THE EFFECTS OF BIOGENIC SILICA ON SEDIMENT CONSOLIDATION AND SLOPE INSTABILITY ON THE ANTARCTIC MARGIN

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Abstract

We present evidence from ODP drilling of how small to moderate amounts of biogenic silica in fine grained Cenozoic deep sea sedimentary sequences can severely affect the physical properties and consequently the slope stability of continental rise sediment drifts of the Pacific margin of the Antarctic peninsula.

This work originates from the analysis of the physical properties measured down hole on cores and on discrete samples conducted in the frame of Ocean Drilling Program (ODP) Leg 178 (Barker et al., 1999). We consider two wells drilled in hemipelagic sediment drifts of the continental rise of the Pacific margin of the Antarctic Peninsula (Figure 1).

Proximal Site 1096 recovered a relatively expanded upper part of the sedimentary section, down to the Early Pliocene (4.7 M.a) by penetrating 608 m in 3152 m water depth. Distal Site 1095 was located in 3842 m water depth at a transition between sediment drift-turbiditic lobe acoustic characters. It sampled 570 m of a more condensed succession down to the Late Miocene at least (10 Ma and possibly older). Deposition at drill sites ranged from dominantly hemipelagic to dominantly distal turbiditic (Barker and Camerlenghi, 1999; in press). In particular, the hemipelagic drifts of the proximal continental rise belong to a mud-dominated sedimentary environment fed primarily by the glacially transported terrigenous input, and secondarily by the rain of planktic and benthic micro-organisms. Among planktics, siliceous micro-organisms prevail. At both sites, the rates of sedimentation decreased gradually through time, from 11 cm/kyr (Middle and Late Miocene) to 5 cm/kyr (Pliocene) to 2.5 cm/kyr (Pleistocene) at Site 1095.

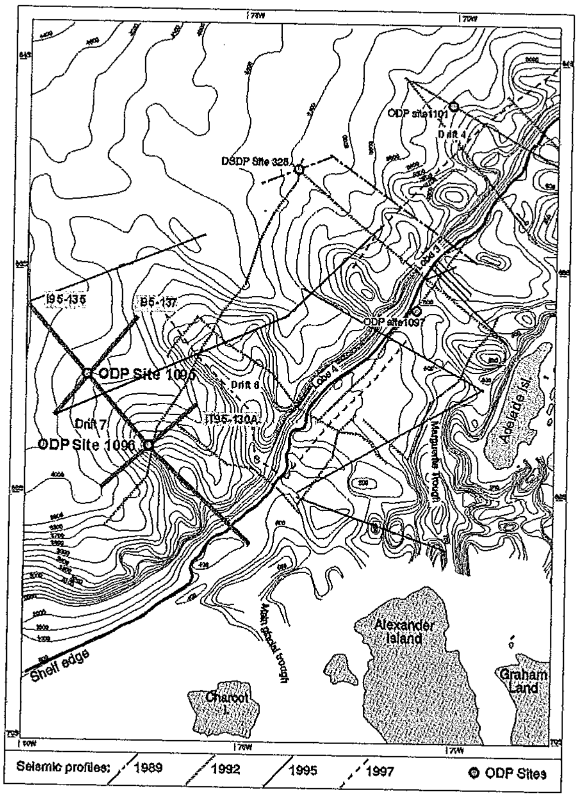

Fig. 1 - Location Map of ODP Leg 178 drill sites on the Pacific margin of the Antarctic Peninsula.

