Ichnology of the Doe Creek Member of the Kaskapau Formation: An Example of the Stark Contrast of Brackish and Fully Marine Assemblages*

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Abstract

The Cenomanian Doe Creek Member comprises sand-dominated units within the Kaskapau Formation shale. The sandstones are of reservoir quality and have been estimated to hold crude oil reserves of 460 million barrels (100 million barrels initial established reserves). The Doe Creek sandstones are sedimentologically complex, with polygenetic origins from open-marine shoreface, deltaic, and brackish settings. This complexity provides a unique situation to study and compare the ichnology of unstressed, open-marine settings and stressed deltaic and brackish settings. The open-marine shelf to lower shoreface profiles present in the Doe Creek Member comprise an exceptionally well preserved record of an unstressed ichnological succession from the Zoophycos ichnofacies beyond maximum wave base to the proximal Cruziana ichnofacies of the lower shoreface. This unstressed offshore trace fossil suite provides a baseline for ichnologic comparison of the deltaic successions of the Doe Creek Member. The deltaic settings in the Doe Creek exhibit an overall stressed ichnologic assemblage induced by fluctuations in salinity, sedimentation rates, and turbidity, all of which influence biogenic activity well into offshore areas. These stresses cause a change in benthic behavior and result in deviations from typical offshore ichnological assemblages. The Doe Creek Member also hosts brackish bay and tidal inlet deposits, which display strong salinity-stressed ichnofaunal assemblages.

Study Area

This study focuses on the subsurface Doe Creek Member in Valhalla Field and its periphery in northwestern Alberta, on the southern flank of the Peace River Arch (Figure 1). The area has excellent well control, including over one hundred cores penetrating the Doe Creek Member. The majority of Doe Creek hydrocarbon production in this area comes from Valhalla Field as well as Spirit River, Progress, Sinclair, Knopcik, and Elmworth Fields.

Stratigraphy and Paleogeography

The Cenomanian Doe Creek Member is stratigraphically the lowest of three sandstone members in the basal Kaskapau Formation, the others being the Pouce Coupe and Howard Creek in ascending order (Figure 2). The Kaskapau Formation is predominantly dark gray, slightly fissile shale that overlies sands and shales of the Cenomanian Dunvegan Formation. The contact between the Dunvegan and Kaskapau Formations is diachronous and displays an interfingering relationship, and is thus placed at stratigraphically higher levels westward and northward (Singh, 1983). The Doe Creek Member Sandstones are encased by Kaskapau Formation shale and are correlative with, but detached from, brackish and fresh-water deposition of the Dunvegan Formation to the northwest (Wallace-Dudley and Leckie, 1993).

The Doe Creek Member was deposited in a shallow marine shelf setting on the western margin of the Western Interior Seaway (Figure 3). Eustatic sea level was on the rise during the late Cenomanian, culminating in peak transgression at the Cenomanian-Turonian boundary. This transgressive setting led to an overall retrogradational stacking pattern in the Doe Creek, Pouce Coupe, and Howard Creek sandstones (Wallace-Dudley and Leckie, 1993). The complexity in vertical facies relationships and lateral facies variability seen within the subsurface Doe Creek sandstones were likely influenced by both allocyclic sea level variation and autocyclic processes such as delta lobe switching and channel avulsion occurring in a more landward position.

Preliminary Observations and Interpretations

14-32-74-9W6

This well is remarkable in that it contains both delta front facies and an open-marine lower shoreface (Figure 4). The delta front facies at the base of the core is distinguished by the presence of hyperpycnal muds, contorted and convoluted bedding, low-angle cross bedding, wave and current cross-lamination, and graded rhythmic lamination. Ichnologically, the delta front displays a slightly impoverished assemblage of the *Skolithos* ichnofacies including, *Rosselia*, *Ophiomorpha*, *Palaeophycus*, and *Bergaueria*. Above the delta front lies an interval representing distal offshore subjected to higher, or fluctuating, sedimentation rates indicated by the high degree of vertical adjustment shown in *Zoophycos*. This unit shifts into a proximal offshore setting showing sporadic deltaic influence. The ichnological suite present is a slightly impoverished *Cruziana* ichnofacies with an upward increasing abundance of vertical *Ophiomorpha*, *Skolithos*, and *Diplocraterion*, forms typically associated with the *Skolithos* ichnofacies. The open-marine lower shoreface present near the top of the core displays typical sedimentological characteristics of amalgamated storm beds with minor wave ripple cross stratification, as well as vertical and horizontal *Ophiomorpha*, *Palaeophycus*, *Planolites*, and *Thalassinoides* of the *Skolithos* ichnofacies.

