-99130 and AWI-99165 the reflector that probably represents the slide base, is located between 230 and 240 m below the seafloor. Assuming this thickness is constant throughout the outer area of at least 4750 km^2 results in a volume estimate of about the same size as that for the inner slide (1100 to 1150 km^3). This gives a total of about 2400 km^3 of sediments for the whole Yermak Slide.

[13] Sediments from carefully selected sites along a representative profile across the western margin were recovered for dating of the main slide [*Stein*, 2005]. Initial AMS radiocarbon dates on planktic foraminifera from core PS66/309-1 KAL give ages of 25,390 ± 220 ^{14}C years B.P. directly on top of the slide-related turbidite and 42,340 + 2020−1610 ^{14}C years B.P. below it (Table 1). Bias of the minimum age by dating foraminifera eroded from older strata exposed in the headwall area can be ruled out because the samples were taken well above the last slide (turbidite) related fining upward sequences, within silty-clayey material. Thus the maximum and minimum ages for the slide prove a pre-LGM (Late Glacial Maximum), upper Marine Isotope Stage (MIS) 3 date (Figure 5).

5. Discussion

[14] The physical appearance of the Yermak Slide suggests that one major and catastrophic event occurred on its formation. Failure of the TMF sediments occurred along major lineations, perhaps initiated by an earthquake, leading to a submarine slide which developed into a debris avalanche (according to accepted classification [*Canals et al.*, 2004, and references therein]). Tectonic triggering of the main event seems to be the most likely explanation in view of straight and sharp walls formed along major lineations on shelf.

