

# **Tidal-Fluvial and Wave-Dominated Estuarine Valley Fills: Ichnological-Sedimentological-Palynological Comparison of Central Basin and Lateral Accretion Deposits, Lower Cretaceous Glauconite and Viking Formations, Central Alberta**

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## **Introduction and Data Sources**

This study documents palynomorphs recovered from estuarine valley fills, and evaluates their paleoecological implications with respect to ichnologic and sedimentologic aspects of the depositional facies. Estuarine valley fills are major hydrocarbon producers in the Lower Albian Glauconite Formation and the Upper Albian Viking Formation of central and southern Alberta. Reservoir units are mainly spatially restricted channelized sandstones, channel morphologies are tidal-fluvial estuarine fills for the Glauconite Formation, versus wave-dominated estuarine fills for the Viking Formation. Channel fills within tidal-fluvial systems typically contain lateral accretion deposits comprising inclined heterolithic stratification (IHS). By contrast, IHS is absent from the Viking Formation estuarine channel fills. Both valley systems possess facies recording the central basin, which retain evidence of the relative interplay of marine (waves and/or tides) and fluvial processes. The accurate characterization of the central basin may improve predictions of adjacent sandstone bodies and paleoecologic interpretations.

Planktonic dinoflagellates produced cysts diversity and abundance generally decreases in salinity-stressed coastal environments compared to offshore-fully marine environments, although particular species may be abundant (e.g., Leckie et al., 1990). Dinocyst assemblages and trace-fossil suites can serve as independent indicators of salinity conditions and other ecologic factors operating in the depositional environment.

Facies descriptions and interpretations of the Viking Formation central-basin facies have been derived from MacEachern and Pemberton (1994). Complementary palynological data was provided in MacEachern et al. (1999). Descriptions of the Glauconite Formation central basin and lateral accretion facies are based on core photos and descriptions in Leroux et al. (1999). Palynological assemblages from these facies are summarized from unpublished consulting reports compiled by Dr. Graham Dolby. All reported palynological assemblages were determined by 200 specimen counts, and through scans of the entire slide for additional taxa. The taxonomic classification used follows Fensome et al. (2009).

## **Viking Formation: Wave-Dominated Central Basin Deposits**

The study intervals are from cores in 16-11-46-04W5, from the Crystal Field (display core), and from 11-15-42-07W5 and 06-27-41-07W5, from the Willesden Green Field. Herein, the facies correspond to central-basin deposits, and comprise sandy mudstones, fine sandstones and dark mudstones organized in wavy and lenticular heterolithic composite bedsets with sharp contacts. Wavy-parallel laminations, oscillation ripples, combined-flow ripples and current ripples are present, although wave-generated structures predominate. Bioturbation encompasses bioturbation intensity (BI) values from 0-5, averaging BI 2-3. Diversities and abundances are variable, and most trace fossils are diminutive. The major and

recurring ichnogenera are *Planolites*, *Teichichnus* and *Schaubcylindrichnus freyi*. Secondary ichnogenera include *Arenicolites*, *Skolithos*, *Palaeophycus*, *Cylindrichnus*, robust *Ophiomorpha irregulaire*, *Thalassinoides*, *Chondrites* and fugichnia. *Phycosiphon* and *Rhizocorallium* are accessory constituents. Secondary and accessory ichnogenera are sporadically distributed. Sandy mudstone beds possess more diverse assemblages and higher BI, representing fairweather accumulation in the central basin under persistently brackish-water conditions, punctuated by short-lived periods of more normal marine salinities. Laminated sandstone beds and bedsets with robust opportunistic structures are attributed to storm waves in the bay. Sparsely bioturbated dark mudstones likely represent rapidly deposited fluid muds. Intercalation of these units results in the repeated bed and bedset juxtaposition of suites attributable to impoverished expressions of both the *Cruziana* Ichnofacies and the *Skolithos* Ichnofacies, one of the hallmarks of brackish-water trace-fossil assemblages (e.g. Pemberton and Wightman, 1992).