07-25-74-11W6

This core display focuses on the upper of two general shallowing up successions present in the core (Figure 5). The lower portion of this succession is interpreted to represent upper offshore deposition with minor deltaic influence. The ichnological assemblage is typical of the *Cruziana* ichnofacies, including spectacular examples of *Zoophycos*, *Helminthopsis*, *Phycosiphon*, *Diplocraterion*, *Teichichnus*, *Planolites*, *Chondrites* and rare examples of *Skolithos*. This facies grades into distal prodelta characterized by a slightly impoverished version of the

Skolithos ichnofacies. An autocyclic change in deposition, such as a delta lobe switch, is the likely cause of diminished deltaic influence in the overlying facies.

06-25-75-10W6

This well shows storm-influenced prodelta deposits characterized sedimentologically by hyperpycnal muds, distal tempestites, starved wave ripples, loading structures at the base of sandstone beds, and minute synaeresis cracks (Figure 6). Ichnologically it hosts reduced diversity, marine *Cruziana* ichnofacies typified by *Helmithopsis, Phycosiphon*, rare *Chondrites, Teichichnus*, rare *Siphonichnus*, rare *Thalassinoides*, and diminutive rare *Zoophycos*. The depositional setting shifts to an unstressed offshore assemblage at a flooding surface displaying palimpsest colonization by *Rhizocorallium*. The unstressed offshore is characterized by a diverse assemblage of the *Cruziana* ichnofacies typified by complete substrate homogenization by abundant *Zoophycos, Helminthopsis, Phycosiphon, Planolites, Palaeophycus*, *Thalassinoides,* and rare *Schaubcylindricnus freyi*. A concealed bed-junction firmground delineates a sharp facies dislocation at the top of this unit, demarcated by a sharp-walled, pebble filled *Thalassinoides*. Above this surface is well-developed sandstone showing characteristics of a tidal inlet (abundant rip-up clasts, discrete carbonaceous mud laminae, current ripple cross-lamination, and double-mud drapes). The ichnological suite present in the tidal inlet facies is characterized as a highly stressed, brackish suite with rare *Thalassinoides* and *Planolites*, which are typically restricted to mud laminae and cryptic bioturbation.

Conclusions

The sedimentologic complexity inherent in the Doe Creek Member provides an excellent opportunity to investigate ichnologic responses to varied environmental conditions. The variation in biogenic behavior in response to stresses found in deltaic and brackish settings, can be modeled and thus providing a valuable tool in environmental reconstruction.

