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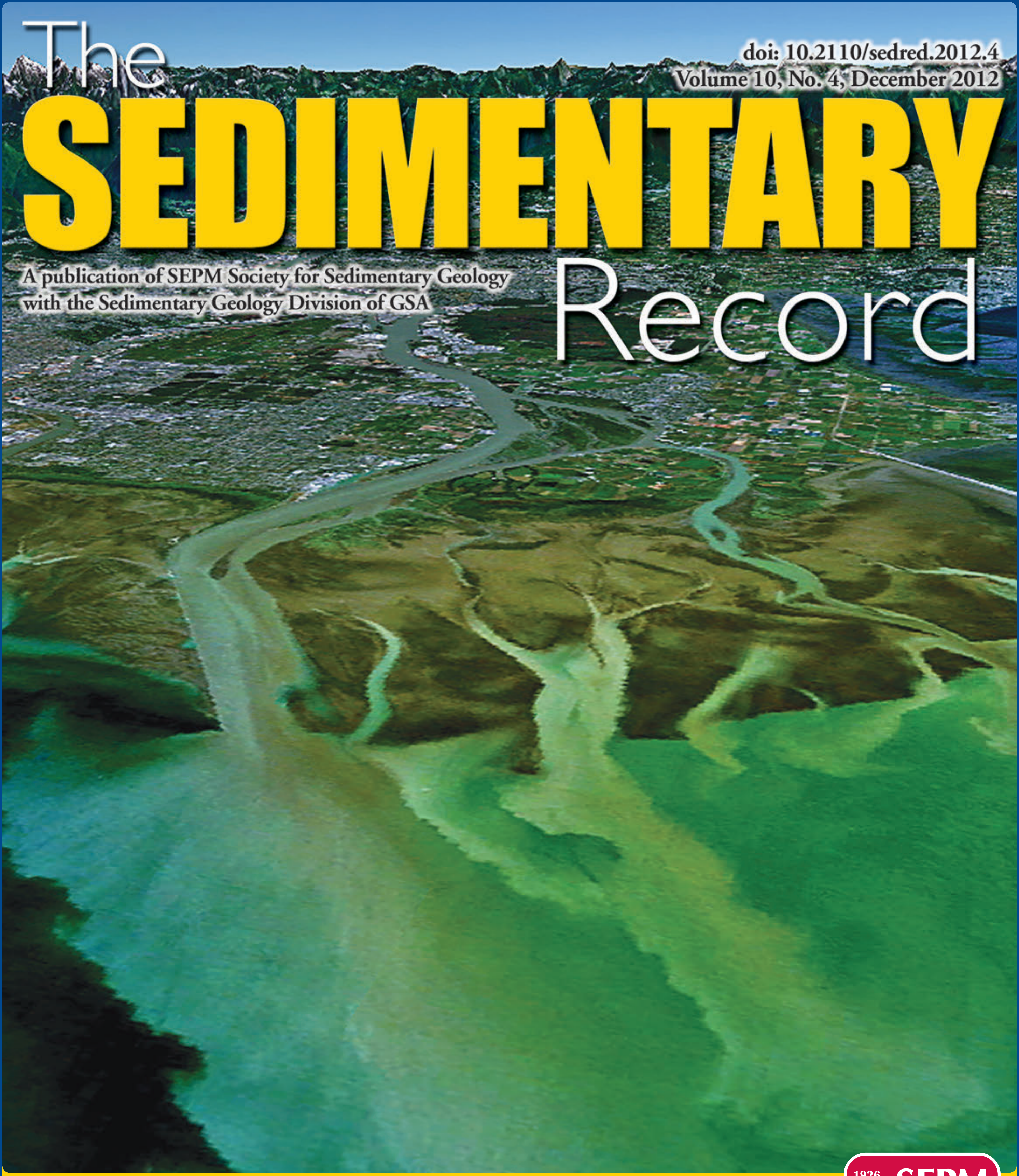

INSIDE: SEDIMENTATION ACROSS THE TIDAL-FLUVIAL TRANSITION IN THE LOWER FRASER RIVER, CANADA

PLUS: PRESIDENT'S COMMENTS, NEW SEDIMENTARY RECORD BOOK REVIEWS

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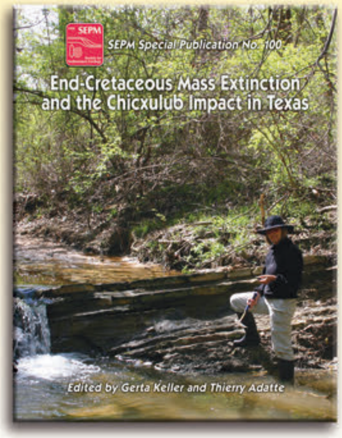
Special Publication #100

The End-Cretaceous Mass Extinction and the Chicxulub Impact in Texas

Edited by: Gerta Keller and Thierry Adatte



One of the liveliest, contentious, and long-running scientific debates began over three decades ago with the discovery of an iridium anomaly in a thin clay layer at Gubbio, Italy, that led to the hypothesis that a large impact caused the end-Cretaceous mass extinction. For many scientists the discovery of an impact crater near Chicxulub on Yucatán in 1991 all but sealed the impact-kill hypothesis as proven with the impact as sole cause for the mass extinction. Ever since that time evidence to the contrary has generally been interpreted as an impact-tsunami disturbance. A multi-disciplinary team of researchers has tested this assertion in new cores and a dozen outcrops along the Brazos River, Texas. In this area undisturbed sediments reveal a complete time stratigraphic sequence containing the primary impact spherule ejecta layer in late Maastrichtian claystones deposited about 200–300 thousand years before the mass extinction. About 60 cm above this level is a submarine channel with lithified spherule-rich clasts at the base followed by two to three reworked impact spherule layers and topped by sandstones. Above this channel deposit late Maastrichtian claystone deposition resumed followed by the KT boundary mass extinction. Brazos River sections thus show three events separated by time—the Chicxulub impact, the reworked spherule layers in a submarine channel, and the KTB mass extinction. In this volume a multi-disciplinary team of researchers from the USA, Switzerland, Germany, and Israel carefully documents this evidence based on paleontology, sedimentology, sequence stratigraphy, mineralogy, isotope geochemistry, trace and platinum group element geochemistry. The results are presented in a series of twelve articles with data tables and supplementary material.