One to two palynomorph samples were analysed from bioturbated sandy mudstone beds within each study interval. Dinoflagellate cysts dominate these assemblages, outnumbering the terrestrial palynomorphs. Cysts from the Peridiniaceae Family are abundant, and are well documented from salinity-stressed, marginal-marine facies (e.g., Leckie et al., 1990). Cysts from the Ceratiaceae Family are uncommon, and cysts possessing proximate and chorate morphologies are rare to absent. For all groups, genera were not determined. Regardless, the abundance of the peridinioid cysts likely represents an endemic dinoflagellate population that was able to thrive under relatively stable estuarine conditions. Uncommon proximate and chorate cysts probably represent dinoflagellates introduced to the estuarine central basin during ocean storms. The ichnologic and palynologic data yield similar paleoecologic interpretations, suggesting that benthic and planktonic organisms were subjected to corresponding stresses, the most likely being persistent salinity reduction.

### **Glauconite Formation: Tidal-Fluvial Central Basin Deposits**

The study interval occurs in the core of 5C-17-20-17W4 (display core) from Lathom. The central basin of this tidal-fluvial estuary displays wavy and lenticular, heterolithic composite bedsets with sandy and silty mudstones, and lesser fine-grained sandstone beds and dark mudstone drapes. Beds and bedsets are generally separated by sharp contacts. The study interval becomes progressively mud-dominated upwards. Both wave-generated and current-generated stratification occur. Syneresis cracks and penecontemporaneous gravity faulting are common. Trace-fossil diversities are reduced and ichnogenera are diminutive. BI ranges from 0-4, averaging BI 2-3. The dominant recurring ichnogenus is *Planolites*, which locally constitutes a monogeneric suite. *Teichichnus* and *Cylindrichnus* with associated fugichnia are secondary, but locally abundant. *Asterosoma* and *Schaubcylindrichnus freyi* are exceedingly uncommon. These deposits represent ponded water with frequent fluvial input, which produced rapid loading, clay flocculation, and pronounced salinity fluctuations in the basin. Salinity-stress was marked, as indicated by the diminutive, low-diversity (locally monogeneric) trace-fossil suites throughout.

Twenty samples were collected from mud-dominated beds displaying BI 0-3. All assemblages recovered from the Glauconite Fm valleys are dominated by land-derived spores and pollen. Dinoflagellate cysts are absent to rare, and are sporadically distributed throughout the sample set. Identifiable cysts are present in 9 of the 20 samples, where they constitute 1% or less of the palynomorphs counted. The only cyst genus that demonstrates recurrence (7 samples), is *Balmula* (*Nyktericysta*) from the Ceratiaceae Family. This genus is among those typical of low-salinity environments in the McMurray Formation (Michoux, 2002). Two of the 7 samples also contain single specimens of cyst genera *Odontochitina* from the Ceratiaceae Family, and *Oligosphaeridium* from the Gonyaulacaceae Family. Gonyaulacacean cysts are more typical of open-marine units of the Cretaceous (Lister and Batten, 1988). Assemblages lacking identifiable cysts typically were collected from beds displaying less intense bioturbation.

All observed cyst specimens represent exotic dinoflagellates that were washed into the bay from a seaward source. From the data, it appears that dinoflagellates were unable to establish endemic populations in the tidal-fluvial bays of the Glauconite Fm estuaries. The palynomorph assemblages could be interpreted to represent a river-dominated environment prone to periodic brackish-water input. However, the trace-fossil suites indicate that benthic conditions were persistently brackish, except for transient periods of marked fluvial input. This discrepancy could be the result of hydrodynamic conditions in the central basin. In riverine estuaries, the confluent fresh and brackish water can be partly mixed, resulting in salinity stratification. Under such conditions, pelagic dinoflagellates could have been exposed to lower salinities than the benthic infauna. This may partially explain the discrepancy between the data.

### **Glauconite Formation: Tidal-Fluvial Lateral Accretion Deposits (IHS)**

The study intervals occur in cores 08-08-38-18W4 (display core) and 15-25-37-18W4 from the Leahurst and Halkirk fields, respectively. Lateral accretion deposits in these cores are characterized by fine-grained, sharp-based sandstones dominated by current ripples and dune-scale cross stratification, regularly interbedded with thin, variably carbonaceous mudstone beds. Stratification foresets are locally draped with mud or carbonaceous detritus. Upwards, sandstone beds become thinner, and mudstone beds become more abundant. Many of the mudstone beds are gently inclined. Trace-fossil diversity is low and ichnogenera are diminutive. Bioturbation intensities are variable, ranging from BI 0-4 and averaging BI 2-3. *Planolites*, *Teichichnus* and *Cylindrichnus* comprise the dominant ichnogenera, but local monogeneric suites of *Planolites* also occur. *Skolithos* and fugichnia are rare. In lower deposits, sandstone interbeds are unbioturbated with rare burrows confined to the mudstone layers. Upwards, both sandstone and mudstone interbeds possess low-diversity ichnological suites. These deposits represent accretion on a tide-influenced bar prone to brackish-water conditions. Rapid and/or high-energy deposition, not salinity fluctuations, are interpreted to have inhibited infaunal colonization.