The analysis revealed anomalous trends down hole of porosity, density, water content, and p-wave velocity that survived cross-checks among different methods of detection, and cleaning of possible errors and artifacts (Volpi et al. 2001). In essence, it was recognized that the sedimentary succession drilled in hemipelagic sediment drifts of the proximal continental rise is mostly under-consolidated. Under-consolidation is outlined by constant, if not increasing, porosity with depth down to as much as 500 m below seafloor. In one of the two boreholes analyzed, a sharp decrease in porosity, matching increasing bulk sediment density and increasing compressional velocity, occurs towards the base of the hole (Figure 2).
A number of studies, mostly originated from DSDP-ODP scientific drilling in high-latitude seas, describe how biogenic silica, if present in large amounts (oozes) affects physical properties of marine sediments (Hein et al., 1978; Bryant and Rack, 1990; Lonsdale, 1990; Tribble et al., 1992 among others). In this study we describe how we interpreted the observed anomalous consolidation trends as due to the presence in the fine grained sediment sequences of small to moderate amounts of biogenic silica, including its diagenetic alteration, as detected with seismic and geochemical methods.

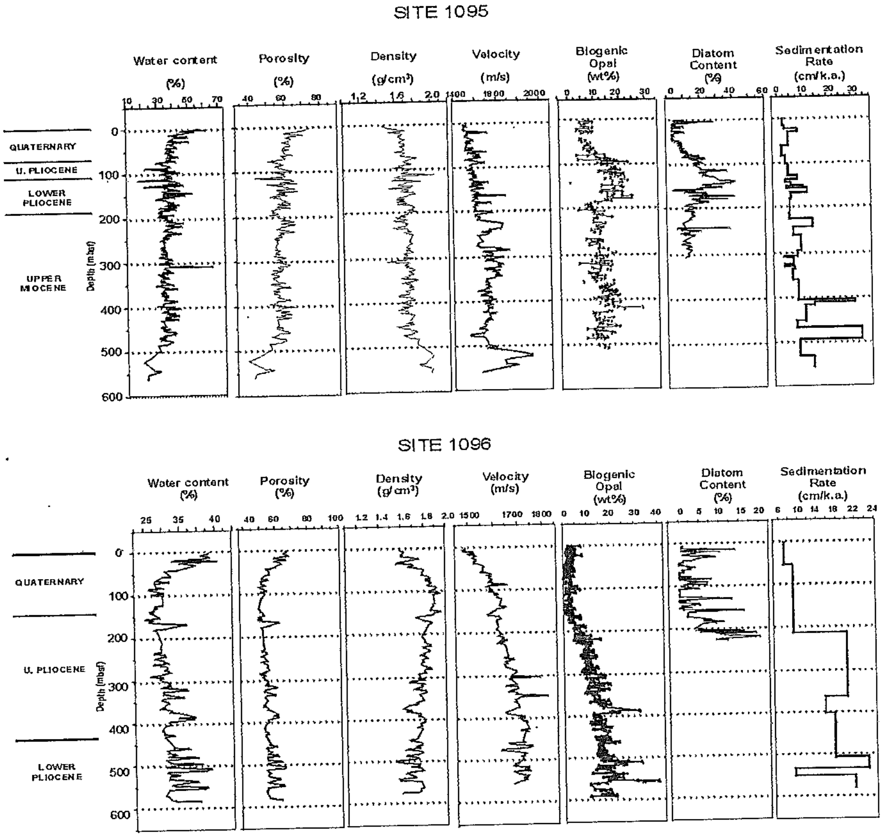

Fig. 2 - Main physical properties logs at Sites 1095 and 1096 (see Figure 1 for location)

The uppermost 80-100 m of the sedimentary column, roughly corresponding to the Quaternary) contain small amounts of biogenic silica, and behave normally in terms of consolidation (normal trend down hole of physical parameters). The lower Pliocene and lower late Pliocene, with biogenic opal content up to 20-40% are underconsolidated and retain large amounts of water at the expenses of pore volume reduction. This is caused by the rigid microfabric built by fragments of diatoms that prevent the process of natural consolidation. At about 490-500 mbsf (at Site 1095), early diagenetic process starts the transformation of opal-A to opal-CT. Though there is no firm mineralogical evidence for opal-CT above the threshold of detection, the rigid microfabric (opal-A) is destroyed by incipient opal transformation, sediments are finally allowed to consolidate, resulting in a dramatic decrease of porosity, water content, and consequently increase in bulk density and seismic velocity. The consequent acoustic impedance contrast affects the seismic data with a bottom simulating change of sediment reflectivity (BSR) that has been imaged in particular with the display of seismic attributes (Figure 3).