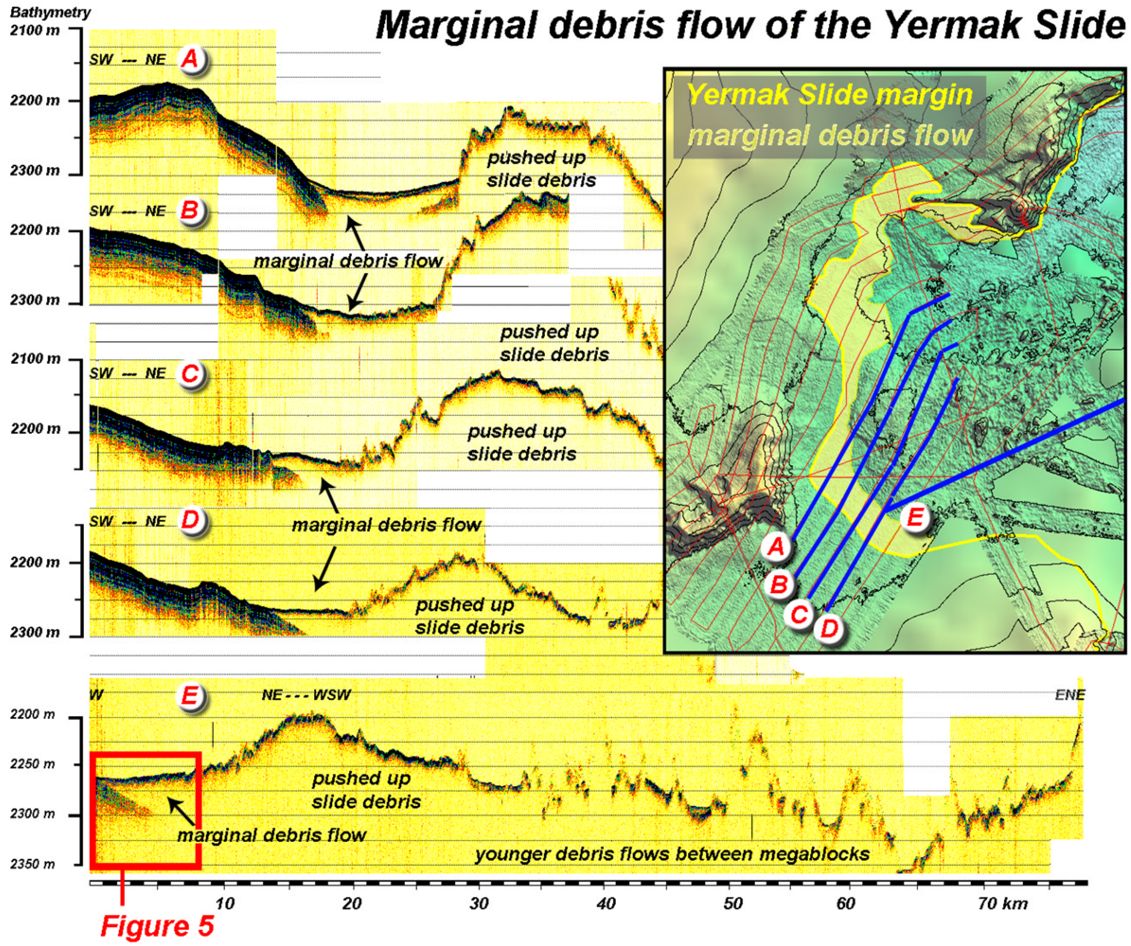

Figure 4. Map of marginal debris flow, with typical PARASOUND profiles across the western margin of the Yermak Slide in the southwestern Sophia Basin. Note the consistent transition from pushed-up slide debris into the marginal debris flow in all profiles. Profile A exhibits a semiallochthonous marginal debris flow with a younger debris flow on top (for location of map, see Figure 1).

[15] The younger slide events that left debris flows on the main slide debris likely correspond to smaller and presumably younger slide scars or escarpments and exhibit a retrogressive character. The scars seem to be related to weak layers or horizons on the shelf [*Vanneste et al.*, 2006] and may be the consequence of adjusting to a new equilibrium of the physical environment following the main event.

[16] Although volume calculation remains a general problem [*Canals et al.*, 2004], the size of the Yermak Slide at more than 10,000 km^2 affected area and up to 2400 km^3 of involved sedimentary material is comparable to the Storegga Slide (95,000 km^2 and 2400–3200 km^3 according to *Haflidason et al.* [2004]). The coincidence of head and sidewalls with major shelf lineations seems however less pronounced in the Storegga Slide than in the Yermak Slide.

[17] Some of the typical parameters used to describe landslides exhibit the difference of this Arctic slide to other slides. Although the comparison of submarine landslides is a complicated affair [e.g., *Canals et al.*, 2004] there seems to be a trend toward increasing maximum height of headwalls and major escarpments from river-fed to glacier-fed margins. A second trend toward larger total areas from low to high latitudes on the European shelves might exist too.

[18] The BIG'95 Slide in the western Mediterranean Sea constitutes a slide representative of those occurring on river-fed, siliciclastic, progradational continental slopes [*Canals et al.*, 2004]. With headwall heights of up to 200 m and ~2000 km^2