Five palynological samples were collected from mudstone and sandy mudstone beds of the IHS. The assemblages are dominated by terrestrial palynomorphs. Dinoflagellate cysts occur in all samples in low abundances, typically 1% of the palynomorph assemblage. Both cores possess *Nyktericysta* cysts; the Leahurst core also possesses single specimens of the genus *Circulodinium* (*Cylonephelium*) from the Areoligeraceae Family. All cyst taxa encountered likely represent exotic dinoflagellates that were washed into the tidal-fluvial channel from seaward sources. Possible factors that precluded the establishment of a dinoflagellate population include marked salinity reduction, elevated water turbidity, and high discharge. Paleoecologic interpretations of these palynomorph assemblages broadly correspond to those derived from the trace-fossil suites.

### **Discussion and Conclusion**

Wave-dominated central basins have been thoroughly studied and comprise one of the most commonly encountered subenvironments in Viking Fm estuarine valley fills. The available palynomorph and trace-fossil data yield analogous paleoecologic interpretations. Benthic and planktonic organisms were subjected to similar stresses because fresh water entering the relatively broad central basin from the river at the landward end of the estuary and marine waters entering the basin from the estuary mouth were probably better mixed through elevated wave activity. The Glauconite Fm central basins, by contrast, are spatially restricted and constitute uncommon subenvironments, typical of tidal-fluvial estuarine valley fills (cf. Dalrymple et al., 1992). In both central basin and lateral accretion deposits, the dinocyst and trace-fossil suites are impoverished, considered to be mainly the result of hydrodynamic processes. Salinity fluctuations, rapid mud emplacement and clay flocculation imposed significant environmental stresses on the benthic community. Planktonic organisms were likely further exposed to fresher waters because of

estuarine salinity stratification. Without comparison to fully marine units, it cannot be stated whether the Viking central basins were 'more' saline than the Glauconite central basins. However, the apparent discrepancy between dinocyst assemblages and trace-fossil suites in the tidal-fluvial basin may prove to be a recurring characteristic of estuarine systems with limited wave influence and heightened fluvial discharge. Central basin deposits are distinguished from the underlying lateral accretion deposits by the presence of wave-generated stratification and generally increased mud contents. Trace-fossil suites and dinocyst assemblages are broadly similar, making detailed sedimentologic analysis vital.

