

Wave and River-Dominated Deltaic Deposits in the Lower Cretaceous (Neocomian) Kamik Formation in the Parsons Lake Gas Field, Mackenzie Delta Region, Northwest Territories

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ABSTRACT

Introduction

The Lower Cretaceous (late Valanginian to middle Hauterivian) Kamik Formation forms part of a major clastic succession hosting significant reserves of natural gas in the subsurface of the Beaufort-Mackenzie Delta region. The onshore Parsons Lake gas field with reserves of approximately 1.8 trillion cubic feet (TCF) represents the largest discovery to date from the Kamik Formation. Sedimentological and ichnological analysis of the sandstone-dominant Kamik Formation in the Parsons Lake field indicates that these strata represent the deposits of a storm-influenced, mixed wave- and river-dominated deltaic setting. Interpreted facies include prodelta, delta front (distributary mouth bar), delta plain and distributary channel deposits. This presentation will use cored intervals from the Parsons P-41 and Siku A-12 wells to illustrate variations in the sedimentological and ichnological characteristics between wave- and river-dominated deltaic deposits present within the Kamik Formation at Parsons Lake.

Study Area and Core Control

The study area is located within the southeastern portion of the Beaufort-Mackenzie Delta region of the Northwest Territories. The study area shown in Figure 1 encompasses the onshore Parsons Lake gas field, located in the southwestern corner of the Tuktoyaktuk Peninsula. Approximately 19 wells penetrate the Kamik Formation within the study area. Of this total, only 7 wells contain Kamik core, with some wells containing multiple cores from the interval.

Stratigraphy and Paleogeography

The Kamik Formation is a late Valanginian to middle Hauterivian succession. It represents the thickest and most widespread coarse clastic interval in the Lower Cretaceous succession of the northern Yukon and adjacent Northwest Territories

(Dixon, 1991). The Kamik Formation is the uppermost unit of the Parsons Group and is underlain by the shales of the McGuire Formation and overlain by the shales of the Mount Goodenough Formation (Figure 2). The Kamik Formation at Parsons Lake consists of a series of stacked, prograding deltaic deposits, open marine, coastal plain and fluvial sediments.

The Kamik Formation was deposited as a thick, sand-dominated succession which prograded from the southeast into the Arctic Ocean during the early Cretaceous. The paleo-shoreline is interpreted to have trended southwest to northeast, approximately parallel to the Eskimo Lakes Fault Zone. The large quantities of clastic material comprising the Kamik Formation are interpreted to have been shed off of the emergent Eskimo Lakes Arch during syn-depositional tectonic movement along the Eskimo Lakes Fault.

The Kamik gas reservoirs at Parsons Lake consist of multiple, thick distributary mouth bar and distributary channel sandstones. Hydrocarbons are structurally trapped within a large rollover anticline associated with the Eskimo Lakes Fault (Cote *et al.*, 1975).