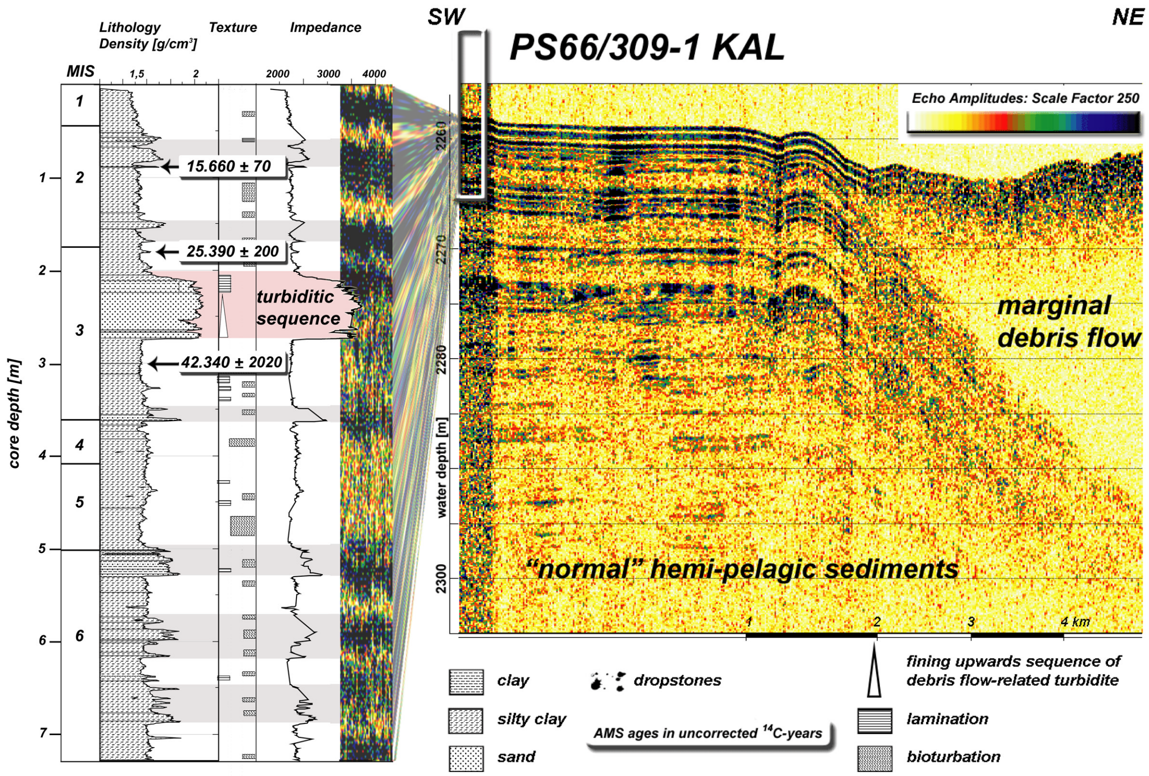

Figure 5. Close-up of PARASOUND data showing marginal debris flow pinching out into hemipelagic sediments; position of key core PS66/309-1 KAL (giant gravity corer, 81°11.22′N, 12°59.07′E, 2270 m water depth, 7.29 m recovery; see *Stein* [2005] for details), including lithology, density, texture, and acoustic impedance of core logging. AMS radiocarbon ages above and below the debris flow–associated turbidite are depicted as ^{14}C years B.P., uncorrected for the marine reservoir effect. Marine Isotope Stages (MIS) are based on preliminary correlation of magnetic susceptibility from core logging to cores with existing isotopic stratigraphy. For position of profile and core, see Figures 4 and 1, respectively.

total area [*Lastras et al.*, 2004], this slide is comparably small.

[19] The headwalls of the Storegga Slide off Mid Norway are up to 120 m high, and the total area accounts for 95,000 km^2 [*Haflidason et al.*, 2004]. In contrast the headwalls of the Yermak Slide reach heights of up to 1400 m, more than ten times higher, while the total area, of at least 10,000 km^2, appears to be smaller. Even when excluding the giant turbidite and compressional area of the Storegga Slide, the area of ~53,000 km^2 is still five times greater. A possible reason for this difference is the fact that the Yermak Slide developed into the relatively small Sophia Basin, and was forced to funnel out into the Nansen Basin, a process which likely consumed a substantial part of its kinetic energy. A similar scenario defined the changing flow direction of the BIG'95 Slide [*Canals et al.*, 2004]. However, a cross plot of geometric parameters (run-out distance, headwall height and total area, as well as the ratio of drop or headwall height and run-out distance) shows the Yermak Slide to resemble any of the lobes of the Storegga Slide [*Haflidason et al.*, 2004] (Figure 7). The volume of sedimentary material moved in the Yermak Slide, at about 2400 km^3, is well in the range of the Storegga Slide lobes.

