 ©Geologie en Mijnbouw 0016-7746/82/6101-0002 $ 2.50/0

THE NORTHEASTERN BERING SHELF: NEW PERSPECTIVES OF EPICONTINENTAL SHELF PROCESSES AND DEPOSITIONAL PRODUCTS – AN INTRODUCTION[1]

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The papers that follow cover a decade of interdisciplinary research on Holocene sedimentation in the northern Bering Sea. The U.S. Geological Survey environment assessment studies in this region brought together the work of a number of marine geologists, physical oceanographers, geochemists, and geotechnical specialists. This epicontinental shelf research focuses on a poorly known, but major environment of northern North America. Although nearly half of the continental shelf area of the United States is made up of epicontinental shelves that surround Alaska, most studies of Holocene shelf sedimentation in North America have focused either on the narrow, tectonically active Pacific coast shelves or the Atlantic continental margin shelves. The general lack of information on modern semi-enclosed, shallow seas is a severe handicap to understanding the extensive ancient rock record of these types of environment, for example, the Mesozoic of the interior of western North America.

Epicontinental seas are dominated by strong currents and constricted by land masses. As a result, large sand ridges and sand wave fields are common, and significant reworking, resuspension, and relocation of Holocene sediment masses is apparent. Storm waves are common to all shelf areas, but large storm surges and strong storm-driven currents are more restricted and occur mostly in broad shallow embayments such as found in Norton Sound of Bering Sea. Extensive glaciation, transgressive shoreline history, and variation in tidal range plus sediment input in different parts of the basins have resulted in the development of heterogenous morphologically different sand bodies of late Quaternary sediment.

The first paper, by C.H. Nelson, on the late Pleistocene to Holocene sedimentation points out that two very different sequences of transgressive deposits can develop within the same shelf region. In Chirikov Basin, Pleistocene peaty mud is covered by typical, but extremely thin, basal and inner shelf transgressive sand units. The strong currents and circulation of water masses, however, prevent the deposition of a modern mud blanket to complete a normale transgressive sequence. The currents rework the surface sediment into a distribution that conforms to the strong geostrophic flow patterns and we therefore do not find a wave-generated gradation from near-shore coarsegrained deposits to finergrained deposits offshore.

The sea floor of Norton Sound is overlain by Pleistocene peaty mud but, in contrast to Chirikov Basin, it lacks transgressive sand layers. Here marine transgressive sequences consist of mud interbedded with thick storm sand layers that grade upsection to thinner storm sands and then to bioturbated muds. Progradation of the modern Yukon prodelta reverses this sequence in southern Norton Sound so that storm sand layers are found in the uppermost Holocene sediment. Patterns of late Pleistocene-Holocene sedimentation in both Chirikov Basin and Norton Sound are different from those on southern Bering shelf where a classic wave-generated seaward-fining is found in Holocene deposits. Thus, when interpretations are made of ancient epicontinental shelf sequences, deposits in current-dominated settings like the North Sea and the northern Bering Sea must be considered because gradations in sediment texture and thickness may have little relation to shoreline location or depth-related variations in wave energy.

The second paper, by K. McDougall, analyzes microfauna in shelf deposits of the northern Bering Sea. It shows that biostratigraphical changes and paleoecological patterns may aid in the reconstruction of epicontinental shelf environments. In the Chirikov Basin there is a vertical change from freshwater to marine facies. In Norton Sound the same

[1]Manuscript recieved: 1981-10-21.
Manuscript accepted: 1982-01-08.
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change is evident, but nearshore and offshore faunal assemblages can be distinguished in thicker transgressive deposits. In the late Holocene sediment, however, a reversal back to brackish water environments is encountered because of formation of the present active delta lobe in southern Norton Sound.

Sedimentary structures in Norton Sound described in the third paper, by J.D. Howard & C.H. Nelson, also mirror the effects of the transgressive and progradational history. Nearshore physical structures occur at the base of the sequence and grade upsection to bioturbated mud; the uppermost sequence, however, changes to well-developed nearshore structures in southern Norton Sound where the delta progrades over the offshore sequences that were laid down in the earlier Holocene. Because of the delta progradation in southern Norton Sound, well-developed physical structures in surface sediment grade offshore to highly bioturbated deposits, as might be expected in onshore to offshore sequences. The high degree of bioturbation nearshore in norther Norton Sound, however, is unexpected near shorelines and reflects low sedimentation rates are caused by resuspension and advection of most Holocene sediment from this region by the Alaska Coastal Water. Because of the large freshwater discharge from the Yukon River into southern Norton Sound, bioturbation there is similar to that found in local coastal embayments and estuaries elsewhere, even though Norton Sound is an open-shelf region. Again, this is an example to keep in mind when interpreting ancient epicontinental shelf deposits.

