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MEASURED STRATIGRAPHIC SECTION OF THE TINGMERKPUK SANDSTONE (NEOCOMIAN), WESTERN NPRA, ALASKA

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Measured stratigraphic section of the Tingmerkpuk sandstone (Neocomian), western Brooks Range

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Introduction

This report summarizes the preliminary results of stratigraphic and sedimentologic analysis of a succession of Neocomian quartzose sandstone that crops out in the foothills of the western DeLong Mountains of the western Brooks Range. These rocks, informally named the Tingmerkpuk sandstone (Crane and Wiggins, 1976), were described during the 1993 field season as part of a collaborative study of Neocomian sandstones in northwestern Alaska by the Alaska Division of Geological and Geophysical Surveys, University of Alaska-Fairbanks, U.S. Geological Survey, Alaska Division of Oil and Gas, and Bureau of Land Management. This report accompanies a detailed measured section that graphically depicts the stratigraphic and sedimentologic organization of the Tingmerkpuk sandstone. The purpose of this preliminary report is to summarize the distinguishing characteristics of the Tingmerkpuk sandstone and to comment on our preliminary interpretations of the depositional history of the succession. Other reports will summarize the results of 1:63,360-scale geologic mapping of the Tingmerkpuk sandstone and data from preliminary paleontologic and geochemical analyses.

Geologic Setting and Previous Research

The Arctic Alaska plate experienced a series of pronounced continental rifting events during Early Cretaceous time related to the formation of the Arctic Ocean and opening of the Canada basin. The actual breakup event is recorded across much of northern Alaska by a regional Lower Cretaceous unconformity (LCu) that progressively truncates older rocks from south to north. Erosional and depositional events related to formation of the LCu were critical in producing many of the hydrocarbon accumulations in northern Alaska. Erosion and progressive truncation along the LCu produced the stratigraphic trap for the Prudhoe Bay oil field, and deposition of mature sandstone above and below the unconformity are hydrocarbon reservoirs in the nearby Kuparuk River oil field. Mature terrigenous clastic rocks of the Neocomian Kemik Sandstone in the northern Arctic National Wildlife Refuge (ANWR) also form well-known exploration targets located directly above the LCu. All of these sandstone intervals deposited along the rifted margin of the Arctic Alaska plate formed within shallow-marine and generally transgressive depositional systems.

Our initial studies of sedimentation related to the Lower Cretaceous unconformity were focused on the depositional history of the Neocomian Kemik Sandstone within ANWR. The concept evolved from this work that the Kemik was not deposited in a single paleoenvironmental setting but during a series of transgressive events that included a wide range of depositional environments at different stages. The migration history of these environments, and consequent geometry and sedimentologic organization of the Kemik Sandstone, were strongly influenced by paleotopography and paleogeology beneath the LCu surface. The Early Cretaceous transgression occurred by a series of drowning events marked by distinctive marine flooding surfaces within the Kemik Sandstone and the lower part of the overlying pebble shale unit. These reconstructions of the relationship between the LCu and the organization of the Kemik Sandstone led inevitably to a related question: Could there have been significant accumulations of compositionally mature sandstone deposited at basinal depths during maximum erosion along the LCu, and could such deposits form potential hydrocarbon traps?

Depositional Setting of Beaufortian Basinal Sandstone

The possibility of basinal Beaufortian sandstone sequences led to a focused effort to better understand the LCu and, particularly, depositional episodes related to formation of this regional breakup unconformity in regions beyond ANWR. During the 1993 field season, we conducted a detailed study of the informal Tingmerkpuk sandstone, a thick sequence of compositionally mature quartzose Neocomian sandstone exposed in the foothills of the western DeLong Mountains. The major product of this work is the accompanying detailed measured section described on the northern flank of Tingmerkpuk Mountain in the DeLong Mountains C-1 quadrangle (Fig. 1). The sedimentologic organization and regional stratigraphic relationships of this succession have led to development of a preliminary depositional reconstruction that predicts a new type of stratigraphic play on the North Slope: Beaufortian submarine fan systems deposited as lowstand systems tracts.

