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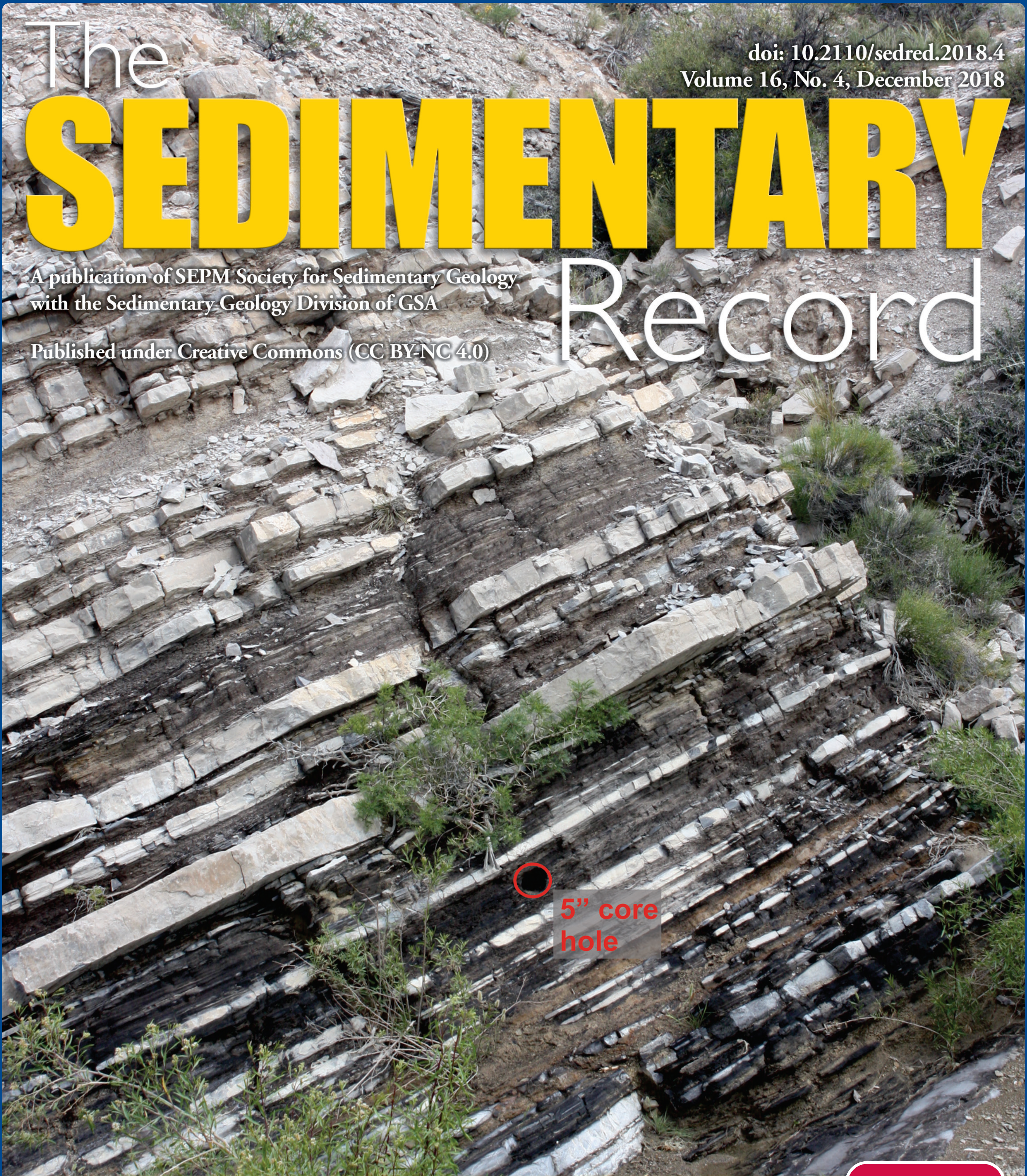