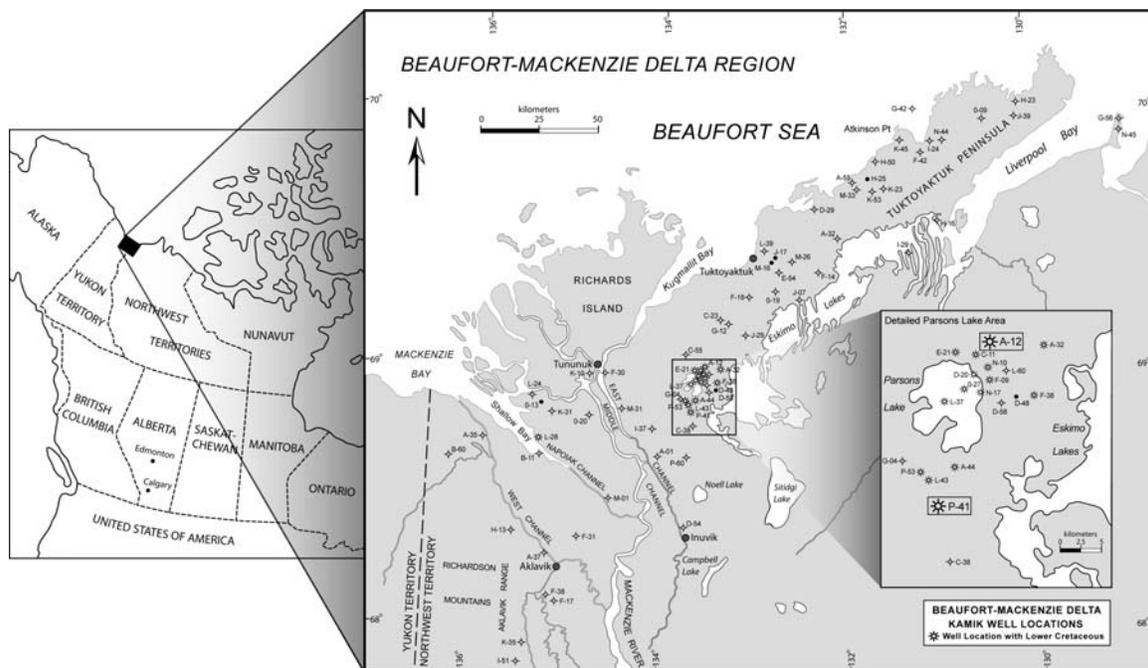


Fig. 1: Location map of the Beaufort-Mackenzie Delta region of the Yukon and Northwest Territories. The map features the location of exploratory wells penetrating Lower Cretaceous strata in the region. Detailed map of the Parsons Lake gas field located in the southwest portion of the Tuktoyaktuk Peninsula. Note the locations of the Parsons P-41 and Siku A-12 cores in the detailed Parsons Lake study area displayed in this study (modified from Dixon, 1982).

		Parsons Lake Field	Biostratigraphic Zonation		
LOWER CRETACEOUS	HAUTERIVIAN	Mount Goodenough Formation	<i>Simbirskites cf. kleini</i>		
		PARSONS GROUP	Kamik Formation upper member	No zones Identified	
	Kamik Formation lower member		<i>Buchia inflata</i> s.l.	<i>B. n. sp. aff. inflata</i>	<i>B. crassicollis</i>
	VALANGINIAN	McGuire Formation	<i>B. n. sp. aff. inflata</i>	<i>B. bulloides</i>	<i>Homolsomites quatsinoensis</i>
		BERRIASIAN	Martin Creek Formation	<i>Buchia keyserlingi</i>	
	upper member			? <i>Polyptychites</i> spp.	<i>Tollia aff. mutabilis</i>
		red weathering member	Husky Formation	<i>Tollia cf. payeri</i>	<i>B. n. sp. aff. volgensis</i>
	<i>Buchia n.sp. aff. volgensis</i>			<i>B. uncitoides</i>	<i>Surites aff. analogus</i>
	JURA-SSIC	arenaceous member		<i>Buchia okensis</i>	
				<i>Craspedites aff. suprasubdites</i>	<i>Craspedites</i>
			<i>B. unshensis</i>	<i>Buchia cf. unshensis</i>	

Fig 2: Stratigraphic chart and biostratigraphic zonation displaying the regional stratigraphy of the Lower Cretaceous (Berriasian to Hauterivian) interval in the subsurface of the Parsons Lake gas field (modified from Dixon, 1991).

Observations and Interpretations

Parsons P-41 Core (2962m to 2980m)

The cored sequence from the Parsons P-41 well is interpreted to represent a storm-influenced, wave-dominated deltaic setting (Figure 3). The core is comprised of two coarsening-upwards sequences separated by a conglomeratic lag. Each coarsening-upward cycle begins with interbedded sandstones and shales and is sharply overlain by low angle to trough cross-bedded sandstones. The lowermost portion of each cycle is interpreted to represent distal distributary mouth bar (lower shoreface) deposits and the overlying sandstones are interpreted to represent the proximal distributary mouth bar (upper shoreface).