This detailed study of the Tingmerkpuk sandstone demonstrated a significant accumulation of mature sandstone that was, in fact, deposited within turbidite depositional systems at basinal depths. The Tingmerkpuk is a 130 m succession of fine-grained quartzarenite comprised of thin- to thick-bedded, laterally persistent sandstone beds with a recurring internal sedimentologic organization. The typical bed has a sharp, erosional base followed in vertical sequence by intervals of conspicuous convolute laminae, plane parallel bedding, rippled laminae, and black shale intervals. At a larger scale, the Tingmerkpuk is organized into numerous upward- thickening sandstone parasequences that range from about 5 to 30 m thick.

Stratigraphic and Sedimentologic Organization

The Tingmerkpuk sandstone rests with apparent conformity above dark-gray to black shale of the Kingak Shale. Although a nearly continuous exposure of the sandstone is present on the steep north face of Tingmerkpuk Mountain, the upper contact is covered, and we have not identified any locality where the upper contact is exposed. At Tingmerkpuk Mountain, we have divided the Tingmerkpuk sandstone into three depositional units based primarily on the internal characteristics of sandstone parasequences within each depositional unit.

Lower Depositional Unit

The lower unit of the Tingmerkpuk sandstone abruptly overlies the Kingak Shale where the lowest sandstone bed rests above dark-gray to black clay shale. Distinctive intervals of maroon-colored clay shale in the Kingak are also locally exposed beneath the Tingmerkpuk on Tingmerkpuk Mountain and elsewhere in the area. The Kingak Shale is dominantly a highly fissile clay shale, and the highest order stratification unit recognized is the laminaeset. Manganese and siderite nodules are common in the float in some intervals in the Kingak but are rarely exposed in outcrop. Laminaesets of light-gray claystone that may be bentonite are occasionally exposed in layers up to 1 cm thick.

The base of the lower unit of the Tingmerkpuk sandstone is a probable sequence boundary. Unlike sandstone successions higher in the Tingmerkpuk, the basal interval of the Tingmerkpuk appears abruptly in the vertical sequence and is not preceeded by an upward-thickening interval. There is no depositional record of a gradational change to give a sedimentologic "warning" of impending sandstone deposition, and the sudden appearance of the thick basal interval of very fine to fine-grained sandstone records an abrupt landward shift in depositional facies.