INSIDE: CARBONATE MUD DEPOSITED BELOW STORM WAVE BASE: A CRITICAL REVIEW

PLUS: PRESIDENT'S COMMENTS, REPORT ON THE INTERNATIONAL SEDIMENTOLOGICAL CONGRESS, QUEBEC, STRATA

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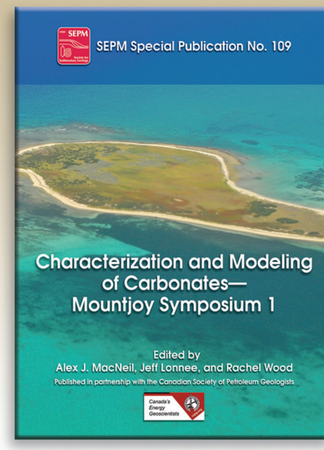
Special Publication #109

Characterization and Modeling of Carbonates—Mountjoy Symposium 1

Edited by: Alex J. MacNeil, Jeff Lonnee, and Rachel Wood



In August of 2015 the first Mountjoy Carbonate Conference, co-hosted by the Society for Sedimentary Geology (SEPM) and Canadian Society of Petroleum Geologists (CSPG), took place in Banff, Alberta. As the approaches to characterization and modeling of carbonate reservoirs are undergoing rapid changes, this was the theme of the meeting. This Special Publication, following the inaugural meeting, contains nine state-of-the art papers relating to the (1) characterization of carbonates and advances in analytical methods, (2) controls on carbonate reservoir quality and recovery factors, and (3) reservoir distribution, the modeling of dolostone geobodies, and reservoir prediction. The Introduction includes an overview of Eric Mountjoy's career and his many contributions to the science. The contents of this Special Publication should be useful to those engaged in the characterization and modeling of carbonate reservoirs, including unconventional carbonate reservoirs, and is highly recommended as one of the most impactful recent publications for those working in this area of sedimentary science.

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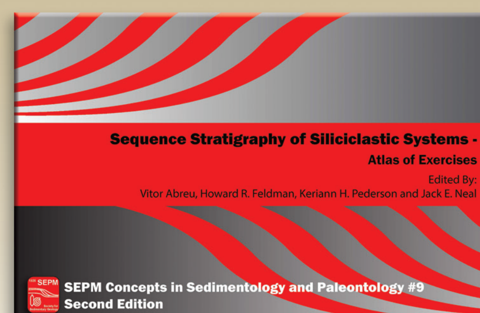
Concepts in Sedimentology and Paleontology 9 (2nd edition)

Sequence Stratigraphy of Siliciclastic Systems

Edited by: Vitor Abreu, Howard R. Feldman, Keriann H. Pederson, and Jack E. Neal



This publication is the result of more than 3 decades of sequence stratigraphy research and application. The objective is to emphasize the most important aspects of Sequence Stratigraphy—a method to guide geologic interpretation of stratigraphic data (seismic profiles, well-logs, cores and outcrops) across scales (from local to regional and global) and depositional environments (from continental to deep marine).The stratigraphic concept of a depositional sequence was introduced to the scientific literature by Peter Vail and his colleagues in the late 70s, building on the shoulders of giants like Chamberlain, Sloss and Wheeler. Since then, several papers compared and contrasted the original sequence-stratigraphic school published in the AAPG Memoir 26 in 1977 with other approaches to subdivide the geologic record, as well as, debating the model validity and impact on the community. At its core, the "model" is really a stratigraphic interpretation method, which was never explicitly documented in the literature. The objective of this book is to present the sequence stratigraphic method in its current form in an attempt to clarify its usage and application in diverse geologic data and depositional environments. This publication is the result of more than 3 decades of sequence stratigraphy research and application. The objective is to emphasize the most important aspects of Sequence Stratigraphy—a method to guide geologic interpretation of stratigraphic data (seismic profiles, well-logs, cores and outcrops) across scales (from local to regional and global) and depositional environments (from continental to deep marine). This book in an 11 x 17 format is designed to be easily used for teaching or self-learning experiences. In the second edition of the "Atlas", the book was divided in 2 separately bound volumes—Exercises and Solutions—to make it easier to use the publication as text book for sequence stratigraphy courses in universities. Also, a new exercise was added and several of the existing exercises went through major updating and editing.