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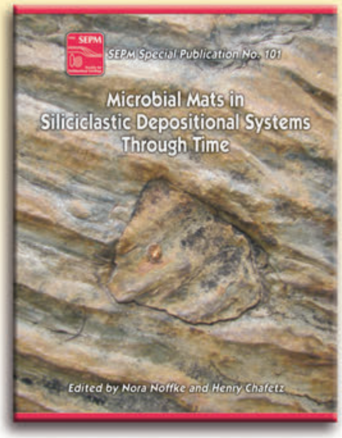

Special Publication #101

Microbial Mats in Siliciclastic Depositional Systems Through Time

Edited by: Nora Noffke and Henry Chafetz

The research field on microbial mats in siliciclastic environmental settings has greatly developed since its establishment by studies of pioneering scientists such as Gisela Gerdes, Wolfgang Krumbein, Jürgen Schieber, David Bottjer and others. This SEPM Special Publication is the result of the SEPM Field Conference on Sandy Microbial Mats (modern and ancient), which was held in May 21st to 23rd, 2010 at Dinosaur Ridge, Denver, Colorado, USA. The volume presents peer reviewed individual case studies on microbial mats and on sedimentary structures (often called “microbially induced sedimentary structures—MISS”) that occur in modern and ancient marine and terrestrial environments. The conference brought together sedimentologists, microbiologists, and paleontologists from 30 countries and all five continents. Topics discussed ranged from the evolution of cyanobacteria, the detection of quorum sensing in biofilms to the taxonomy of MISS and microbial mat ecology. The talks and posters presented fossil material from 3.2 Ga old rock successions to microbial mat samples from sediments of the present day. This volume is designed to present the wide spectrum of research in this multidisciplinary scientific field, and to integrate the many different points of views and approaches.

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Special Publication #102

Sedimentary Geology of Mars

Edited by: John P. Grotzinger and Ralph E. Milliken

Often thought of as a volcanically dominated planet, the last several decades of Mars exploration have revealed with increasing clarity the role of sedimentary processes on the Red Planet. Data from recent orbiters have highlighted the role of sedimentary processes throughout the geologic evolution of Mars by providing evidence that such processes are preserved in a rock record that likely spans a period of over four billion years. Rover observations have provided complementary outcrop-scale evidence for ancient eolian and fluvial transport and deposition, as well as surprisingly Earth-like patterns of diagenesis that involve recrystallization and the formation of concretions. In addition, the detection of clay minerals and sulfate salts on Mars, coupled with large-scale morphologic features indicative of fluvial activity, indicate that water-rock interactions were once common on the martian surface. This is in stark contrast to the dry and cold surface environment that exists today, in which eolian processes appear to be the dominant mode for sediment transport on Mars. These issues and others were discussed at the First International Conference on Mars Sedimentology and Stratigraphy, held in El Paso, Texas in April of 2010. The papers presented in this volume are largely an extension of that workshop and cover topics ranging from laboratory studies of the geochemistry of Martian meteorites, to sediment transport and deposition on Mars, to studies of terrestrial analogs to gain insight into ancient Martian environments. These papers incorporate data from recent orbiter and rover missions and are designed to provide both terrestrial and planetary geologists with an overview of our current knowledge of Mars sedimentology as well as outstanding questions related to sedimentary processes on Mars.

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Cover photo: False color image of the Fraser River and delta during high river discharge in July 2000. The image is draped over the digital elevation model for the lower Mainland, British Columbia, Canada. The image is centered in the Strait of Georgia and the field of view is to the east. (Image source: NASA Wind (http://worldwind.arc.nasa.gov)).

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Sedimentation Across the Tidal-Fluvial Transition in the Lower Fraser River, Canada

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ABSTRACT

The Fraser River is the largest undammed river on the west coast of North America. In its lower reaches, a saltwater wedge intrudes up to 30 km inland during mixed semi-diurnal tidal cycles that range up to 5.3 m in height. Sediments deposited in the lower reaches of the Fraser River show distinctive characteristics that reflect the relative control of river versus tidal processes, as well as the persistence of saline water at each point along the channel.

Grain-size trends along the river are controlled by the hydrodynamics in each distributary. Mud deposition is concentrated in the zone of saltwater-freshwater mixing. Coarse-grained sand and mud/fine-grained sand deposition is largely seasonally controlled, wherein bed material (diameter > 0.177 mm) is deposited during the waning freshet, and washload transported mud and fine-grained sand (< 0.177 mm) is deposited during the late-stage waning freshet flow and during base flow.

The diversity and density of bioturbation changes according to the volume and residence time of brackish water at the bed. Higher salinity water and greater durations that saline water is sustained at any locale, supports a more diverse and uniformly distributed trace assemblage. With decreasing salinity, the trace assemblage decreases in diversity and bioturbation becomes more sporadically distributed. This results in a reduction of infaunal diversity from 100% on the nearly fully marine tidal flats in the abandoned part of the lower delta plain, to 14% in intertidal sediments of the brackish-water reach.

The character of the sediments deposited across the tidal-fluvial transition provide criteria for differentiating sediments deposited within freshwater-tidal reaches, brackish-water-tidal reaches, and mixed tidal-fluvial distributaries. These data are presented as a process-based analog for tidal-fluvial sediments preserved in the rock record. The results can be used to predict changes in facies character across the tidal-fluvial transition of similar tide-influenced, river-dominated systems or their rock-record equivalents.

INTRODUCTION

With increasing interest in recognizing differences in the sedimentological and ichnological character of sediments deposited across the tidal-fluvial transition, it is necessary to study a variety of modern analogs subjected to varying degrees of fluvial and tidal input. One such analog is the Fraser River, British Columbia, Canada, which in its lower reaches is affected by strong tidal flow. The grain sizes of sediments deposited in the channel are strongly linked to the degree of tidal flow relative to river flow, and to the extent and duration of saltwater intrusion at sites of sediment deposition. Consequently, the sedimentological and ichnological character of the sediments reflects the depositional conditions under which they were deposited, and hence, can be used as a proxy for establishing the volume and duration of saline water intrusion and the relative input of tidal versus river flow.

Understanding sediment deposition across the tidal-fluvial transition has received increasing attention in recent years (e.g., Dalrymple and Choi 2007) in large part because subsurface reservoirs of the bitumen-hosting middle McMurray Formation in northeast Alberta are interpreted as paleo-estuarine channel bars (Pemberton and Wightman 1992; Ranger and Pemberton 1997; Musial et al. 2012). The lateral and vertical extent of mud beds and muddy bedsets interbedded with sand in the channel bars is the dominant control on reservoir compartmentalization, and can strongly impact the economic viability of exploiting hydrocarbons contained in these deposits (Strobl et al. 1997; Hein and Cotterill 2006). To better understand mud distribution in tide-influenced river channels, a range of modern analogues are being evaluated across the spectrum from tide-dominated (Dalrymple et al. 2003; Choi et al. 2004; Pearson and Gingras 2006), to fluvially influenced, tide-dominated (Smith 1988; Gingras et al. 1999; Smith et al. 2009), to mixed tidal-fluvial (Johnson 2012), to tide-influenced, fluvially dominated (Sisulak and Dashtgard 2012) to fluvially dominated (Smith et al. 2009; Smith et al. 2011) settings.