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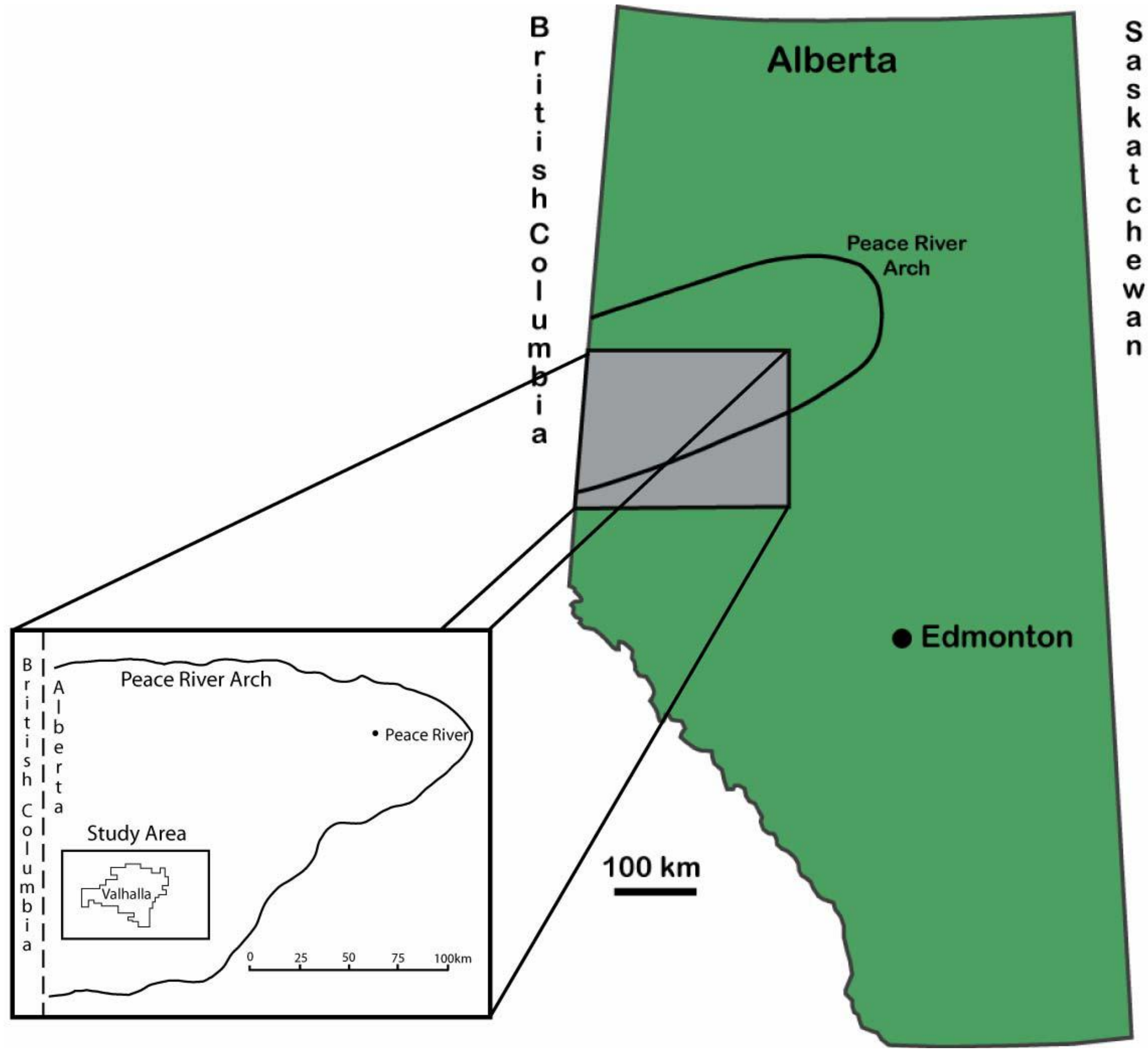

Figure 1. Location of study area (Outline of Peace River Arch from Cant, 1988).