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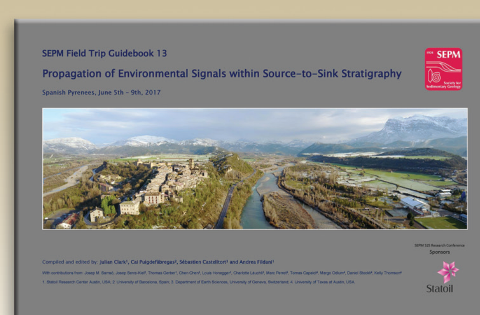
SEPM Field Trip Guidebook #13

Propagation of Environmental Signals within Source-to-Sink Stratigraphy

By: Julian Clark, Cai Puigdefàbregas, Sébastien Castelltort and Andrea Fildani



This guidebook was compiled for the field trip excursions of the SEPM Research Conference on the *Propagation of Environmental Signals within Source-to-Sink Stratigraphy*, (June 4th-10th, 2017). The world-class outcrop exposures and localities visited enabled the investigation of correlative stratigraphy from alluvial, fluvial, shallow marine, slope and deep marine environments with the direct observations of different segments of sediment routing systems. Decades of research in the region have contributed to our understanding of the basin-filling stratigraphic response to orogenic evolution and climatic events. These geologic insights and the well-preserved exposures have made the region a classic locality for both academic and industry-related geologic training, and a natural laboratory for continued research.

This SEPM Field Trip Guidebook presents key outcrops visited during the conference within a source-to-sink framework. The geologic map published herein is a cornerstone of this contribution, enabling and revising stratigraphic correlations required for this approach. An overview of source-to-sink concepts, methods and tools that can be applied to the stratigraphic record is provided, together with new data and analysis demonstrating environmental signals at different scales within the basin.

Catalog #80013 • Softcover Print • List Price: $50.00 • SEPM Member Price: $30.00

Cover image: Outcrop view of lower Cretaceous Agrio Formation (lower Pilmatué Member) at El Portón locality, Neuquén Basin, Argentina. Interbedded limestones (resistant beds) and shales (recessive dark beds). Upon further detailed inspection in outcrop and thin section, both limestones and shales are carbonate mudstones deposited below storm wave base, forming a ~600 m thick succession of carbonate mudstone. Shales contain a higher percentage of detrital silt and limestones contain a lower percentage of detrital silt and higher occurrence of microfossil, like formanifera and calcite- replaced radiolaria. Photo taken by Lauren Birgenheier.

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Carbonate mud deposited below storm wave base: A critical review

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INTRODUCTION

As it pertains to carbonate mud generation, there are both neritic and open water, pelagic carbonate mud factories. The origin of carbonate mud is well documented (Appendix A). With the exception of whitings in select modern locations, carbonate mud has a biogenic origin. As it pertains to carbonate mud transport, existing carbonate facies models emphasize suspension settling. Literature on off-bank sediment gravity flow transport is well established (e.g., Goldstein et al., 2012), and there is a growing amount of current literature on carbonate slope processes and the reworking of sediment via contour currents (e.g., Betzler et al., 2014). Even so, existing literature on sediment gravity flows and contour currents are bias toward the documentation and interpretation of coarser-grained carbonate facies, with limited focus on carbonate mud transport.

Here, we focus on a critical review of carbonate mud deposited below storm wave base in modern and ancient carbonate settings. We use storm wave base as an indicator of marine offshore deposition, beyond the majority of wave influence, with the caveat that storm wave base is likely not a feature found at one fixed water depth and can vary significantly with sea floor morphology (e.g. carbonate platform versus ramp), through time, and with storm strength (Peters and Loss, 2012).