The lower Fraser River (Fig. 1) is a natural laboratory for studying sediment deposition in tide-influenced, fluvially dominated channels and mixed tidal-fluvial channels. The availability of historical and real-time hydraulic data (e.g., Johnson 1921; Ages 1979; Thomson 1981), the fact that the Fraser River is undammed along its entire length, and the extensive studies of sediment transport in the river (e.g., Kostaschuk and Luternauer 1989; Church and Krishnappan 1995; Kostaschuk and Villard 1996; Kostaschuk et al. 1998; McLean et al. 1999; Kostaschuk and Best 2005) provide datasets that can be used to link sedimentological, ichnological, and architectural characteristics of the sediments to the hydrodynamic and chemical conditions under which they were deposited and colonized by infauna.

THE FRASER RIVER

The Fraser River drains 228000 km^2 of mountainous terrain and has a mean annual river discharge of 2710 m^{3}s^{-1} at Hope, BC, ~165 river km upstream of the delta front. Low flow rates in winter are ~1000 m^{3}s^{-1}, and the annual peak flow ranges between 5130 and 15200 m^{3}s^{-1} with a mean of 8642 m^{3}s^{-1} (Water Survey of Canada, http://www.wateroffice.ec.gc.ca/, accessed Sept 7, 2012). At low flow, the saltwater wedge (SWW) intrudes ~30 km upriver (Kostaschuk and Atwood 1990). During high river flows, the SWW is displaced towards the mouth of the channel. At river flows between 5000 and 7000 m^3 s^{-1} (at Hope), a SWW has been observed to penetrate only a few kilometers up the Main Channel (red line, Fig. 1) during spring high tides (Milliman 1980). At high peak flows (> 8000 m^3 s^{-1} at Hope), however, the SWW likely does not enter the Main Channel.

In its tide-influenced lower reach, the Fraser River bifurcates into two distributaries, the North Arm and the Main Channel (Fig. 1). The North Arm bifurcates again to form the Middle Arm. Observations made in 1970 at a flow rate close to the mean annual peak rate (8670 m^3 s^{-1}) indicated that the North and Middle arms carried ~7% and ~5% of channel flow respectively (WCHL 1977). The Main Channel carried 70% of the flow and its distributary, Canoe Pass, carried 18% of the flow (Fig. 1).

Sediment flux in the Fraser is washload dominated. *Washload* is sediment not present in the channel bed and lower banks of the river, and that stays in suspension through a *defined* river reach (Church 2006). In the Main Channel and the North Arm, the washload is composed of fine sand (< 0.177 mm), silt, and clay, whereas in the Middle Arm and probably Canoe Pass, similar grain sizes are deposited on the channel bed during non-peak flows (Johnson 2012). Landward of New Westminster, before the Fraser bifurcates into its various distributaries, McLean et al. (1999) reported that between 1966 and 1986, the total sediment load was 17 x 10^6 t yr^{-1}. Forty-nine percent of the sediment load was silt-sized material, whereas clay made up 15%. Sand-sized sediment constituted 36% of the total load, roughly half of which was carried as washload into the lower river reaches. The remaining 18% of the sand volume was carried as bed-material load, defined as sediment present in the bed or lower banks of the river and transported as bedload or in temporary suspension (Church 2006). The distribution of the sediment load through the various distributaries and delta is, however, only understood conceptually from estimates of aggradation-degradation of the channel and from sediment deposits.

Anthropogenic modification of the lower Fraser River and delta is significant. The channel banks were first diked between 1913 and 1919 (Johnson 1921) essentially stopping lateral and downstream migration of distributaries. The dike system has been gradually expanded to restrict 90% of the river in the Fraser Valley, downstream of Hope (Fig. 1). Extensive placer mining (Nelson and Church 2012) along the Fraser River over the past 150 years has contributed to periods of high sediment yield, which have influenced the delta topography. For example, the South Arm Marshes bar complex (discussed later) is thought to have aggraded significantly following the influx of sediment from placer mining activities in the mid to late 1800s (Public-Works-Canada 1957; Hales 2000).

The Main Channel has been regularly dredged since 1945 to provide a deep water navigation channel up to New Westminster. Prior to that, the sandy bed-material load passed through the estuary, and 3.0 x 10^6 t yr^{-1} of sand was delivered to the delta front. Over-deepening of the channel due to dredging has produced a knick-point that has been migrating upstream of New Westminster towards Mission, lowering the bed elevations and recruiting an additional 1.05 x 10^6 t yr^{-1} of sand. As such, ~4.25 x 10^6 t yr^{-1} of sand are now delivered to the river of which 70% is dredged. Over the past 50 years, dredging has removed an average of 2.95 x 10^6 t yr^{-1} of bed-material load (sand > 0.177 mm; Church 2010), which restricts the fluvial sand supply to the delta front to ~1.3 x 10^6 t yr^{-1}.

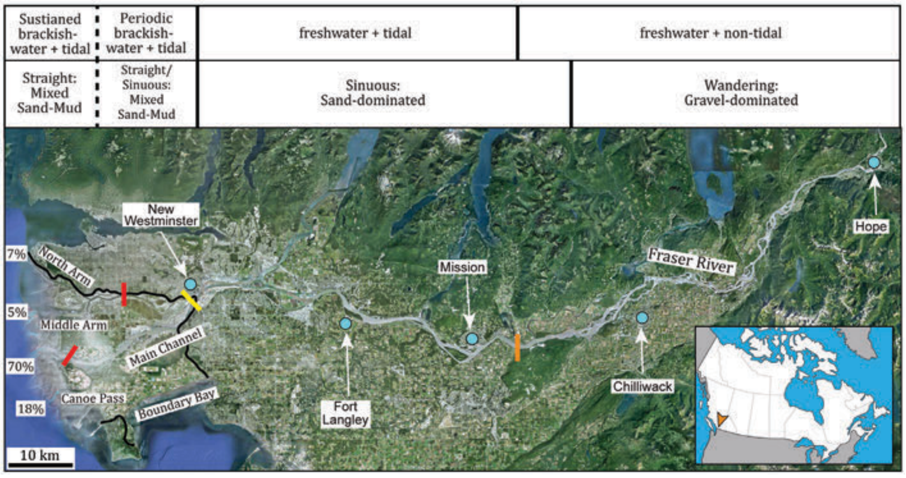

Figure 1: Composite airphoto of the lower Fraser River from Hope, British Columbia, Canada to the delta front (Image source: Google Earth). At the top of the image, the general hydrodynamic and salinity conditions (e.g., sustained brackish water + tidal) are defined, as is the general channel morphology (e.g., straight) and dominant grain size(s) (e.g., mixed sand-mud). The approximate position of the defined zones are bracketed by the solid (applicable to all distributaries) and dashed (varies between distributaries) black lines above the airphoto. The red lines mark the maximum upstream extent of saltwater intrusion during high river flow (freshet) and the yellow line marks the maximum upstream intrusion of saltwater during base flow. The orange line is the approximate upstream location of observable tides. The percentages on the left hand side of the photo are the estimated percent volume of flow that is transported down each distributary (WCHL, 1977). The thick black line on the airphoto marks the landward boundary of the Fraser delta. The location of the Fraser River delta in Canada is shown in the inset map. The blue circles mark the position of cities and towns along the lower Fraser River that are referred to in the text and in Figure 2.