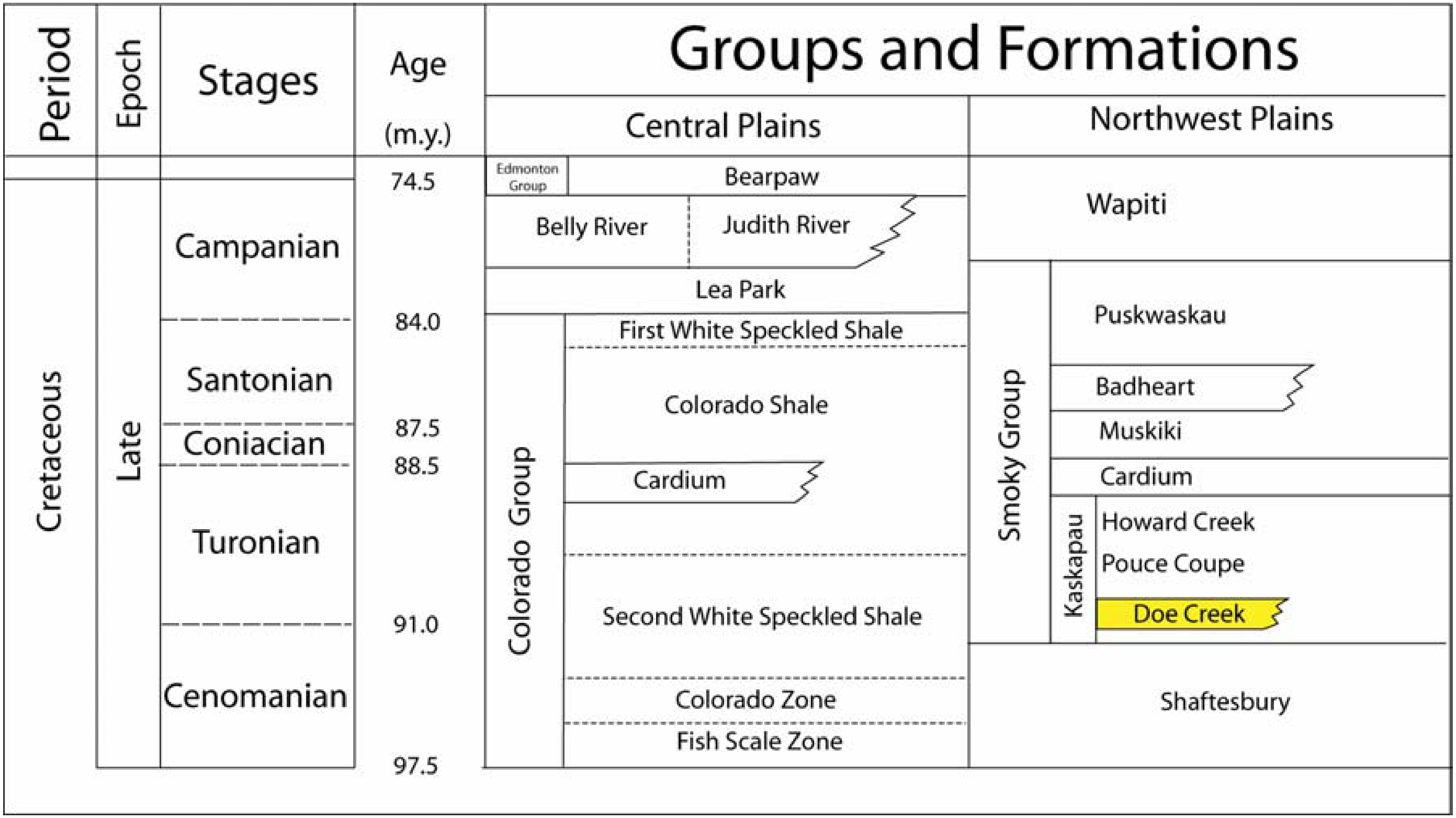

Figure 2. Stratigraphic chart of the Late Cretaceous in the central plains and northwest plains of Alberta, Canada (Modified from E.R.C.B. 1992).