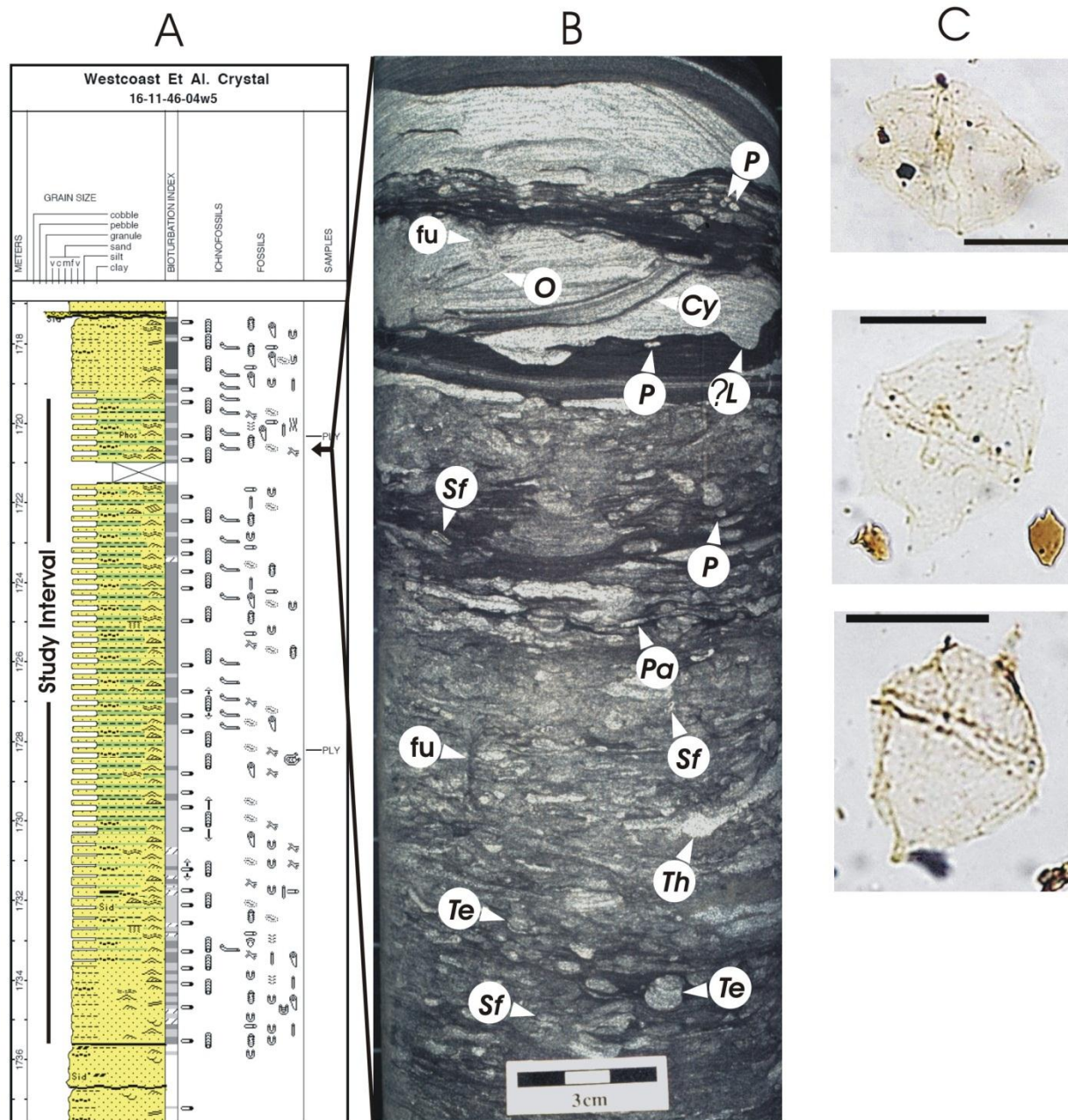
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**Figure 1: Wave-Dominated Central Basin Deposits  
Viking Formation, Crystal Field 16-11-46-04W5**