Regardless of the anthropogenic modification of the Fraser River and delta, the Fraser is undammed and only one significant tributary has regulated flow: a rarity amongst major rivers. As such, precipitation and climatic conditions in the mountainous catchment basin are reflected in the depositional conditions in the lower reaches. Seasonal variations in river discharge, and brackish water and tidal inundation up the Fraser distributaries reflect natural hydraulic conditions. This makes the Fraser an excellent analog for comparing sedimentological and ichnological trends to hydrodynamic processes and water salinity.

SEDIMENTOLOGICAL TRENDS IN THE LOWER FRASER RIVER

There are pronounced sedimentological trends in the lower Fraser River related to: 1) channel morphology and grain size, 2) mud content and distribution, 3) bedding cyclicity and architecture, and 4) sedimentary structures.

1) Perhaps the most obvious trends in the lower Fraser River are the pronounced changes in grain size and channel morphology between the non-tidal freshwater reach, the freshwater-tidal reach, and the brackish water-tidal reach (Fig. 1). The Fraser experiences tides ~90 km inland to Mission, but only the most seaward 30 km is regularly inundated by brackish water. The remaining 60 km of tide-influenced river is freshwater and tidal. The Fraser River exhibits a major grain size and morphological change 15 km upstream of Mission where the channel changes from a wandering gravel-bed river (Church 1983; McLean 1990; Ham 2005) to a sinuous sand-bed channel (Venditti et al. 2010) with in-channel (tidal) bars. The position of this transition is thought to be topographically controlled (Venditti et al. 2010), although tides may play a secondary role. The wandering gravel-bed river occurs wholly in the freshwater, non-tidal reach, whereas the sand-bed channel extends through the freshwater-tidal and brackish water-tidal reaches.

In the brackish water-tidal reach, saltwater intrusion (brackish-water + tidal, Fig. 1) is periodic (depending on river discharge) and the tidally affected portions of the bars contain significant volumes of both sand and mud (Fig. 2). The channels in this reach also show evidence of lateral and downstream migration (prior to the channel being diked) and tend to

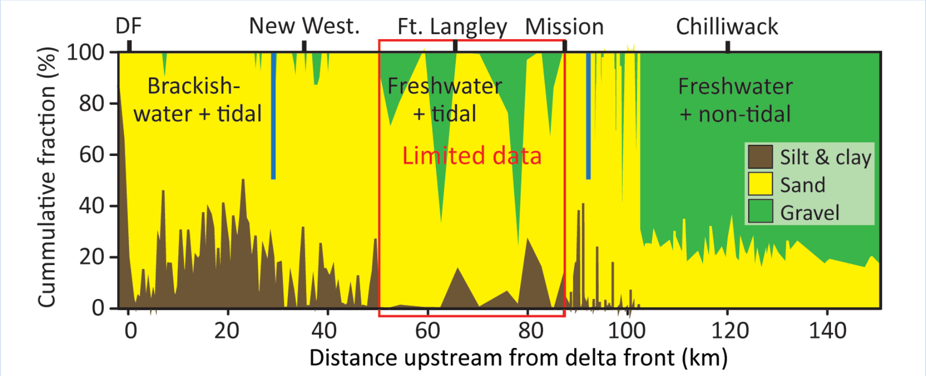

Figure 2: Downstream change in the grain-size fraction in the Fraser River from Hope to Sand Heads (just seaward of the break in slope between the lower delta plain and the delta front). Each data point on the graph averages the results of samples collected from the channel base to the channel margins. Data compiled from McLaren and Ren (1995), Venditti (unpublished data), Venditti et al. (2010), McLean (1990), and Ham (2005). Modified from Venditti et al. (2010). DF = delta front, New West = New Westminster.

be straighter than in the freshwater-tidal reach. Finally, in the river reaches that experience more sustained brackish water, the channels are straight and the sediments in this region are mixed sand and mud (Figs. 1 & 2).

2) The most significant change observed in the sedimentology between the freshwater-tidal reach and the brackish water-tidal reach is in the distribution of mud. In the freshwater-tidal reach, mud-dominated beds and bedsets are typically thin (< 10 cm thick) and are laterally continuous for meters to tens of meters. The channel bottom and intertidal banks are sand-dominated (Fig. 2), and mud deposited during base flow is typically eroded during the freshet. In the brackish water-tidal reach, mud deposition is increasingly widespread (Fig. 3). Mud beds and mud-dominated bedsets thicken (to > 1 m thick) and are laterally continuous for hundred's of meters to kilometers in the intertidal zone and likely the upper subtidal zone (Johnson 2012; Sisulak and Dashtgard 2012). The thickness and lateral continuity of muddy bedsets is linked, at least in part, to the persistence and duration of saline water and the development of a turbidity maximum, and in part to the relative influence of fluvial versus tidal processes on sediment deposition. This is best expressed in the differences in the mud content on bars in the Main Channel (South Arm Mashes (SAM) bar complex, Fig. 3B; Sisulak and Dashtgard 2012) and in the Middle Arm (Fig. 3C-E; Johnson 2012).

3) The cyclicity and architecture of bedding within bars changes with position along the channel, and reflects both the relative influence of fluvial and tidal processes, and the variability in the amount of mud deposited in and along the margins of the river. This, in turn, is linked to the position of the saltwater wedge. Johnson (2012) found significant uniformity in the thickness of sand beds and sand-mud interbeds (Fig. 4) in the admixed tidal-fluvial (i.e., tidal and fluvial processes equally control sediment deposition) Middle Arm. She attributed this uniformity in bedding to the relatively strong tidal influence on sediment deposition. In the tide-influenced, fluvially dominated Main Channel, Sisulak and Dashtgard (2012) found that along the margins of the SAM bar complex (Fig. 3B), sand beds were non-uniform in thickness, and sand-mud interbedding was non-rhythmic (Fig. 5). They attributed this relation to the fact that sand transport and deposition was dominated by river flow, which changes significantly from year to year. Mud beds, however, were deposited during lower flow and base-flow conditions, when estuarine circulation was re-established and the washload started to settle out of suspension. Landward of the maximum upstream position of the saltwater wedge, mud deposition is limited, and the seasonal cyclicity between sand and mud interbeds is not observed. Consequently, vertical bedding in the freshwater-tidal and freshwater-non-tidal reaches (Fig. 1) are either sand-dominated or gravel dominated, with rare thin and discontinuous mud interbeds.