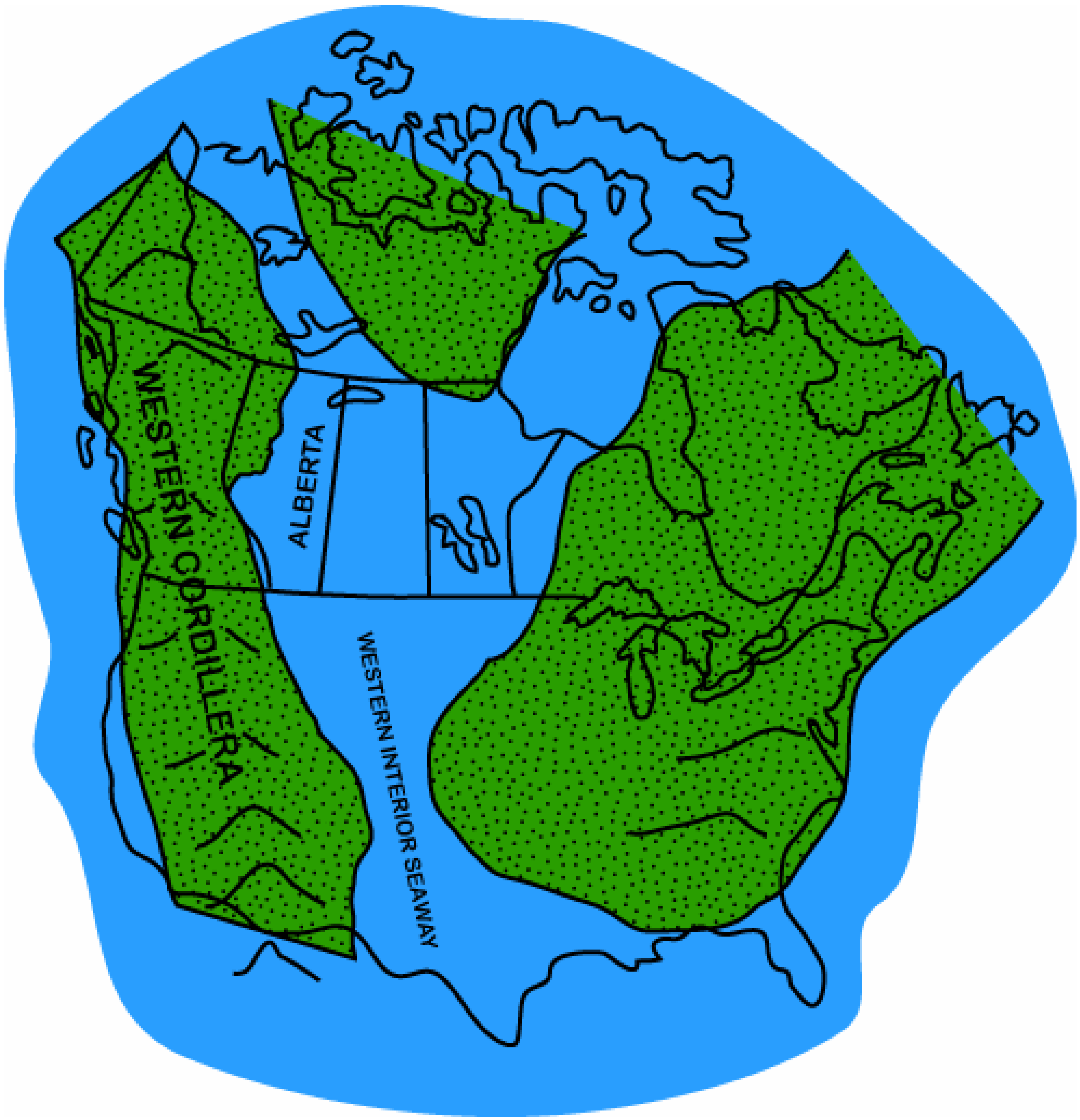

Figure 3. Cenomanian paleogeography of North America (Modified from Bhattacharya, 1993).