The basal portion of each coarsening-upwards cycle is typified by a 'laminated-scrambled' texture with interbedded laminated hummocky cross-stratified sandstone beds and burrowed (scrambled) silty shales. There are also abundant wavy-bedded intervals, wave-ripple structures and convolute bedding. Coalified wood fragments are common and rare pyrite and siderite concretions are locally developed. Ichnological characteristics include a mixed *Cruziana* and *Skolithos* ichnofacies. The storm deposited scour-based sandstones are dominated by opportunistic colonization by infaunal organisms corresponding to the *Skolithos* ichnofacies. Interstratified fair-weather argillaceous deposits are characterized

by the lower energy *Cruziana* ichnofacies. Identified ichnotaxa include, *Rhizocorallium*, *Asterosoma*, *Teichichnus*, *Cylindrichnus*, *Arenicolites*, *Diplocraterion*, *Ophiomorpha*, *Rosselia*, *Palaeophycus*, *Chondrites*, *Planolites*, *Helminthopsis*, *Phycosiphon*, *Thalassinoides*, *Skolithos*, *Zoophycos* and cryptic bioturbation. These tempestite deposits are associated with wave/storm-dominated settings and are interpreted to have been deposited below fair-weather wave base in the distal distributary mouth bar (offshore transition to lower shoreface).

The uppermost portion of each coarsening-upward cycle is composed fine to medium-grained sandstones and minor silty and shaley intervals. Sedimentological characteristics include low angle cross-bedding, trough cross-bedding, planar tabular bedding and wave-ripple lamination. The sandstones contain common coalified wood fragments, phytodetrital material and rare siderite and pyrite concretions. Portions of the sandstones exhibit graded rhythmities. These graded rhythmities are identified in core as centimeter-scale, fining upwards beds generally capped by micaceous and/or phytodetrital material. They are interpreted to correspond to 'pulses' of sedimentation in deltaic environments generated by decaying sediment plumes entering the delta front from distributary channels.

These sandstones are characterized by an assemblage comprised of *Conichnus*, *Cylindrichnus*, *Rhizocorallium*, *Palaeophycus*, *Diplocraterion*, *Planolites*, *Teichichnus*, *Ophiomorpha*, *Macaronichnus*, fugichnia and cryptic bioturbation. The *Macaronichnus* trace fossil is known to occur in the upper shoreface and provides evidence of a high-energy shoreface environment. The overall trace fossil diversity is moderate with the majority of forms present displaying diminutive sizes relative to those found in non-deltaic shoreface deposits. These sandstones are interpreted to represent a high-energy proximal distributary mouth bar (upper shoreface) in a storm-influenced, wave-dominated deltaic environment. The conglomeratic lag separating the two coarsening-upwards cycles coincides with a flooding surface and likely represents a transgressive surface of erosion.

Siku A-12 Core (2713m to 2731m)

The Siku A-12 core is interpreted to represent the deposits of a river-dominated deltaic setting (Figure 4). The core is composed of an overall shallowing-upwards sequence from sandstone-dominated distributary mouth bar deposits at the base to fine-grained interdistributary bay deposits at the top. The lower two-thirds of the core is interpreted to represent the deposits of a prograding delta front and the upper one-third is interpreted to represent delta lobe abandonment and subsequent sediment infilling of an interdistributary bay environment.