4) The sedimentary structures preserved within bars along the Fraser River record tidal influence on sediment deposition. In the admixed tidal-fluvial Middle Arm, bars contain abundant mm- to cm-scale sand-mud laminasets that occasionally occur in full sets of 12-14 couplets and are interpreted as tidal rhythmites. Tidal rhythmites are still present in bars through the tide-influenced, fluvially dominated part of the Main Channel and Canoe Pass (Fig. 6B), but the number of rhythmites is greatly reduced. Cross-bedding similar to sigmoidal cross-bedding (Kreisa and Moiola 1986) was also observed in sandy dunes developed in the intertidal zone in Canoe Pass (Fig. 6A), although this bedding style is attributed to tidal modification of fluvially formed dunes. Flaser bedding was

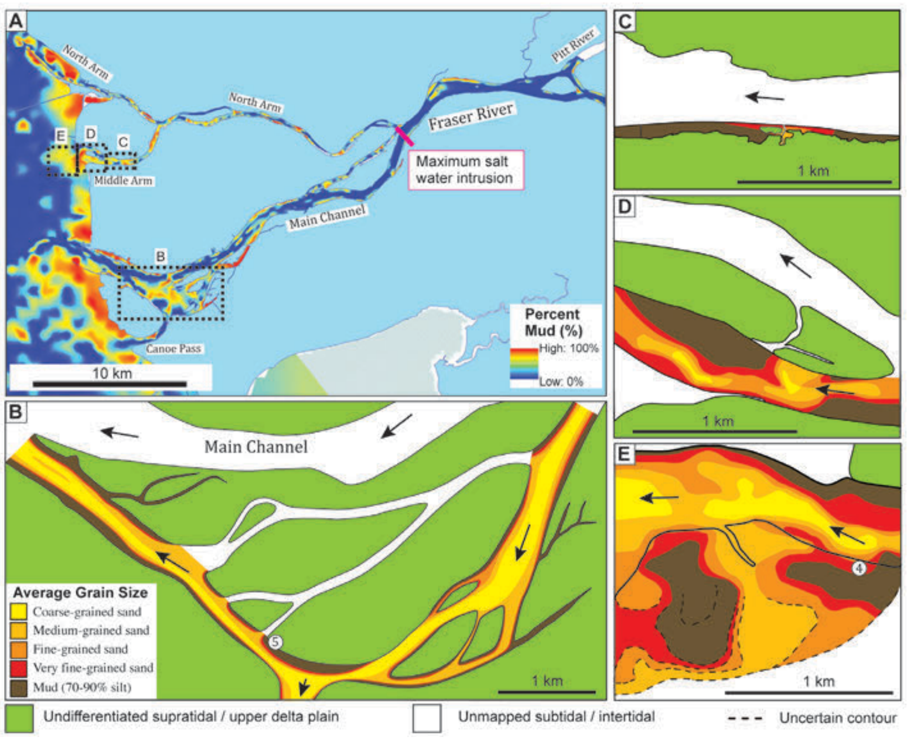

Figure 3: A) Percent mud map for the Fraser River distributaries complied by the Geological Survey of Canada. The location of maximum saltwater intrusion is shown. The dashed black boxes mark the position of Figures 3B-E. B-E) Detailed grain size maps of four bars along the Main Channel and Middle Arm of the Fraser River. Grain size maps are the result of intertidal surface sediment sampling and subaqueous grab sampling. The numbers "4" and "5" shown in white circles on E and B, respectively, indicate the position of the vibracore strip logs in figures 4 and 5. Figure 3B is of the South Arm Marshes (SAM) bar complex, and is modified from Sisulak and Dashtgard (2012). Figures 3C-E are modified from Johnson (2012).

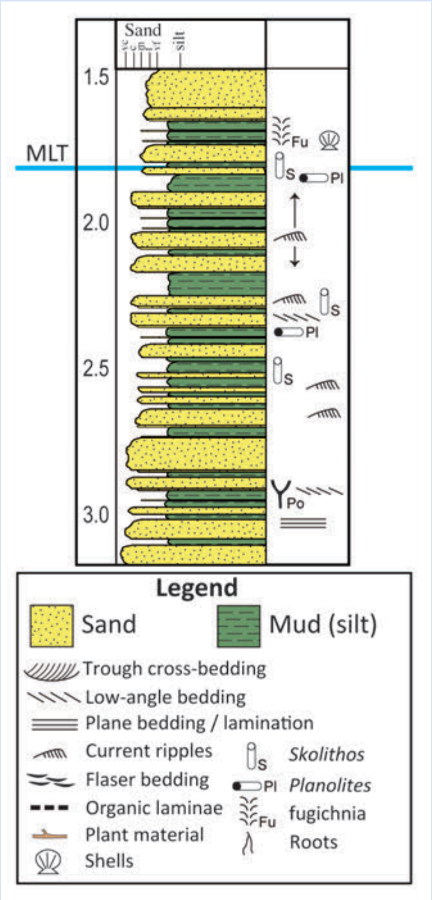

Figure 4: Strip log and symbol legend for a vibracore taken from a point bar in the tidal-fluvial Middle Arm, lower Fraser River (modified from Johnson (2012)). Note the regular interbedding and consistent thicknesses of both sand and mud beds. This rhythmicity of bedding is considered to reflect increased tidal control on sediment deposition. The location of this core is shown in Figure 3E. The blue line labeled "MLT" is the mean low tide line.

commonly observed in the intertidal and upper subtidal portions of the Main Channel bars, and mud rip-ups were exceedingly common due to the annual deposition of mud beds and subsequent erosion during the freshet (Sisulak and Dashtgard 2012).

ICHNOLOGICAL TRENDS IN THE LOWER FRASER RIVER

The ichnological character of sediments in the lower Fraser River is consistent with the expected trace assemblage for brackish-water settings (e.g., Pemberton and Wightman 1992; MacEachern and Gingras 2007), in that the trace assemblage on all bars in the tide-influenced part of the river is dependent upon the persistence of brackish water at each locale. In the freshwater-non-tidal and freshwater-tidal reaches of the Fraser River, bioturbation is very rare and is limited to sporadically distributed, thin (<2 mm diameter) oligochaete burrow networks. The trace assemblage in these zones is best described as a very low density (bioturbation index (BI) 0 with very rare occurrences of BI 1-2; Fig. 6F) of small diameter *Planolites*- to *Thalassinoides*-like, horizontal burrow networks. For reference, the bioturbation index is a non-linear scale, from 0 to 6, of biogenic reworking of the sediment: the scale is included in the legend in Figure 6.