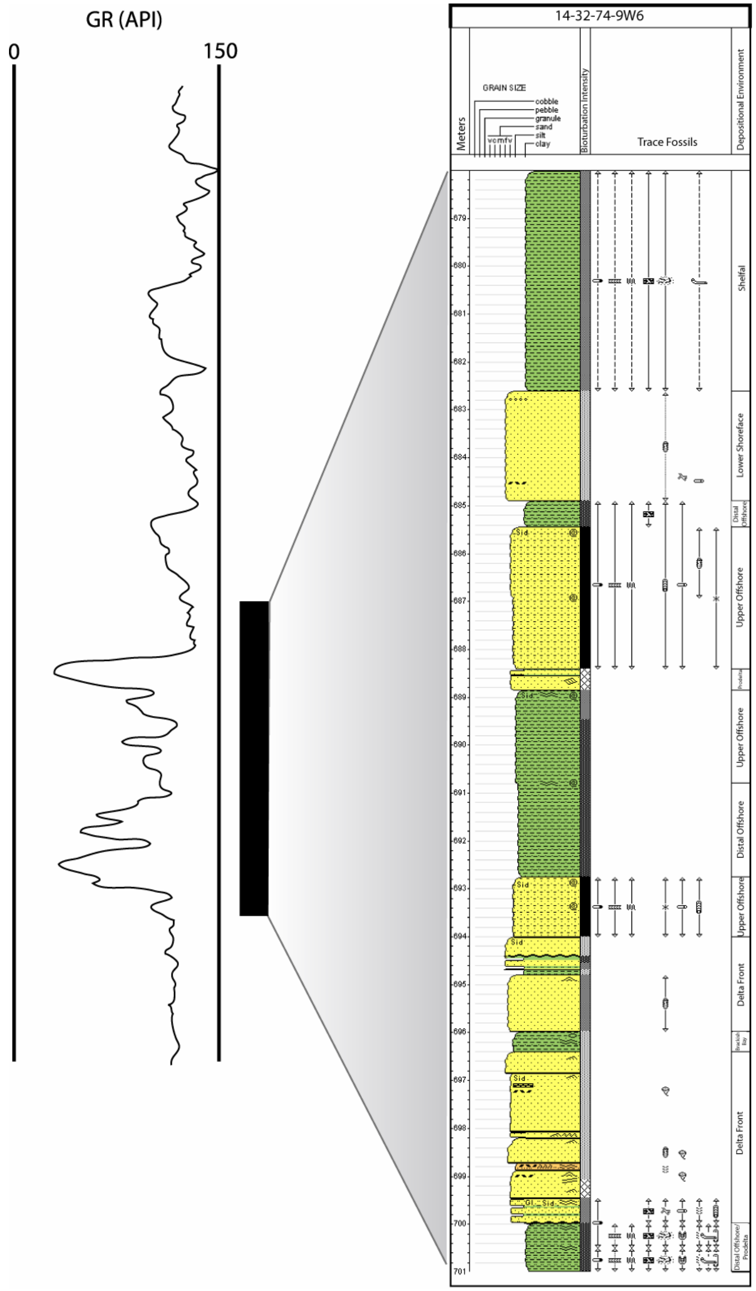

Figure 4. Litholog of 14-32-74-9W6. Legend in Figure 7.