Pelagic carbonate deposits are commonly associated with type II, oil-prone organic matter and can be exceptional source rocks (e.g., Miceli Romero et al., 2018). They are also proving to be important reservoir rocks in unconventional hydrocarbon plays, for example the Eagle Ford and Niobrara of North America (Sonnenberg, 2011; Hentz et al., 2014). Because coarser-grained carbonates have historically been important hydrocarbon reservoirs, they have been the focus of decades of research. As a result, there are some significant knowledge gaps pertaining to the deposition of thick, ancient carbonate mudstone successions deposited below storm wave base.

Researchers have long assumed that carbonate mud was deposited through suspension settling below storm wave base. However, a modern understanding of carbonate mud deposition contends that depositional mechanisms are not limited to suspension settling. In fact, flume experiments have demonstrated that, like terrigenous mud, carbonate mud forms floccules and is transported in bedload, forming ripples (Schieber et al., 2013).

The assumption that carbonate mud, mostly pelagic in origin, was deposited through suspension settling alone is largely based on the fine grained nature of carbonate mud and the fact that there is no sedimentary fabric preserved to suggest otherwise. This apparent lack of sedimentary fabric arises from a few common obstacles in regards to the sedimentologic examination and interpretation of carbonate mudstones. Properly identifying sedimentary structures, like ripples for instance, in mudstones requires detailed cm-scale description of carbonate mudstone successions from outcrop and core coupled with careful petrographic analysis using ultra-thin, thin sections and scanning electron microscopy, all with a trained eye. Not many research studies have set out to do this specifically in carbonate mudstone successions deposited below storm wave base. Furthermore, carbonate mudstone facies are difficult to image through scanning electron microscopy (SEM) due to the lack of grain size and compositional contrast. Carbonate mudstone successions deposited below storm wave base are commonly burrowed, obscuring the majority of the original depositional fabrics and sedimentary structures. Quantifying the volume of depositional versus diagenetic micrite in carbonate mudstones can be challenging, particularly in successions that have experienced significant burial diagenesis. Existing studies on periplatform deposits suggests the presence of aragonite leads to early cementation that preserves primary structures. However, during burial diagenesis calcareous tests in marls are more easily lost to dissolution and overgrowth than in purer carbonate mudstones, like chalks or pelagic limestones (e.g., Frank et al., 1999; Frank and Bernet, 2000; Westphal et al., 2004). At greater depth and through interaction of basinal fluids micro- and nannofossil features may be lost, in some cases, making it difficult to quantify the original