With increasing saltwater intrusion and the persistence of brackish water conditions at any point along the channel profile, there is a corresponding increase in the diversity and density of bioturbation (Fig. 6B-E; Chapman and Brinkhurst 1981; Johnson 2012; Sisulak and Dashtgard 2012). In bars through the tide-influenced, fluvially dominated Main Channel, the trace density increases from BI 0-2 (Fig. 6D-E) to BI 0-4 (Fig. 6B-C), where the burrow density in individual bedsets is dependent upon both the persistence of saltwater and the sedimentation rate. The trace assemblage comprises a low diversity suite of *Arenicolites*-, *Skolithos*-, and *Polykladichnus*-like burrows (Fig. 6B-E), most of which are the vertical dwellings of polychaetes. In the tidal-fluvial Middle Arm, burrows produced by marine organisms are maintained year-round due to the persistence of brackish water and a reduced sedimentation rate resulting from lower river discharge. As such, Middle Arm sediments tend to exhibit a higher density (BI 2-6) and diversity of burrowing with the addition of both large and small *Siphonichnus*-like (bivalve-generated) traces (Johnson 2012). The traces in the tidal-fluvial Middle Arm are larger on average than those found in the tide-influenced, fluvially dominated Main Channel.

The increase in the density and diversity of traces with increasing brackish-water influence in the channels is relatively subtle when compared to the large increase in trace density and diversity from the channels onto the lower delta plain tidal flats of the Fraser River (Dashtgard 2011b), and to the nearly fully marine tidal flats in Boundary Bay (Fig. 1; Dashtgard 2011a). The brackish water-tidal reach of the Main Channel has an infaunal diversity of 3, which is 14% that of the nearly fully marine tidal flats of Boundary Bay. In the tidal-fluvial Middle Arm, the infaunal diversity of intertidal zone sediments doubles from 3 to 6 common animals. There is a significant increase in infaunal diversity from the intertidal zone of the Middle Arm to the active lower delta plain tidal flats, with an increase in infaunal diversity from 6 to 14 common animals. However, the lower delta plain tidal flats show a diversity reduction of 34% from the Boundary Bay tidal flats (Dashtgard 2011a; Dashtgard 2011b).

The most significant reduction in infaunal diversity occurs from the lower delta-plain tidal flats into the distributaries of the lower Fraser River. The low diversity and density of infauna observed in the channels is distinctive of the brackish-water reaches of the Fraser River, and provides a useful indicator of channel versus non-channel, marginal-marine facies. The upstream decrease in trace diversity and density is indicative of the relative persistence of brackish-water conditions along the channel profile, and can be used as proxy for determining salinity in the channel. The interbedding of bioturbated and non-bioturbated beds is indicative of seasonal changes in river discharge and the corresponding decrease in salinity and increase in the sedimentation rate.

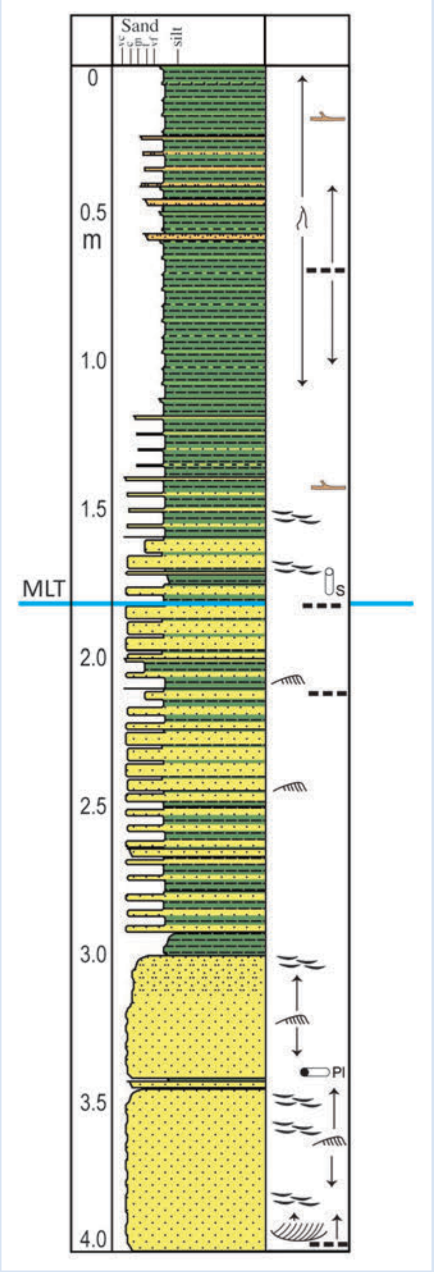

Figure 5: Strip log for a vibracore taken from the South Arm Marshes bar complex (tide-influenced, fluvially dominated), an in-channel bar along the Main Channel (from Sisulak and Dashtgard, 2012). Note the irregular thickness of mud-dominated and sand-dominated bedsets between 1.25 and 3.0 m depth. The thickness of sand beds is controlled by the river discharge volume, which varies annually. Similarly, mud bed thicknesses are partly controlled by river discharge. The location of this core is shown on Figure 3B. The symbol legend is shown in Figure 4.

IMPLICATIONS FOR SEDIMENT DEPOSITION ACROSS THE TIDAL-FLUVIAL TRANSITION

The lower Fraser River is an excellent analog for studying changes in the sedimentology and ichnology of channel-associated deposits across the tidal-fluvial transition in a tide-influenced, fluvially dominated river. The character of sediments can be linked to the hydrodynamic conditions in the distributaries and to water salinity at various bars along the channel. Based on the results of our research, we make the following observations for the purpose of application to the rock record.

1) Grain-size distributions along the lower Fraser River are linked to tidal influence, and to flow reduction or flow reversal during the flood tide. The river is gravel-bedded upstream of the landward extent tidal effects. The river transitions to a sand-bedded river ~15 km upstream of the freshwater-tidal reach, where tides may play some role in determining this transition. The Main Channel and most of the distributaries are also sand-bedded along the brackish water-tidal reach; however, mud is commonly deposited along the channel margins and in the upper part of in-channel bars in the Main Channel, and on the channel floors and bars of distributaries that carry lower volumes of the river water (e.g., Middle Arm).

