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Sheet 1 of 1

Tingmerkpuk Sandstone

Measured Stratigraphic Section

North Flank of Tingmerkpuk Mountain
DeLong Mountains, Western Brooks Range, Alaska

Section measured by R.K. Crowder, K.E. Adams and D.H. Jordan
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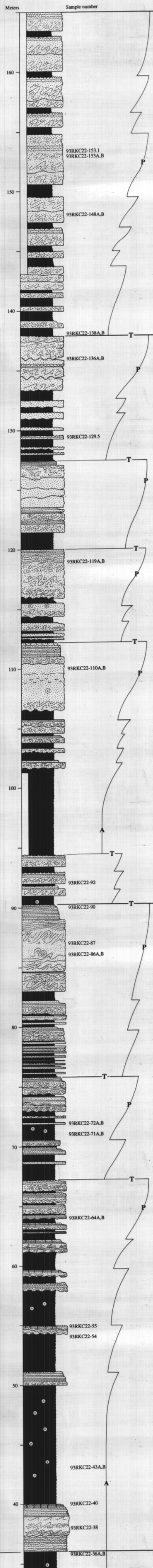
Neocomian
Tingmerkpuk Sandstone



Kingak Shale

Upper Sandstone Unit:

The upper unit of the Tingmerkpuk sandstone consists primarily of very fine-grained sublitharenite with lesser interbeds of dark gray to black, fissile clay shale. Although the upper unit forms a prominent topographic profile, the sandstone beds are poorly preserved and form a rubble-covered ridge along the flank of Tingmerkpuk Mountain. Sandstone beds within the upper unit contain all of the vertical sequence of primary sedimentary structures that are developed in sandstone of the middle unit. The chief sedimentologic criterion for recognizing the upper unit is that the majority of sandstone beds are in fact amalgamated beds with varying degrees of erosional relief along amalgamation surfaces. Amalgamation surfaces are developed only within the uppermost sandstone beds of parasequences in the middle unit. In contrast, nearly 80 percent of all sandstone beds in the upper unit are amalgamated beds recording several depositional events. Most sandstone beds show 3 or more amalgamated intervals that preferentially preserve the convolute laminae interval. Typically, only the upper few centimeters of the composite bed preserves plane-parallel and rippled laminae.

Bedding thicknesses change abruptly and without apparent periodicity in the upper unit. The vertical arrangement of sandstone beds into upward-thickening parasequences is not well-developed. Although the succession is not well-exposed, several beds showed minor erosional relief along basal bedding planes.

Interpretation of Depositional Processes

Sandstone beds of the upper unit were deposited by highly erosive, fluidized turbidity flows. The characteristic amalgamation of sandstone, coupled with erosional relief along basal bed surfaces, suggest that the entire upper unit may record the fill of low-relief channels. If so, the primary control on bed thickness in vertical succession was the degree to which erosion during the beginning of individual flows superimposed successive sandstone beds.

Upper Parasequence Set

The upper unit is a sandstone-dominant succession of primarily amalgamated beds ranging in thickness from .5 to 5 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 thickly bedded parasequences.

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

The upper parasequence set was deposited by turbidity currents active within the most proximal confines of submarine depositional lobes. Poor exposure prevent tracing beds laterally to determine stratal geometries. However, the degree of erosional truncation, amalgamation, and irregular parasequence organization suggests at least a part of the upper unit may have been deposited within low-relief distributary channels.

Middle Sandstone Unit:

The middle unit of the Tingmerkpuk sandstone consists of interbedded sublitharenite and dark gray to black clay shale. It is distinguished from the lower unit by higher sandstone:shale ratio, thicker sandstone beds, thinner parasequences, and by characteristic amalgamated beds developed at and near the top of individual parasequences. The shale intervals separating both sandstone beds and parasequences vary in thickness from a maximum of 6.5 m to thin shale partings less than 1 cm thick. The clay shale is highly fissile, and the highest order stratification unit recognized is the laminaeset. Manganese and siderite nodules are present, but not as common as in the underlying unit. A thick shale interval is present near the base of the unit and has a distinctly recessive topographic expression that can be traced across the north flank of Tingmerkpuk Mountain.

Sandstone beds vary from thin- to thick-bedded and are composed of subangular to subrounded, very fine-grained chert sublitharenite. Individual sandstone beds retain the characteristic internal sedimentologic organization described in the lower unit, with sharp, erosional bases, load, flute and groove casts, and conspicuous soft-sediment deformational features, particularly convolute laminae and overturned bedding. Plane-parallel laminae and ripple-drift cross-laminae form the thinnest of the internal divisions and are developed along the top of the bed.

The arrangement of sandstone beds in vertical section into upward-thickening parasequences is a continuation of the pattern developed in the lower unit, but distinct variations distinguish the middle unit. Individual parasequences have higher sandstone:shale ratios overall as a result of thicker and more closely spaced sandstone beds, thinner shale intervals, and more complete internal stratification sequences. The most notable characteristic that distinguishes parasequences of the middle unit is a tendency toward amalgamation within sandstone beds near the top of each parasequence. Amalgamation is characteristic of upper sandstone beds of parasequences in the middle unit, but is rare in the lower unit.

Interpretation of Depositional Processes

Sandstone beds of the middle unit were deposited by episodic, highly fluidized turbidity flows which 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 parasequences. 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.

Middle Parasequence Set

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 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 overlain by a thick interval of clay shale.

The middle parasequence 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. Individual parasequences range from 17 to 7 m in thickness, becoming thinner upsection in response to increasingly closely spaced sandstone beds and thinner intervening shale.