The lower coarsening-upwards sequence is a fine to medium-grained sandstone-dominated interval with minor interbeds of shale, siltstone and shaley siltstones. The interval is characterized by sedimentary structures indicating rapid

sedimentation rates and a highly stressed biological setting. Sedimentological characteristics include low angle and trough cross-bedding, planar tabular cross-bedding and wave-ripple cross-lamination. Within the basal portion are abundant soft-sediment deformation structures, including convolute bedding, curvilinear bedding and oversteepened bedding. Abundant climbing wave-ripple structures, large-scale aggrading wave-ripples and ball and pillow structures are commonly observed. The sandstones also contain abundant phytodetrital material and common siderite and pyrite concretions. No trace fossils were identified within any of these sandstones, siltstones and shales. The lack of bioturbation within this interval is interpreted to be the result of a multitude of biological stresses in the depositional system. One specific stress within this interval were the very high sedimentation rates which likely precluded colonization of the substrate by infaunal organisms. Overall the interval displays strong evidence of deposition proximal to a sediment-rich fluvial point source and is interpreted to represent a distributary mouth bar setting in a fluvial-dominated delta front setting.

The uppermost fine-grained portion of the core is composed predominantly of fine-grained silty sandstones, siltstones and shale. Sedimentological characteristics include wavy, flaser, and lenticular bedding, wave and current-ripple lamination and convolute bedding. The interval contains abundant organic material including carbonaceous rootlets, leaf imprints and common siderite and pyrite concretions. Overall bioturbation is low and includes only *Teichichnus*, *Palaeophycus*, *Planolites*, *Skolithos* and rare *Thalassinoides* and *Diplocraterion*. The low abundance and low diversity of trace fossils in this interval is interpreted to be result of biological stresses in the depositional system including variability in sedimentation rates, salinity, oxygen levels and water turbidity. These fine-grained sediments are interpreted to represent interdistributary bay deposits, specifically bay fill and crevasse splay deposits.

Conclusions

The Kamik Formation in the Parsons P-41 and Siku A-12 cores display variations between storm/wave-dominated and river-dominated deltaic systems. The differences between the two deltaic settings are interpreted to be due to variations in the local shoreline due to evolving basin morphologies. The majority of individual trace fossils present within the Kamik Formation display low to moderate diversities and diminutive morphologies. The overall low occurrence of bioturbation in both cores is interpreted to result from a multitude of biological stresses in the depositional system. Specific stresses include sedimentation rates, substrate consistency, salinity, oxygen levels, water turbidity and light. These biological stresses are characteristic of deltaic settings and the trace fossil assemblages contrast with those found in non-deltaic shoreface environments.

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Sedimentary Structures and Ichnofossil Symbols		
	- Hummocky cross-stratification	 - Rootlets
	- Low angle cross-bedding	 - Plant debris
	- Trough cross-bedding	Ar - <i>Arenicolites</i>
	- Convoluted bedding	As - <i>Asterosoma</i>
	- Wave ripple lamination	Ch - <i>Chondrites</i>
	- Wavy bedding	Co - <i>Conichnus</i>
	- Flaser bedding	cryptic - cryptic bioturbation
	- Lenticular bedding	Cy - <i>Cylindrichnus</i>
	- Current ripple lamination	Dp - <i>Diplocraterion</i>
	- Stylolite	fg - fugichnia (escape trace)
	- Climbing ripples	He - <i>Helminthopsis</i>
	- Large scale wave ripples	Ma - <i>Macaronichnus</i>
	- Mud rip-up clasts	Oph - <i>Ophiomorpha</i>
	- Ball & Pillow structures	Pa - <i>Palaeophycus</i>
	- Pebbles/Granules	Ph - <i>Phycosiphon</i>
		Pl - <i>Planolites</i>
		Rhz - <i>Rhizocorallium</i>
		Ro - <i>Rosselia</i>
		Sk - <i>Skolithos</i>
		Te - <i>Teichichnus</i>
		Th - <i>Thalassinoides</i>
		Zo - <i>Zoophycos</i>
		Mc - Micaeous material
		Py - Pyrite
		Wd - Wood fragment
		Sid - Siderite
		Cal - Calcite
		— - sharp contact
		- - - - - gradational contact
		~ - undulatory/scoured contact