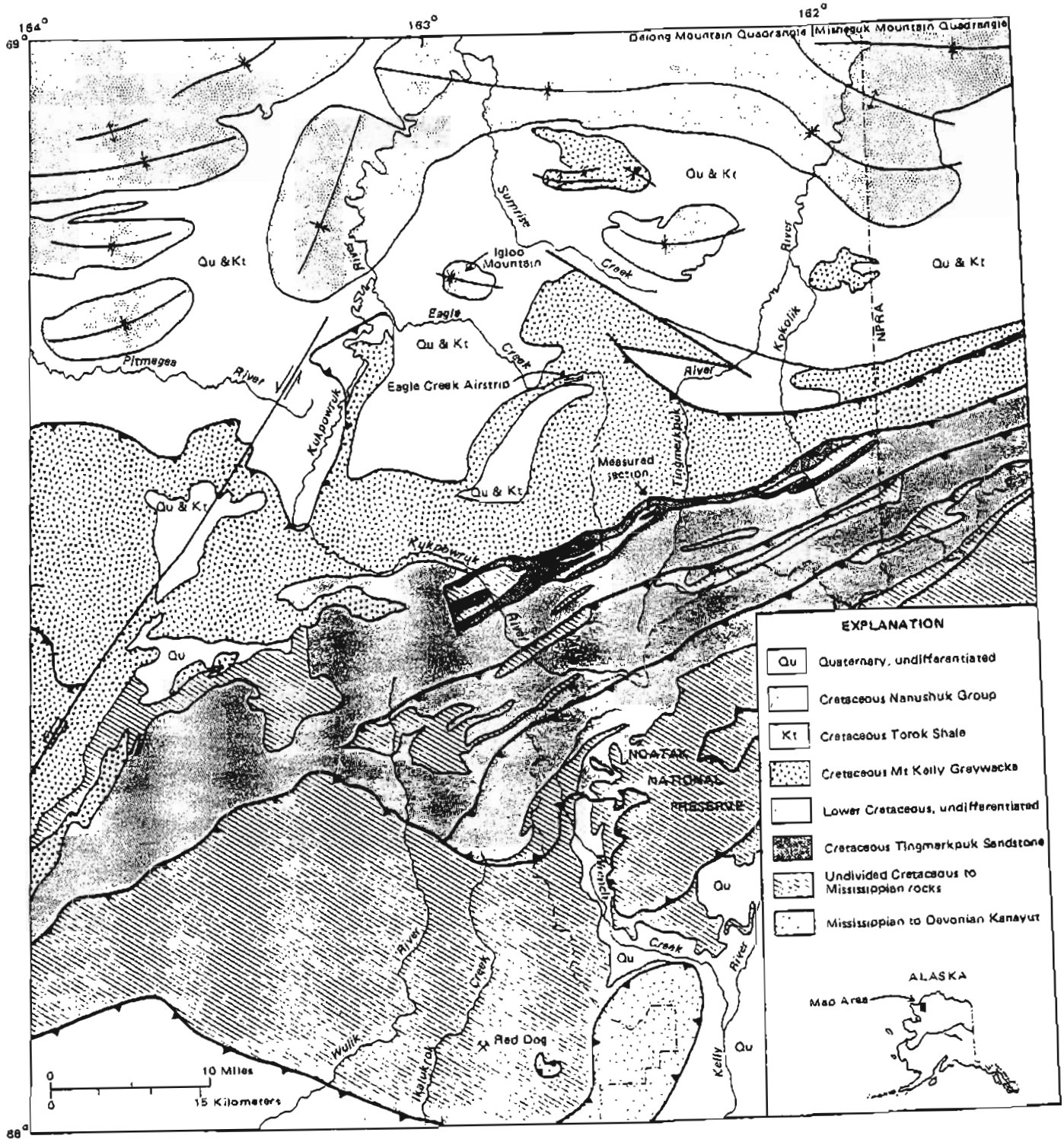

Figure 1. Index geologic map showing location of measured stratigraphic section.

The lower unit of the Tingmerkpuk sandstone is organized into a series of three upward-thickening parasequences. The base of each parasequence is a gradational succession of interbedded clay shale and very fine grained sandstone. The sandstone-shale ratio and average thickness of individual sandstone beds increase regularly upsection. The top of each parasequence is a sharp surface above the highest sandstone bed. This bounding stratal surface is overlain by a thick interval of clay shale.

The lower parasequence is a shale-dominant succession that forms the thickest (31m) and most strongly progradational interval within the Tingmerkpuk sandstone. Most sandstone beds that punctuate the interval contain the complete Bouma turbidite sequence of internal primary sedimentary structures. Sandstone beds are irregularly spaced in the vertical sequence but in general thicken and become more closely spaced upsection. The parasequence terminates in a series of thick sandstone beds separated only by thin shale intervals less than 10 cm in thickness. The middle and upper parasequences are sandstone-dominant and contain thicker and more closely spaced sandstone beds than the lower parasequence. The middle parasequence culminates in the first amalgamated sandstone beds that are developed in the Tingmerkpuk sandstone. The upper parasequence is a composite succession composed of several smaller scale upward-thickening intervals.

The overall stacking pattern of the lower parasequence set is strongly progradational. Each successive parasequence has a higher sandstone:shale ratio, thicker and more closely spaced sandstone beds, and an increased tendency toward amalgamation in the uppermost beds. The stacking pattern records progradation of a series of submarine lobes built by successive turbidity flows. Sharp upper bounding surfaces record avulsion and abrupt lateral migration of the depositional environment.