2) Mud deposition is concentrated in the zone of freshwater-saltwater mixing (i.e., the turbidity maximum), such that the amount of mud preserved in the bars is linked to the persistence of saltwater at any point along the channel axis. In tidal-fluvial and tide-influenced, fluvially dominated settings, intertidally exposed mud beds are laterally continuous for up to 1 km (Johnson 2012). The lateral continuity of mud beds decreases rapidly landward of the zone of saltwater intrusion.

3) In the brackish-water influenced reaches of the lower Fraser River, coarse sand (> 0.177 mm) is deposited during the waning freshet. Clay, silt and fine sand (< 0.177 mm) are deposited during late-stage waning freshet flow and during base flow, although mud deposition in the Main Channel is restricted to the channel margins. This results in a seasonal cyclicity to sand-mud interbedding (Sisulak and Dashtgard 2012). Seasonal cyclicity is generally not discernable in sediments landward of the brackish-water influenced zone.

4) The diversity of infauna (and their traces) exhibits the greatest decrease from the lower delta plain tidal flats into the channels. In tidal-fluvial and tide-influenced, fluvially dominated channels, infaunal diversity is low: 14-28% of the diversity of the nearly fully marine tidal flats at Boundary Bay. Trace diversity across the tidal-fluvial transition decreases with decreasing saltwater intrusion, suggesting that trace diversity can be used to predict the salinity conditions under which the sediments were colonized. For tidally influenced rivers, this would correspond to a position along a channel.

5) Trace density is controlled by salinity and the sedimentation rate. Trace density decreases and becomes more sporadically distributed with decreasing salinity, although tidal-fluvial and tide-influenced, fluvially dominated upper bar and channel-margin deposits show BI values of 2-6 and 0-4, respectively. The sedimentation rate also exerts a major control on trace density in that high rates of sediment deposition translate into low density burrowing. In the bars in the tidal-fluvial Middle Arm, this is manifest as lower BI values in sand beds versus mud beds (Johnson 2012). In the tide-influenced lower reach of the Main Channel, the SAM bar complex, sand beds in the upper part of the bar tend to lack bioturbation or are burrowed from the top down, and mud beds show the highest levels of burrowing (Sisulak and Dashtgard 2012). The correlation between bioturbation and grain size further emphasizes the seasonal cyclicity recorded by interbedded sand and mud beds in brackish-water influenced channels.

Significant variability occurs between the distributaries of the lower Fraser River, such that one style of sedimentation cannot be applied to all channels. However, the sedimentological and

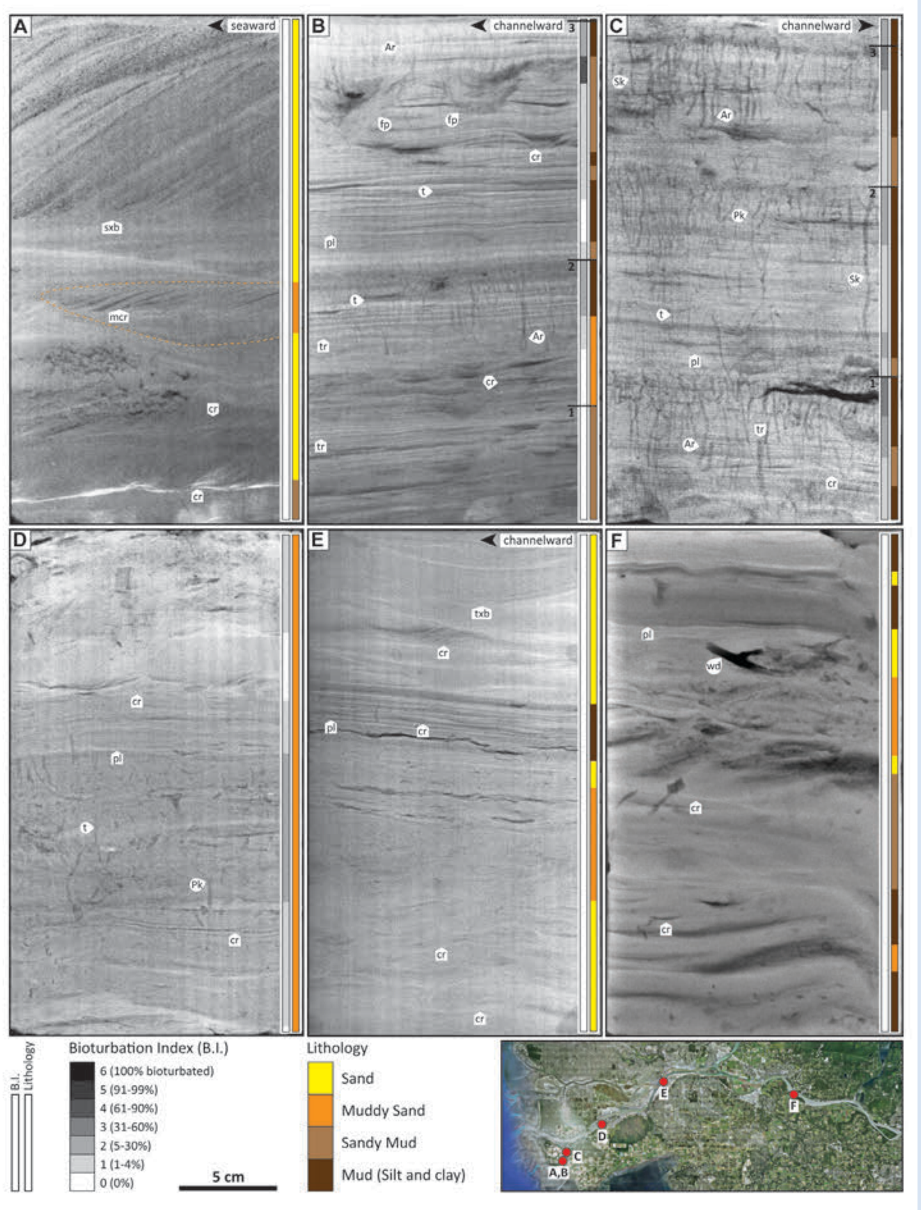

Figure 6: X-radiographs of box cores taken from bars along the lower Fraser River. The position of each box core is shown on the air photo at the bottom of the figure. The two vertical columns on the right-hand side of each x-radiograph show the general lithology and bioturbation intensity (recorded as the bioturbation index). In figures 6B and 6C, the solid horizontal black lines labeled 1,2 and 3 define the tops of seasonal cycles of deposition. Abbreviations for sedimentary structures (squares with arrows): current ripple lamination (cr); muddy current ripple lamination (mcr); planar lamination (pl); sigmoidal cross bedding (SXB); tidal rhythmite (tr); trough cross-bedding (txb). Abbreviations for ichnological/biogenic structures (circles with arrows): **Arenicolites** *(Ar); bird footprint (fp);* **Polykladichnus** *(Pk);* **Skolithos** *(Sk); threadworm burrow (t); wood (wd).*

ichnological character of the sediments deposited at any location in the river can be used to predict the depositional conditions (processes) under which those sediments were deposited.