[20] Given the volume of the evacuation area (950 to 1000 km^3) the Yermak Slide seems to have incorporated substantial amounts of sedimentary material on its way. This phenomenon has been reported from several other sites as well [e.g., *Gee et al.*, 1999, 2005; *Canals et al.*, 2004] and may be a common feature of slides involving large detached blocks [*Gee et al.*, 2005]. The head walls are situated at the mouth of a cross shelf trough, the Hinløpen Strait, where the usually associated TMF is missing. The unknown volume of the TMF has

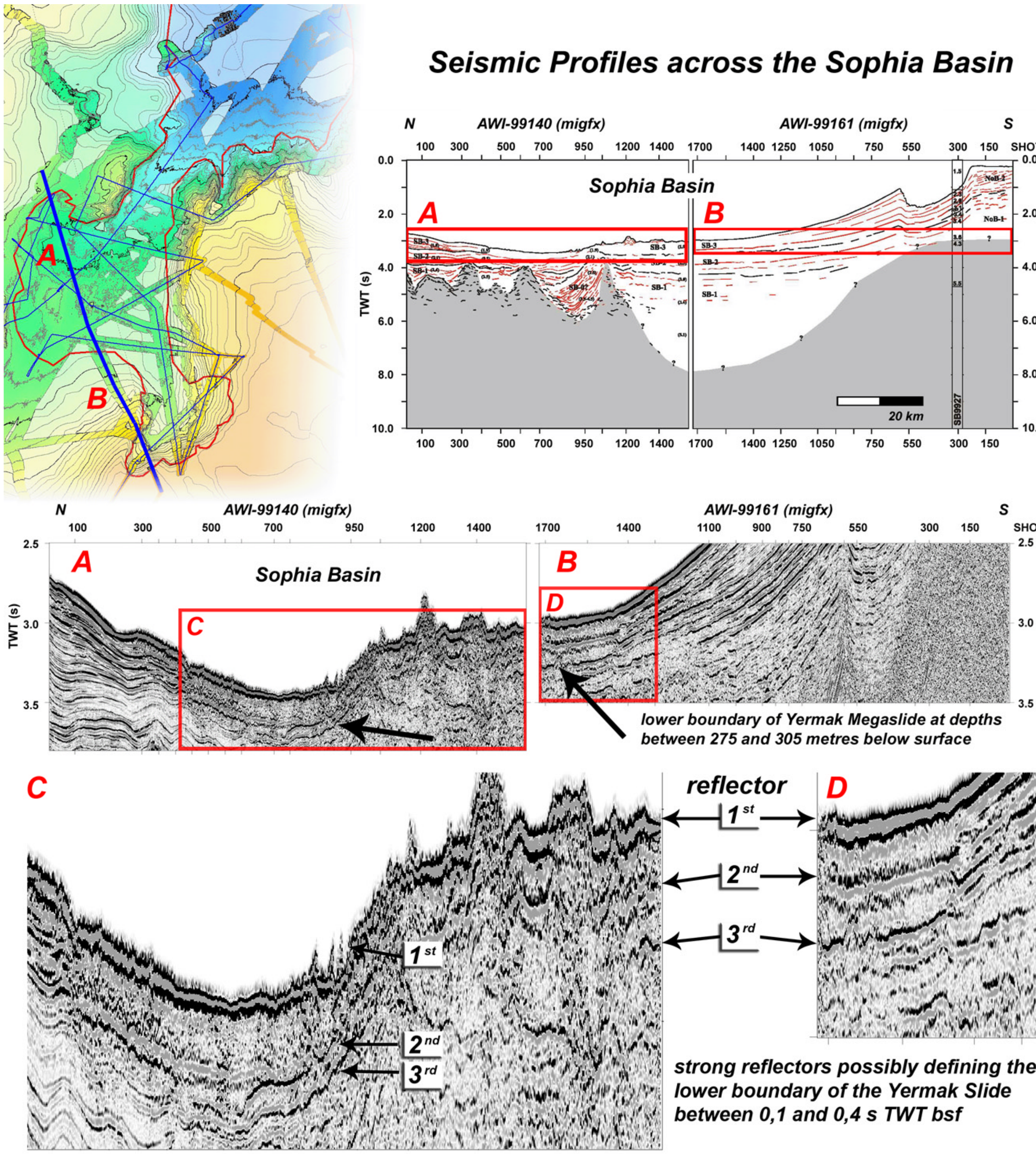

Figure 6. Seismic profiles AWI-99140 and AWI-99161 across the Sophia Basin showing reflectors which most likely represent the lower boundary of the Yermak Megaslide between 275 and 305 meters below seafloor. Modified line drawing from *Geissler and Jokat* [2004].

not been taken into account, but nevertheless, the total volume of the slide (including its entire outer part) would still exceed the volume of the evacuation area.