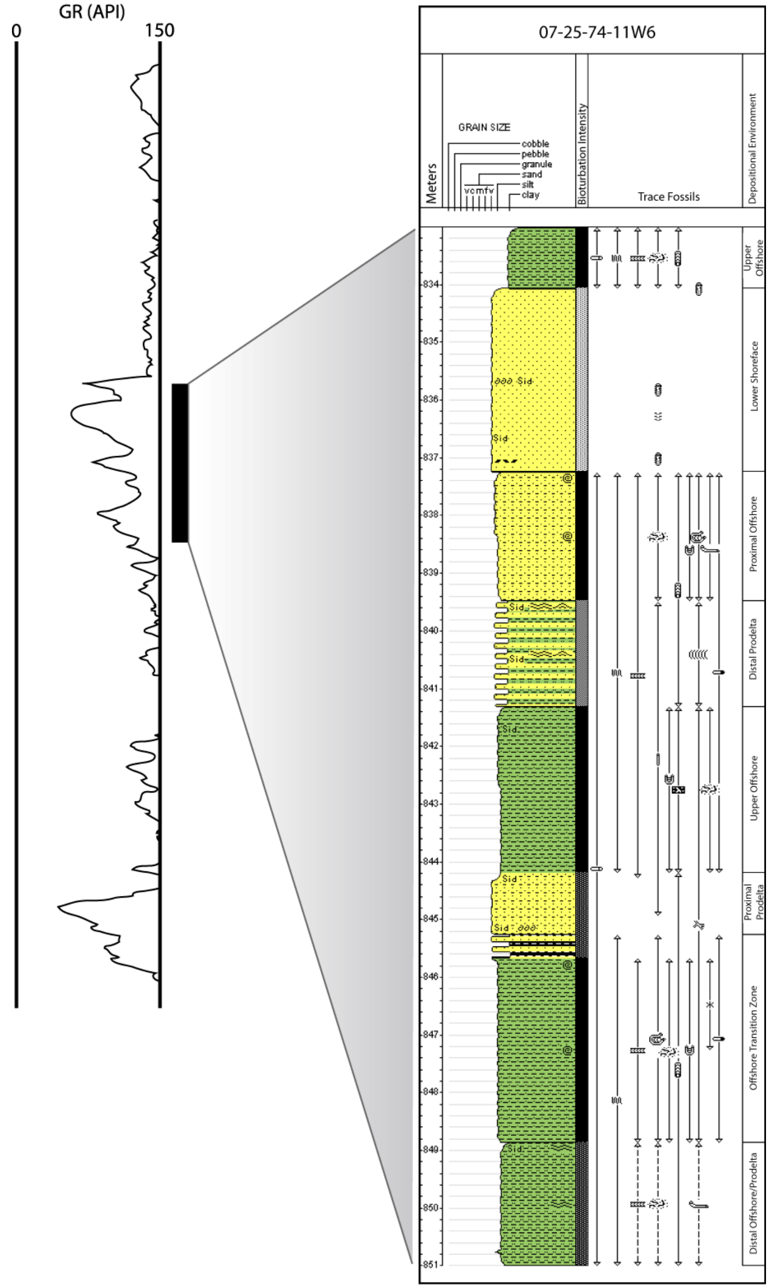

Figure 5. Litholog of 07-25-74-11W6. Legend in Figure 7.

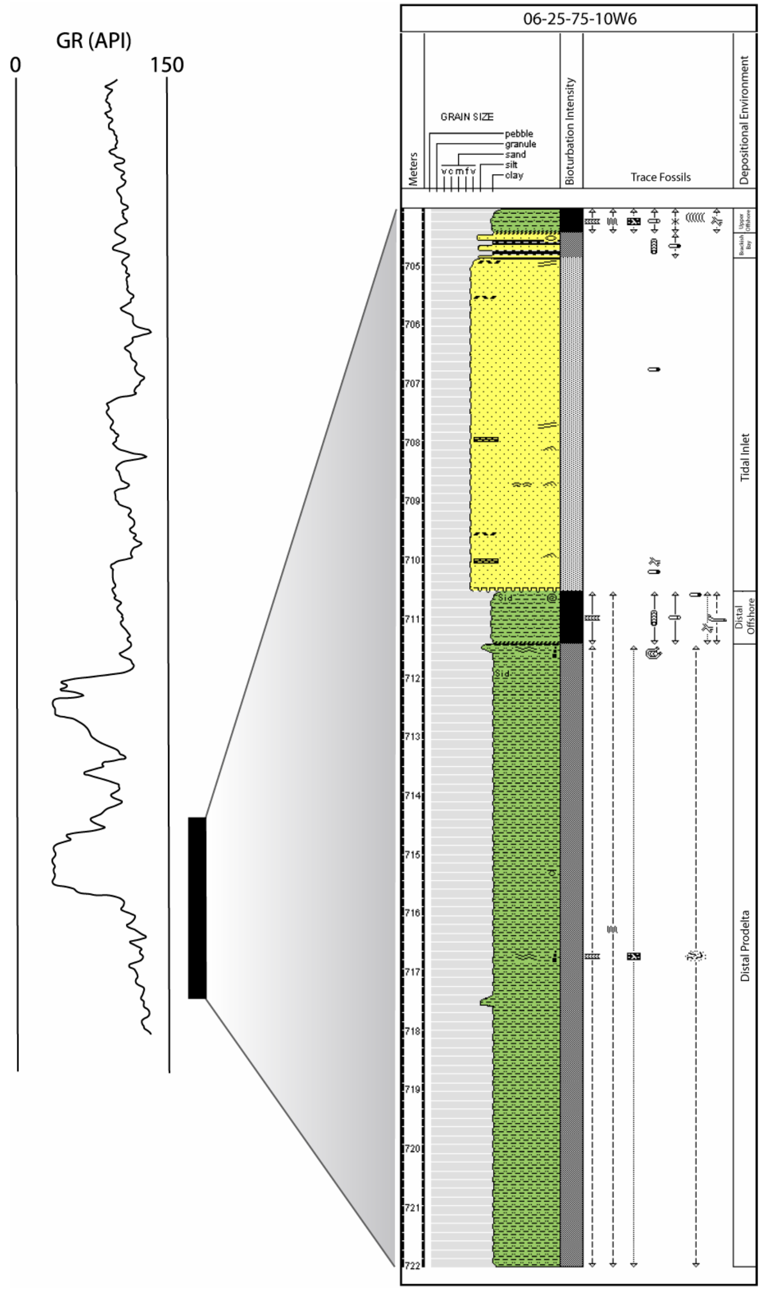

Figure 6. Litholog of 06-25-75-10W6. Legend in Figure 7.