In addition to the regular internal sedimentologic organization, the most characteristic feature of the middle unit are thick sandstone bodies at the top of each parasequences 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.

The overall stacking pattern of the middle parasequence varies significantly at different scales. At the level of a single parasequence, the stacking pattern is strongly progradational and records outbuilding of individual depositional lobes. The entire parasequence set, however, lacks a strong progradational or retrogradational stacking pattern, indicating the overall depositional record is aggradational in organization. This pattern suggests that the depositional lobes switched dispersal sites regularly by avulsion.

Lower Interstratified Sandstone and Shale Unit:

The lower unit of the Tingmerkpuk sandstone consists of interbedded sublitharenite and dark gray to black clay shale. The shale intervals vary in thickness from a maximum of 10 m to thin shale partings interstratified within sandstone less than 1 cm thick. The clay shale is highly fissile, and the highest order stratification unit recognized is the laminaeset. Manganese and siderite nodules are common throughout the unit. Thin bentonite layers up to 1 cm thick are rarely exposed. Shale is the dominant lithology in the lower 40 percent of the unit, but becomes progressively replaced upsection by sandstone.

Sandstone beds within the lower unit are thin to thick beds of subangular to subrounded chert sublitharenite. Individual sandstone beds have a distinct and recurring internal sedimentologic organization. The typical bed has a sharp, erosional base characterized by load casts, flute and groove casts, and rare ball-and-pillow structures. The lower 20 to 40 percent of the bed contains conspicuous soft-sediment deformational features, particularly convolute laminae and large flame structures. The deformed interval is overlain successively by plane-parallel laminae and ripple-drift cross-laminae. The interval of rippled laminae is typically the thinnest of the internal bed divisions and, except where truncated by an overlying sandstone, forms the top of the bed. Current ripple forms are usually preserved along the upper bedding plane and are abruptly overlain by a thin (< 4 cm) interval of brown silty shale, in turn overlain by dark gray or black clay shale.

The arrangement of sandstone beds in vertical section defines a number of distinct upward-thickening parasequences with gradational bases and sharp tops. Individual parasequences range from 5 to 15 m in thickness. Typically, the base of the parasequence is marked by thin sandstone beds within a shale-dominant interval. The thinnest sandstone beds often lack the convolute interval, and contain only plane-parallel and rippled laminae. Upsection, sandstone beds become progressively thicker, more closely spaced, contain the complete sequence of sedimentary structures, and are increasingly amalgamated beds. The thickest sandstone commonly forms the upper bed of the parasequence, and it is abruptly overlain by dark gray to black shale above a sharp, planar surface. Strata above this surface are the basal beds of the next parasequence.

Interpretation of Depositional Processes

Sandstone beds of the lower unit of the Tingmerkpuk are interpreted as a repetitive record of short-lived, episodic depositional events under conditions of regularly decreasing flow regime. The initial stages of the flows were generally erosive and left sharp erosional bases beneath sandstone beds. Initial deposition was by highly fluidized flows that rapidly dewatered and internally deformed to produce the interval of convolute laminae. Deposition under the plane-bed phase of high flow regime followed to produce plane-parallel laminae. As the strength of flow diminished, the upper intervals of ripple laminae and overlying silty shale were deposited by the final vestiges of the decaying current.

The sediment flows responsible for the episodic depositional events were turbidity flows, evidenced by the recurring Bouma sequence of stratification intervals, repetitive bed organization at varying scales, stratigraphic setting, and lack of indication of shallow water deposition. The successive turbidity flows built a series of depositional lobes recorded by the upward-coarsening parasequences.

Lower Parasequence Set

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 (27 m) 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.

The base of the lower unit is a probable sequence boundary. Unlike other sandstone successions in the Tingmerkpuk, the basal sandstone interval appears abruptly in the vertical sequence and is not preceded 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 sandstone records an abrupt landward shift in depositional facies.

Probable Sequence Boundary

Neocomian
Kingak Shale

Kingak Shale:

Measured section begins at the lowest prominent shale bench exposed on the north flank of Tingmerkpuk Mountain where the upper Kingak Shale forms steep slopes beneath the Tingmerkpuk sandstone. Immediately beneath this measured section, distinctive intervals of maroon-colored silty shale characteristic of the lower Kingak Shale are exposed in gullies.

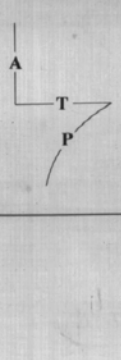
The upper Kingak Shale forms the basal unit of the measured section and is composed of 36 m of dark gray to black clay shale. The interval is highly fissile, and the highest order stratification unit recognized is the laminaeset. Manganese and siderite nodules are common where concentrated in float and are rarely exposed in outcrop. Laminaesets of light gray claystone, probably bentonite, are rarely exposed in layers up to 1 cm thick.

The formation contact between the Kingak Shale and Tingmerkpuk sandstone is picked at the base of the first sandstone bed. Stratigraphic and sedimentologic relationships suggest this contact is a probable sequence boundary and possibly the correlative stratal surface to an unconformity developed to the north and east.

Explanation

- White column to left indicates lithology interpreted from rubblecrop or float.
- Plane-parallel laminae
- Wavy laminae
- Ripple laminae
- Convolute bedding
- Load casts
- Flame structures
- Concretions
- Burrows

Paleoenvironmental Migration Pattern



A Aggradation
T Transgressive surface
P Progradation