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PRESIDENT'S COMMENTS

I want to share what I think is some exciting news. SEPM, GSA, and the Paleontological Society have joined forces to form a coordinating office for ***STEPPE*** research (***S***edimentary geology, ***T***ime, ***E***nvironment, ***P***aleontology, ***P***aleoclimate, and ***E***nergy). This office concept has been recommended by NSF and discussions with NSF have been an important part of STEPPE's formation. The office will encourage collaborative research activities, help develop digital and infrastructure capacity, and facilitate community-building research, education and outreach initiatives. External funding to support this endeavor are being sought by the three societies.

THE PERCEIVED NEED. - Numerous NSF and NRC reports have called for broad interdisciplinary collaborations to address major societal and environmental research challenges. Those reports have emphasized that these new efforts must be grounded in a greater understanding of the Earth's history, a concept that all SEPM members can surely embrace. The community that explores the deep-time archives of the sedimentary crust has historically focused on research relevant to that goal. Our future pursuits, however, will require more sophisticated analytical tools, larger and more integrated data bases, and a greater diversity of research specialists working in close collaboration. Contributions will be needed from sedimentologists, physical & bio stratigraphers, geochemists, petroleum and coal geologists, paleolimnologists, paleobiologists, paleopedologists, and basin analysts.

This is cross-disciplinary, "big", science. Yet "big", science is hard to accomplish. Barriers include building consensus on research goals; securing sufficient funding, developing new tools and resources; creating efficient and open communication structures for sharing ideas and data; and forming pathways for those with new ideas to step forward and muster the personnel needed to attack the "grand challenges". These open and holistic collaborations cannot be forced but can be facilitated. The STEPPE coordinating office is created to be that community-based facilitator.

WHAT WILL STEPPE DO? - STEPPE's mission will be multifaceted. First, it is charged with stimulating and facilitating collaboration and communication among existing and new NSF initiatives involved in deep-time sedimentary systems. This includes geoinformatics (e.g., Paleobiology Database, NeotomaDB, MorphoBank, Macrostrat, SESAR, SedDB, EarthChem, EarthCube, and IEDA), research infrastructure (e.g., LacCore, US Continental Scientific Drilling), applicable science and technology centers (e.g., NCED), research programs (e.g., DELETON, GeoPRISMS), and research communities (e.g., PAGES, EarthTime, and CSDMS). The fact that many of us do not know what all those acronyms represent highlights the need for better communication and information distribution.

Second, STEPPE will bring researchers from the sedimentary geology, time, environment, paleontology, paleoclimate, and energy communities together to define innovative and comprehensive research plans, develop large integrated proposals, and formulate persuasive arguments for research support. The office also will act as a liaison between academia, government, and industry. In particular, it is hoped that STEPPE can create a bridge to open-access, industry-derived data sets, including well, outcrop and seismic information.

Third, the office will help our community address facility and infrastructure needs. How can we increase access to, and affordable analytical output from, existing facilities and laboratories? What new facilities are needed to conduct the next generation of research into the Earth's sedimentary record? What are the priorities for such facilities? How can we improve the integration and sharing of data, provide access to data, and link to visualization and modeling tools and platforms?

Fourth, STEPPE is charged to build community capacity. This means articulating the need and vehicles for cross-disciplinary education of students and researchers, supporting corporate internships for students and young faculty, and supporting opportunities for corporate employees to intern in academia.

BENEFITS TO SEPM. - SEPM has taken a lead role in the creation of STEPPE because of the obvious benefits to all members whose research focuses on Earth history. We will all benefit from more collaboration, more resources, more data, more tools, more integration, and more communication. SEPM's association with STEPPE should position us favorably in terms of co-sponsorship of workshops and research conferences, and publication of the eventual research products. If STEPPE is successful, I anticipate the development of a new generation of more interdisciplinary geoscientists and the creation of new and broadly integrated research communities. Some of those people will become active members and future leaders of SEPM, thus bringing new scientific diversity to our ranks. Lastly, SEPM's association with STEPPE will enhance the overall geoscience community's view of our society as progressive, engaged, and forward looking.

WHAT TO LOOK FOR IN THE NEAR FUTURE. - Specific developments to watch for in the future include: creation of blogs, wikis and eNewsletters for promoting new initiatives, sharing information, and generating community input. Virtual "Idea" Fairs to encourage new initiatives and programs. A call for proposals for science workshops intended to focus the community on specific goals and facilities. Keep in touch with STEPPE developments at the SEPM website.

David A. Budd, President

New Sedimentary Record Book Reviews

Links to these and previous reviews are located at The Sedimentary Record homepage
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Geology underfoot, in Yellowstone country,
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The global cryosphere - past, present and future,
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Sedimentary rocks in the field - a practical guide (4th ed.),
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*Please note that for 2013, SEPM Council had decided that we can no longer invest in printed versions of the *Journal of Sedimentary Research* or *PALAIOS* due to ever increasing costs, the growth of demand for internet access to the same content and the advantage of cheap full color and multimedia aspects of online publishing. The good news is that both journals should be able to publish more content and include color freely to all authors. A printed version will contain significantly less content than the online version. However, SEPM has arranged with Allen Press to create Print-on-Demand (POD) versions, which unfortunately will be at a significant increase in cost. Payment will still be made to SEPM but the price is just a pass through to Allen Press; SEPM is not adding anything to their price. The Allen Press price will have to be added on to the subscription total if you require print.

LinkedIn

Did you know that SEPM is on LinkedIn? If you are not a part of LinkedIn, it is a 'facebook' for professionals. The SEPM site is there for Discussions of sedimentary geology topics, notices about upcoming events and a Jobs tab is also present. Once you join LinkedIn and the SEPM group, you can start discussions or contribute to them. There are a lot of students in the group with a lot of interesting questions. It is also a place to build connections around the globe in sedimentary geology. SEPM Executive Director, Howard Harper oversees this site.

Twitter

SEPM now has a Twitter feed - @SEPMGEO (see the bottom of the SEPM Home page at www.sepm.org). While this has just started, it is gaining followers. SEPM Councilor Brian Romans oversees the Twitter action. So if you are a Twitter member or want to follow carefully selected SEPM tweets, then sign up.

Note that for both of these, LinkedIn and Twitter, SEPM will maintain a strong review presence to keep the sites 'useful' for the SEPM science mission.