[21] Considering the removed volume, the megablocks, and the bathymetric appearance of the shelf edge in the area, the main slide event must have involved a substantial part of the shelf proper. Whether these megablocks represent intact parts of the shelf moved from positions close to the headwall, or whether they have been pushed out to the shelf edge by the Hinløpen Ice Stream [*Ottesen et al.*, 2005] and buried within the TMF, as has been reported for the Bear Island TMF (large-scale glaciotectonic features [*Andreassen et al.*, 2004]), remains unclear since no information about their full vertical extension nor lithology is available yet. The solid lithology and their physically intact shapes may support the latter suggestion.

Table 1. Dating Results for Core PS66/309-1 KAL[a]

Sample ID	Core depth	^{14}C Age	Corr. ^{14}C Age	Calendar Age	Dated Material
KIA 25699	088–091 cm	15660 ± 70	15240 ± 70	18491 ± 237 B.P.	*N. pachyderma sin.*
KIA 25700	179–182 cm	25390 ± 200	24970 ± 200	29928 ± 310 B.P.	*N. pachyderma sin.*
KIA 27116	299–302 cm	42340 ± 2020	41920 ± 2020	45858 ± 1898 B.P.	*N. pachyderma sin.*

[a] Water depth 2270 m; recovery 765 cm. AMS radiocarbon dating was on carbonaceous shells of *Neogloboquadrina pachyderma sinestralis* at the Leibniz_Labor for Radiometric Dating and Isotope Research in Kiel, Germany. Conversion to calendar ages was done using the CalPal online software (http://www.calpal-online.de) with the CalPal2005_SFCP calibration curve. A standard reservoir age of 420 years has been applied for all dates.

[22] The transition from the rather stable shelf north of the Spitsbergen mainland to a shelf with decollements and indications of deformed sediments north of Nordaustlandet, as seen in seismic (seismic line MF-I-90, Norwegian Petroleum Directorate Moffenflaket 1990 Survey of the Svalbard margin [*Cherkis et al.*, 1999; *Geissler and Jokat*, 2004]) and acoustic profiles and core material from the shelf [*Stein*, 2005, and references therein], is located in the Hinløpen Strait area. This is interpreted as an adjustment following the removal of the TMF. It may also point toward a differing deep structures and tectonic behaviors of the shelf north of Spitsbergen and the shelf edge bordering the Sophia and Nansen Basin north of Nordaustlandet. The decollements may have played a crucial role in preconditioning, at least for the younger events. These often low-permeability clayey ''weak layers'' are supposed to commonly correspond to slip planes beyond the headwalls and their formation, as well as the preconditioning of slides in general, is climatically controlled [*Canals et al.*, 2004]. The trigger mechanism for a preconditioned submarine slide is usually assumed to be an earthquake (especially in high-latitude margins where postglacial rebound intensifies magnitude) but destabilization of hydrates has also been suggested [*Canals et al.*, 2004].