The fourth paper, by C.H. Nelson et al., describes the Bering shelf sand body types and their formation. It provides new information to trace petroleum reservoirs in ancient shelf systems. The sand bodies of the Bering shelf, although similar to one another in their linearity, size, and sediment type, can be separated into genetic types based on subtleties of grain size, sedimentary structure, morphology, and orientation. Recognition of lee side sand bodies formed of very fine sand may help to distinguish such large sand bodies that were deposited far offshore obliquely to shorelines, from the more common and generally coarsergrained, shore-parallel sand bodies of the inner shelf.

Several of the process-oriented papers that follow show that the development of different sand body types is a result of a wide variation in hydrographic setting and sediment input on the Bering shelf. In the modern inner shelf area, down to water depths of 10-15 m, the sea floor is typically affected by wave energy. Along southern Seward Peninsula, however, a complex pattern of bedforms is evident that is related to wave and unidirectional currents. Interplay of current-formed features with ice scour in this subarctic environments adds to the complexity of bedforms in this region. The result is a mosaic of oscillation and unidirectional current ripples, ice gouges, and a complex pattern of varying sediment types.

The inner shelf off the Yukon delta complex of southern Norton Sound contrasts with that of the rocky headland and coastal plain coast of the Seward Peninsula. It is dominated by deltaic sedimentation and a seasonally influenced set of fluvial, hydrographic, and ice processes. In winter, river discharge is almost totally lacking and extensive shorefast ice develops. The wide apron of shorefast ice results in much farther extension of distributary channels offshore from the delta than is the case in temperate or tropical deltas. The sub-ice channels serve as sediment conduits during maximum discharge conditions in late spring and summer. Thus, extremely large quantities of sediment enter the sound in a very short period of time and accumulate rapidly in southern Norton Sound. Major storms in the fall rework, resuspend, and remove large quantities of sediment from Norton Sound. Under occasional extremely large storm surges major sand sheets prograde from the delta shoreline out over southern Norton Sound.

Quantitative measurements of significant reworking and resuspension of bottom sediment during storms have been made in northern Norton Sound using GEOPROBE instrumentation. The longterm in situ measurements of currents and suspended sediment made with the GEOPROBE in the benthic boundary-layer provide new information that has broad implications for any epicontinental shelf region. The continuous monitoring of shear velocities proves that storm-related currents are the major processes in the constricted shallow waters of epicontinental shelf regions like northern Bering Sea. Measurements also show the importance of continual advective suspended sediment transport over northern Bering shelf and of sediment resuspension and transport during spring tidal conditions.

In contrast to the more classic wave and current processes outlined in several papers, new concepts of epicontinental shelf processes are suggested by the geotechnical, geochemical, and geophysical studies. Poorly consolidated mud of restricted quiet-water lagoons and sheltered, but open-shelf embayments, contrasts with highly overconsolidated sediment in other regions where fetch over the open sea generates large waves that permit strong cyclic loading on shallow bottom sediment. Biogenic gas trapped beneath Holocene mud of Norton Sound can create poorly consolidated zones and regions of gas-charged sediment that are traced as acoustic anomalies in seismic reflection records. New studies also show that cyclic wave loading during major storm surge events has the potential to liquefy, and indeed may liquefy, the very fine sand of the Yukon Delta. Thus, liquefaction may be very important in conjunction with strong, storm-generated currents to develop the prograding storm-sand sheets and extensive scour features observed on epicontinental shelves like Bering Sea.

The research on the Bering shelf suggests that sedimentary processes on shallow semi-enclosed, epicontinental shelves include synergistic effects of wind, tidal, and barotrophic-driven currents and also poorly understood effects of instability of gas-charged sediment and cyclic wave loading. Future interdisciplinary research on epicontinental shelves is required to define the relative importance of these factors in sediment transport.

We hope that this set of papers on the Bering epicontinental shelf will provoke new thoughts on Holocene sedimentation processes that are common to all epicontinental shelves. In a summary chapter we emphasize some similarities and contrasts with the North Sea.

Large new studies are being instigated and it appears that common characteristics of Holocene transgressive sedimentation and modern sedimentary processes are present. Once this modern data base is available from a wide variety of settings like the East China Sea, the Bering Sea, and the North Sea, new refined interpretations can be applied to similar ancient environments.

The editors would like to thank John Collinson, G.D. Sharma, and G.V. Middleton for their useful suggestions. We also want to thank Miss A. van Geen and Miss Y. Furster for typing the final version of the manuscripts.

Last but not least we are grateful to the editors of Geologie en Mijnbouw, who were very helpful to publish the North Eastern Bering Sea papers within such a short period.