Middle Depositional Unit

The middle unit is a sandstone-dominant succession that forms the most well-organized interval within the Tingmerkpuk sandstone. Sandstone bed thicknesses increase regularly upsection and become more closely spaced within each parasequence. and sandstone-shale ratio increases correspondingly. Individual parasequences range from 4 to 18 m in thickness, becoming thinner upsection in response to increasingly closely space sandstone beds and thinner intervening shale. The middle unit of the Tingmerkpuk sandstone is organized into a series of five upward-thickening parasequences. Except for the lowest interval, the base of each parasequence is a gradational succession of interbedded clay shale and very fine grained sandstone. The top of each parasequence is a sharp surface above the highest sandstone bed overlain by a thick interval of clay shale.

The most characteristic feature of the middle unit is thick sandstone bodies at the top of each parasequence that are composite, amalgamated sandstone intervals. Each composite bed is composed of 3 to 5 internal beds separated by distinct erosional surfaces with minor relief. Stacked sets of amalgamated beds preferentially preserve the thick intervals of convolute laminae characteristic of the lowermost stratification style in "complete" Tingmerkpuk turbidites.

Upper Depositional Unit

The upper unit is a sandstone-dominant succession of primarily amalgamated beds ranging in thickness from 0.5 to 4 m. Irregular, upward-thickening sandstone intervals are present in the upper unit of the Tingmerkpuk, but the regularly organized parasequences characteristic of the lower and middle units are not well developed in the upper unit. The major control on parasequence organization is apparently the degree to which erosional truncation at

the base of successive sandstone beds has incised underlying strata. The resulting organization is a series of relatively thin, irregular, and thick to very thickly bedded parasequences.

The upper parasequence set is the culmination of progradational and aggrational stacking patterns recorded in the underlying units. In contrast to the lower and middle units, which contain amalgamated sandstone intervals only in the uppermost parts of individual parasequencs, the upper unit is characterized by amalgamation throughout the parasequence set. The upper unit experienced the highest sedimentation rates and volume of sand transport during individual depositional events and the highest degree of erosional truncation and amalgamation in the Tingmerkpuk sandstone.

Interpretation of Depositional Systems

Sandstone beds throughout the Tingmerkpuk sandstone were deposited by episodic, highly fluidized turbidity flows that were initially erosional. With decreasing strength of flow, deposition occurred under conditions of rapid dewatering and consequent soft-sediment deformation. Over time, turbidity flows built a series of depositional lobes recorded by individual upward-coarsening parasequeces. During the growth of each parasequence, successive flows were deposited under higher energy conditions and were increasingly erosive. Thicker and more closely spaced beds indicate that successive flows were more sand rich, more frequent and, perhaps, more proximal. These trends were responsible for producing the upward-thickening pattern of sandstone beds with increasing amalgamation upsection within each parasequence.

The stacking pattern of parasequence sets is uniformly progradational with each parasequence thicker than the preceeding. The recurring internal stratification within individual beds was produced by waning turbidity flows that rapidly dewatered due to uniform grain size and hight textural maturity. Repeated progradation of submarine depositional lobes produced the upward-thickening organization of parasequence sets.

We interpret the Tingmerkpuk sandstone as a basinal submarine deposit that is genetically related to regional truncation along the Lower Cretaceous unconformity. The interpreted sequence boundary at the base of the Tingmerkpuk is likely a conformable stratal surface equivalent to the LCu erosional surface to the north. If so, this represents the first documented lowstand wedge of Beaufortian affinity deposited beyond the southern edge of the Neocomian shelf during the maximum extent of erosion along the LCu surface. Strata equivalent to the Tingmerkpuk sandstone have been identified in the subsurface of the North Slope and Chukchi Sea within the thermal window for oil generation. The presence of mature Neocomian sandstone within lowstand settings warrants systematic exploration for this unique stratigraphic play on the western Arctic Slope.

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