[23] The timing of the main slide event in MIS 3 around 30,000 calendar years B.P. (25,390 ± 200 ^{14}C years) (Figure 5, Table 1), coincides with the transition of the Kapp Ekholm Interstadial into Glaciation G of Svalbard [*Mangerud et al.*, 1998] and the buildup phase of the Svalbard-Barents Sea Ice Sheet (SBIS). Thus the TMF collapsed during a period of overall falling sea level, increasing ice volume, and presumably increasing glaciotectonic activity [*Chappell and Shackleton*, 1986; *Chappell et al.*, 1996; *Svendsen et al.*, 2004, and references therein]. One implication of such a setting is gasification of potential gas-hydrates, due to lowering of the hydrate stability zone (HSZ) as a consequence of lowered pressure. The possibility of postglacial hydrate dissociation following reduction of shear strength within ''weak layers,'' promoting failure, has been proposed for the Norwegian margin [e.g., *Posewang and Mienert*, 1999; *Mienert et al.*, 2001]. In addition, the buildup of the SBIS required a moisture supply, which has been attributed to intervals of inflow of (warmer) Atlantic water into Fram Strait and associated open water conditions during the LGM [*Hebbeln et al.*, 1994; *Nørgaard-Pedersen et al.*, 2003]. A corresponding peak in abundance of foraminifera between 30,000 and 27,000 calendar years B.P. in the Yermak Plateau region (high-productivity zone 2 [*Dokken and Hald*, 1996; *Hald et al.*, 2001]) points toward such conditions in the slide area. Thus elevated water temperatures may have contributed to a lowering of the HSZ. A possible relation of hydrate stability and slope failure due to warm water influx onto the headwall region has been modeled and discussed for the Storegga Slide [*Mienert et al.*, 2005]. To what extent warmer surface waters influence the stability field of the underlying shelf strata in the Yermak Slide's headwall area is difficult to access since information on the thickness of the (paleo-) warm water layer is not available. At the present day, the warm and saline Atlantic water west and north of Spitsbergen reaches depths down to ~700 m water depth on the shelf and within Sophia Basin [*Schlichtholz and Houssais*, 1999a, 1999b; *Rudels et al.*, 2000; *Saloranta and Haugan*, 2004]. Given a lowered and steadily falling sea level, warm surface waters might have had a significant impact on the HSZ and thus slope stability in the headwall area of the Yermak Slide. In addition, investigations of a small area near the Storegga Slide headwall, showed abundant pockmarks and linear depressions probably related to pore water or gas escape, but do not prove a direct connection between extensional features and gas seepage [*Parsons et al.*, 2005]. However, we see no indications of either shallow