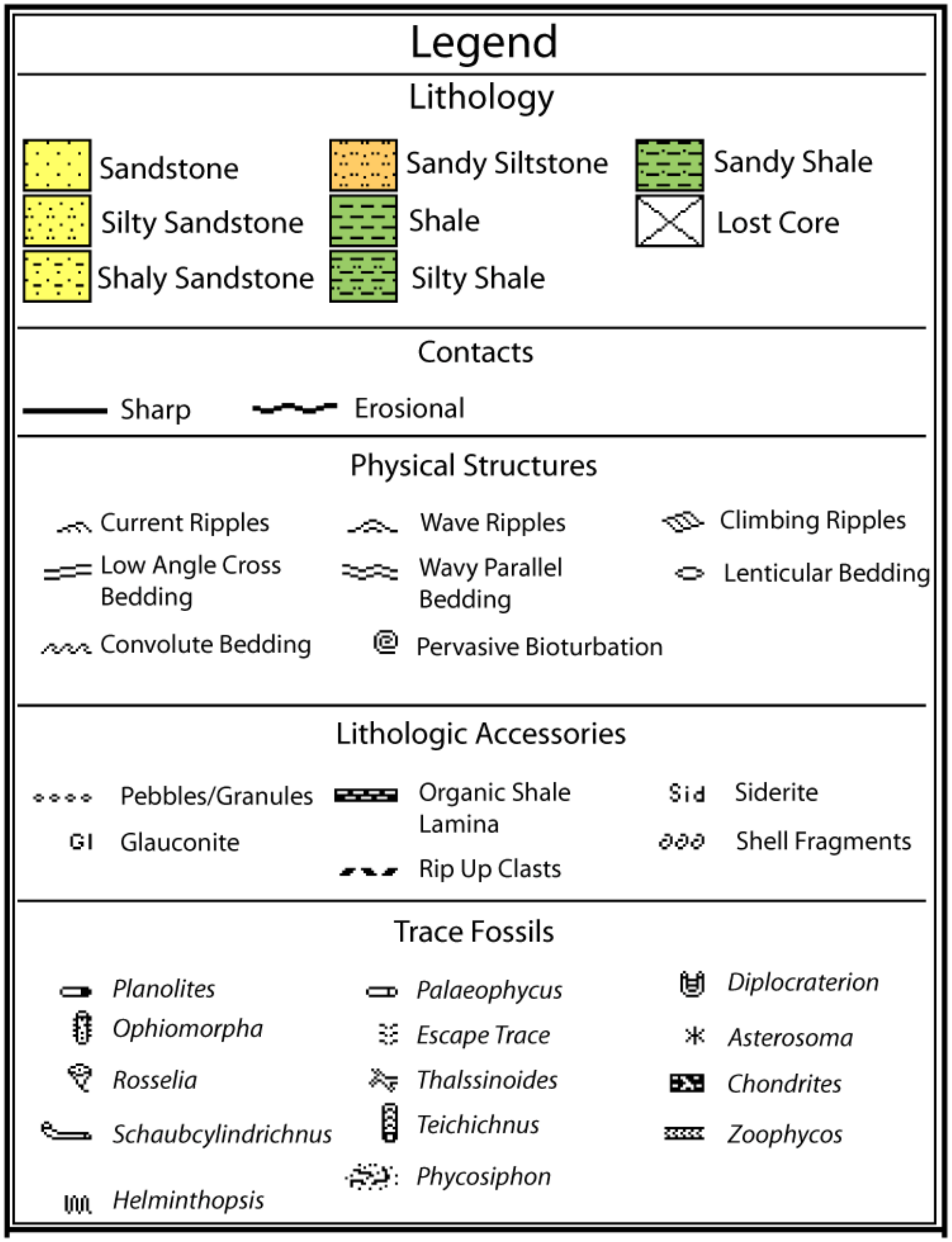

Figure 7. Legend for lithlogs seen in Figure 4, Figure 5, and Figure 6.