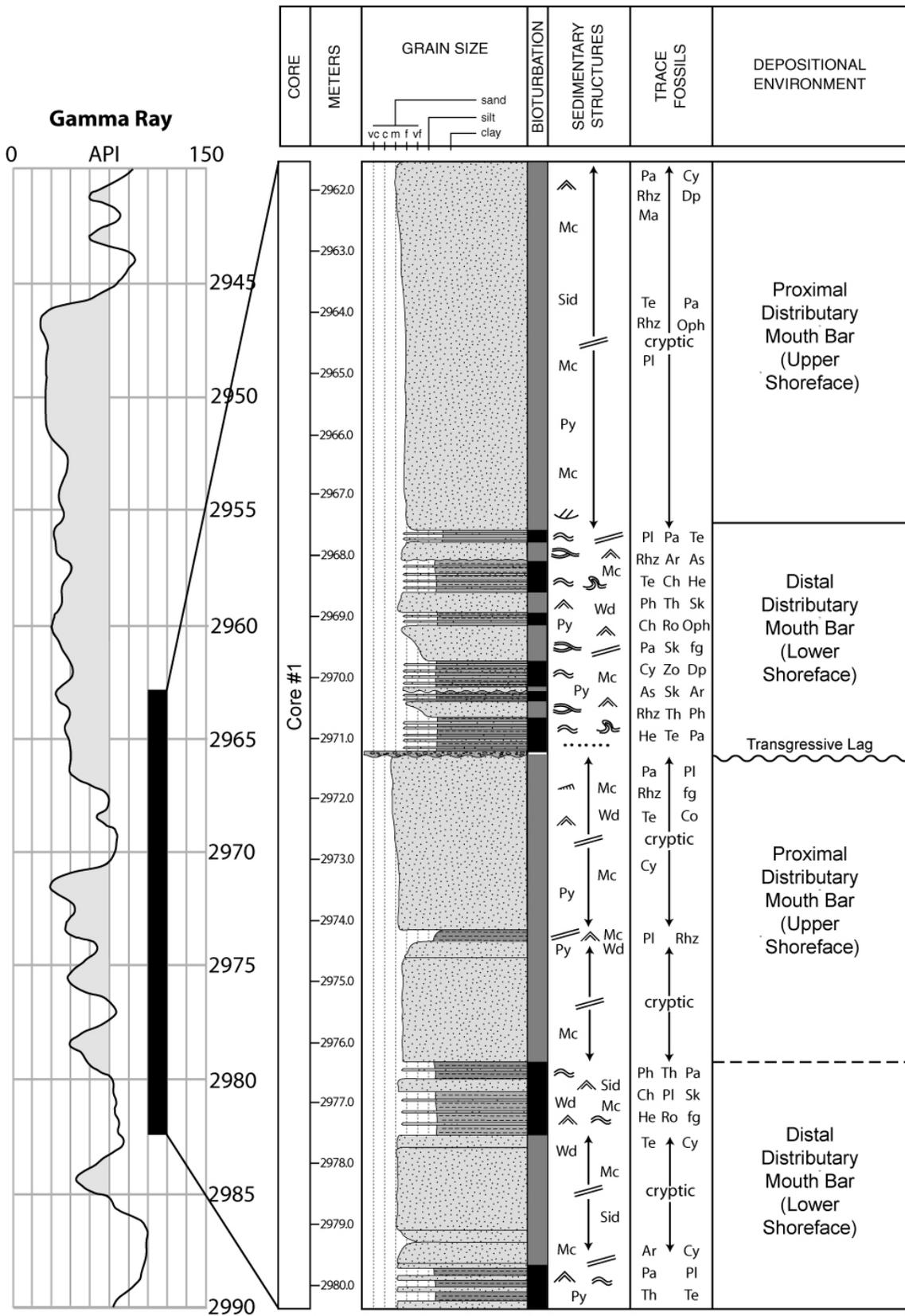


Fig. 3: Detailed core log of the Kamik Formation from the Parsons P-41 well.