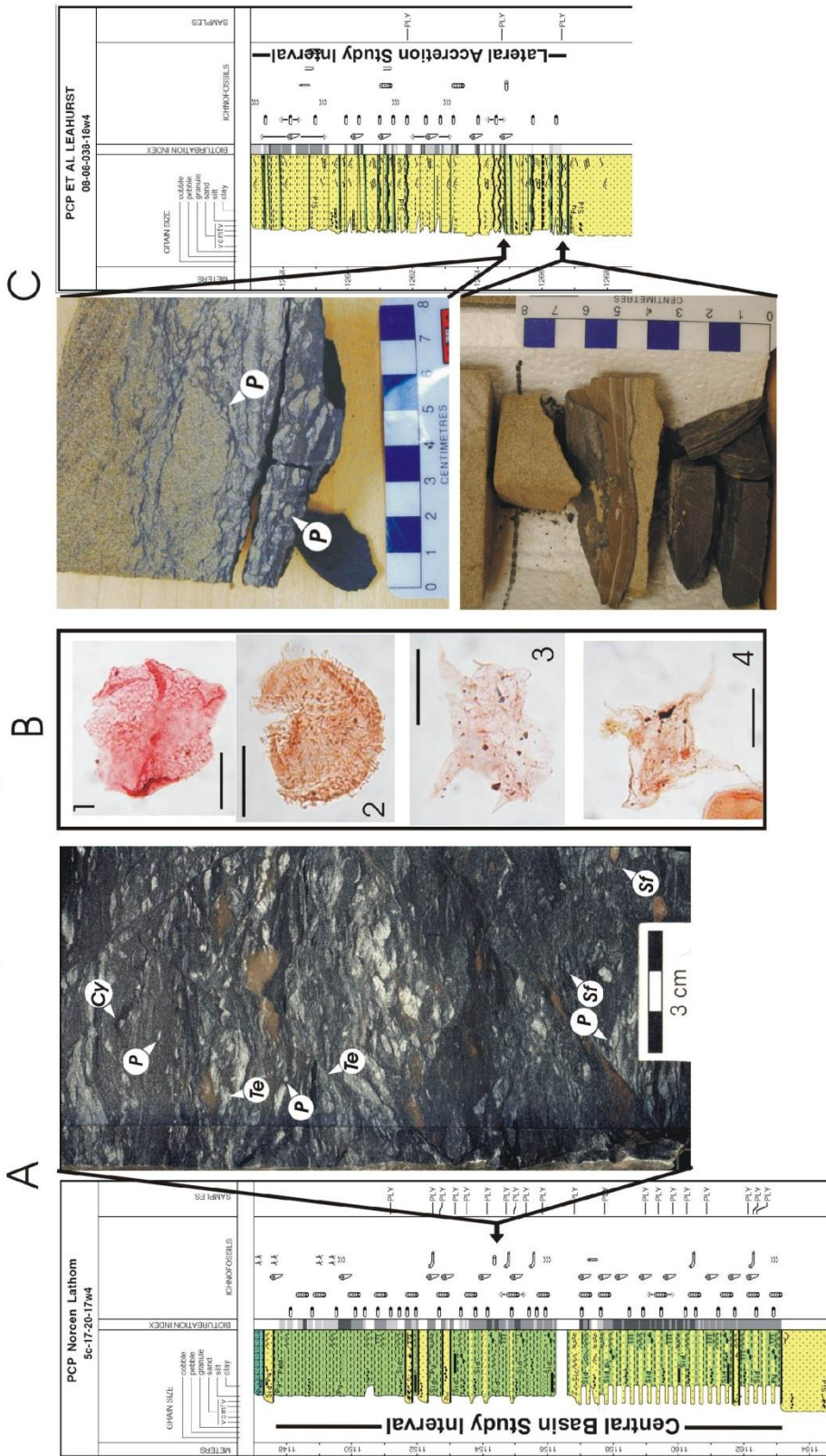
1a: Graphic litholog for 16-11-46-04W5 from the Crystal Field. 'Study Interval' corresponds to central basin deposits. Horizons sampled for palynomorphs denoted by 'PLY'.

1b: Representative facies shot of wave-dominated central basin deposits. Samples were collected from sandy mudstone beds, observed in the lower part of the photograph. Characteristic ichnogenera include *Schaubcylindrichnus freyi* (Sf), *Teichichnus* (Te), *Paleophycus* (Pa), *Planolites* (P), *Cylindrichnus* (Cy), *Thalassinoides* (Th), *Ophiomorpha* (O), possible *Lockeia* (L), and fugichnia (fu). Cyst-dominated palynomorph assemblage.

1c: Dinoflagellate cysts from the Peridiniaceae Family collected from the 16-11 study interval, interpreted to represent an endemic dinoflagellate population in the basin. All scale bars are 30 microns.



Figure 2: Tidal-Fluvial Central Basin (Latham Field) and Lateral Accretion Deposits (Leahurst Field) Glauconite Formation



2a: Representative facies shot and graphic litholog for 5C-17-20-17W4 from the Latham Field, possessing tidal-fluvial central basin deposits. Horizons sampled for palynomorphs denoted by 'PLY'. In the facies shot, ichnogenera include *Planolites* (P), *Teichichnus* (Te), *Cylindrichnus* (Cy) and *Schaubcylindrichnus freyi* (Sf).

2b: Dinocysts collected from the Glauconite Formation study intervals. All cysts shown are from the lateral accretion mudstones. Photographs 1 and 2 are of *Circulodinium* (*Cyclonephelium*) species from the Areoligeraceae Family. Photographs 3 and 4 are of *Nyctericysta* species from the Ceratiaceae Family. All dinocysts are interpreted to represent exotic dinoflagellates that were washed into the estuarine system. All scale bars are 30 microns.

2c: Representative facies shots and graphic litholog for 08-08-38-18W4 from the Leahurst Field, possessing tidal-fluvial lateral accretion bar deposits. Samples were collected from unbioturbated muds (bottom) and bioturbated muds (top) dominated by *Planolites* (P).