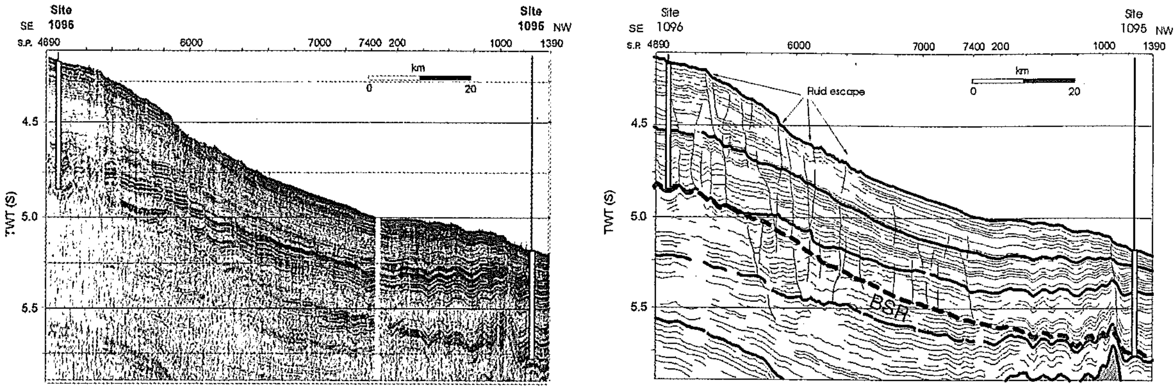

Fig. 3 - Instantaneous amplitude display and line drawing of IT95-135 seismic profile along a dip-section of Drift 7 between sites 1095 and 1096 (see location in Figure 1)

We conclude that the process of consolidation at depth results in overpressuring and decreasing of the effective stress. Excess fluids are expelled towards the sediment surface along conduits (faults) that displace seafloor and deeper reflectors. The sedimentary sequence above the diagenetic front is therefore affected by gravitational creep along the weakened overpressured horizon of the silica diagenetic front (Figure 4).
We further speculate on the potential of physical properties as basin-wide indicators of biogenic silica abundance in sediments. Anomalous sediment consolidation should be considered here and elsewhere if studies of sediment budget and basin analysis are undertaken on fine grained diatom-bearing sediments from high-latitude margins.

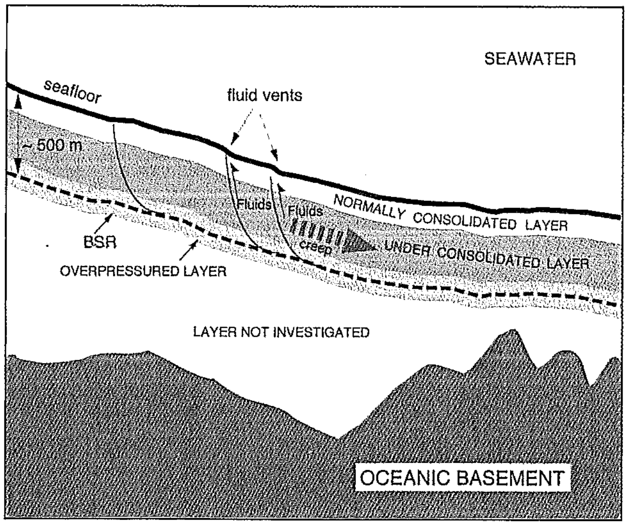

Fig. 4 - Schematic model of the consolidation state and slope instability induced by the distribution of biogenic silica in the late Cenozoic sedimentary section.

Acknowledgements

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