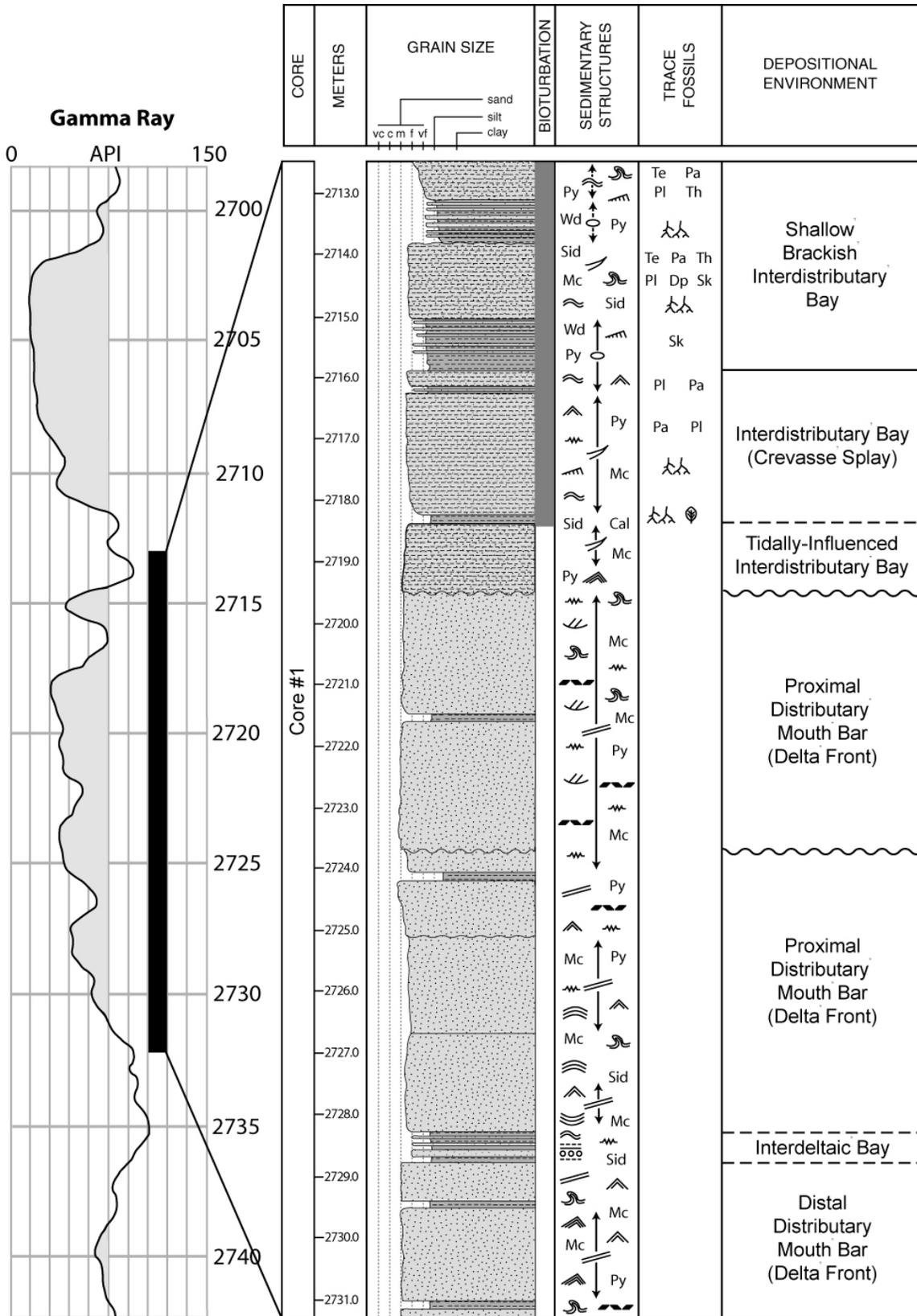


Fig. 4: Detailed core log of the Kamik Formation from the Siku A-12 well.