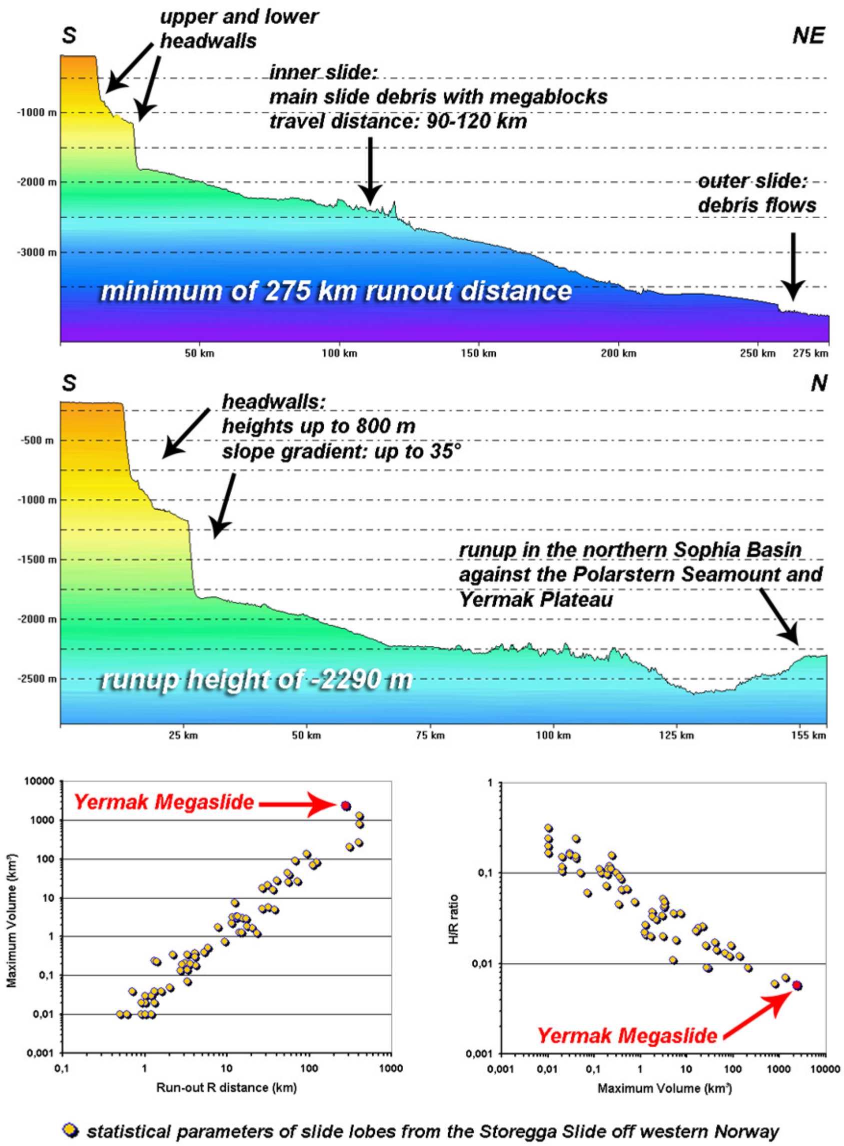

Figure 7. Bathymetric profiles (see Figure 1 for location) and geometrical parameters of the Yermak Megaslide: headwall height, runout distance, transport distance of megablocks, and slope gradients of headwalls, compared to parameters from the Storegga Slide [*Haflidason et al.*, 2004].

gas, degassing features like pockmarks or bottom simulating reflectors (BSRs) in the headwall area of the Yermak Slide. Nevertheless, there are some striking similarities between the Storegga and the Yermak Slides. Both developed on the right flank of a TMF, and their flow paths consequently turned right. Both exhibit a retrogressive character. In both cases, major lineations are present and probably intrinsic to the trigger mechanism. To what extent the probable development of a fore-bulge from increasing load on the lithosphere may have affected the conditioning and/or trigger mechanism north off Svalbard remains difficult to asses, since information on the lithospheric rheology is not available. In addition, the physical behavior of a shelf corner in response to waxing and waning ice sheets is poorly understood.

[24] Given that the consistent appearance of the slide in the Sophia Basin points toward one main slide event, and the large amount of mass moved in this event, at least one big tsunami can be postulated. Possible tsunami deposits, as have been identified for the Storegga Slide tsunami [e.g., *Bondevik et al.*, 2005], may be expected in the

adjacent fjords or on the shelf proper. Whether tsunami deposits will be identified on the Spitsbergen archipelago remains open to question, given that ice coverage close to the archipelago may have hampered the wave propagation. In addition, the potential pre-LGM tsunami deposits on land or on the shelf may not have survived the subsequent glaciation, deglaciation and flooding of the shelf.

[25] Cores taken from carefully selected sites [*Stein*, 2005] will be used for further characterization of the slide process concerning preconditioning, trigger mechanisms and timing in relation to the climate history of this Arctic area. Numerical modeling, based on geometrical parameters, will shed light on the actual mass movement mechanism in terms of speed and internal dynamics with its further implications for a tsunami model.

6. Conclusion

[26] 1. The Yermak Slide extends farther west and farther into the Nansen Basin than reported by *Cherkis et al.* [1999]. The slide affected an area exceeding 10,000 km^2 and involved more than 2400 km^3 sedimentary material. Thus it is to be ranked among the largest exposed submarine slides.

[27] 2. The slide consists at least of one main event, judging by its consistent appearance within the Sophia Basin and toward the Nansen Basin, that occurred during MIS 3. Repeated minor slide events followed this major event.

[28] 3. The physiographic appearance, together with the character and volume of the involved material (e.g., tens of megablocks), rather points toward a partial shelf collapse than a submarine slide within less consolidated material. This may favor a tectonic preconditioning and triggering mechanism.

Acknowledgments

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