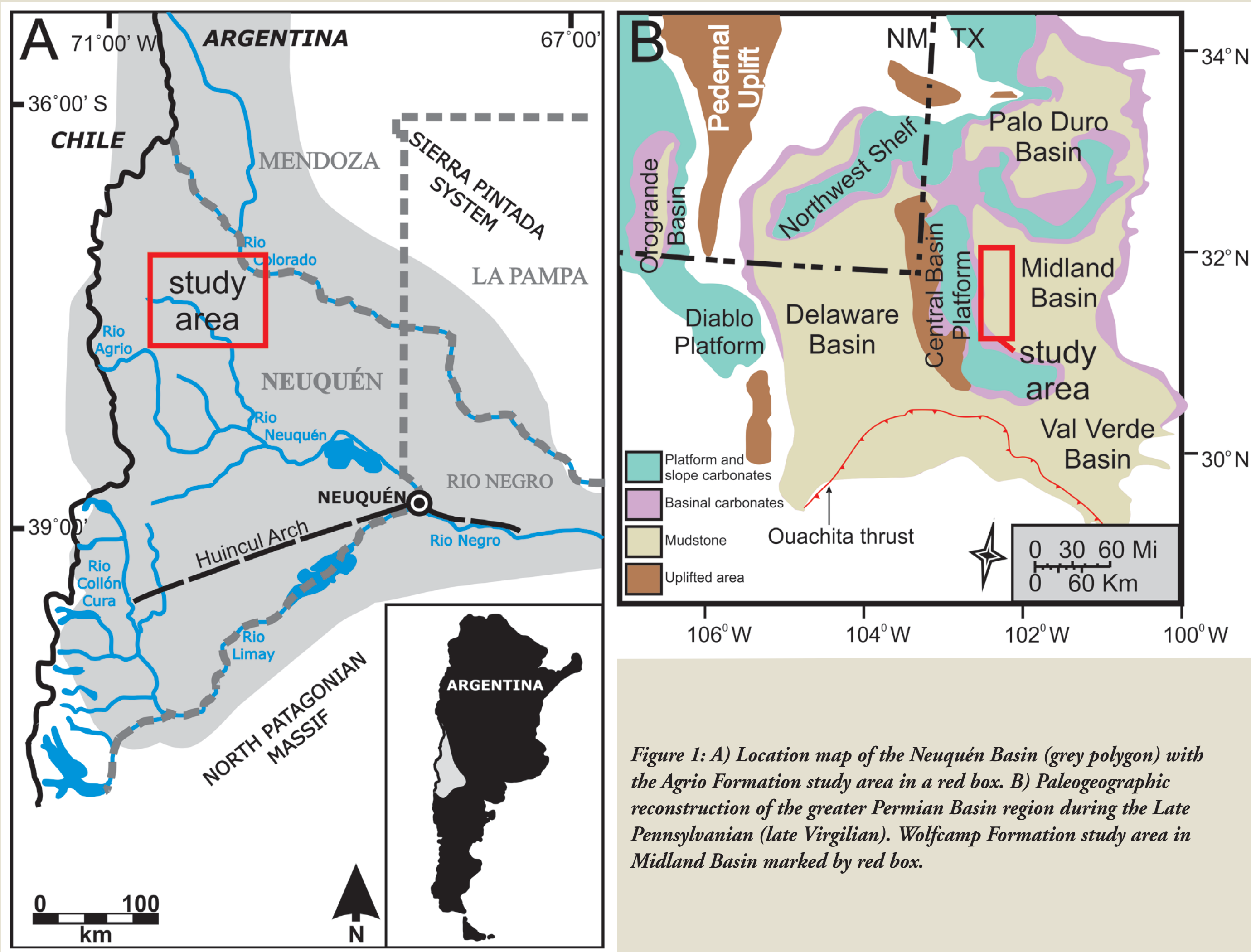

Figure 1: A) Location map of the Neuquén Basin (grey polygon) with the Agrio Formation study area in a red box. B) Paleogeographic reconstruction of the greater Permian Basin region during the Late Pennsylvanian (late Virgilian). Wolfcamp Formation study area in Midland Basin marked by red box.

volume of nanno- and microfossils that make up the carbonate mudstone.

The carbonate mud transport problem is brought into particular focus in interpreting the depositional origin of thick successions of carbonate mudstone deposited below storm wave base in an ancient marine environment. Estimated sedimentation rates from thick carbonate mudstone-dominated successions deposited below storm wave base challenge the notion that suspension settling was the only depositional mechanism. Additionally, a handful of classical chalk successions, like the Eagle Ford Group and upper Cretaceous Danish Chalks, have recently been re-interpreted to contain evidence of current-influenced mud deposition, not just pelagic biogenic production followed by suspension settling (Rasmussen and Surlyk, 2012; Minisini et al., 2018). Minisini et al. (2018) interpret several carbonate-rich mudstone facies in the Eagle Ford Group to have been deposited by bottom currents. Rasmussen and Surlyk (2012) interpret upper Cretaceous Danish Chalks as contourite deposits.

In light of this more recent sedimentologic understanding, the transport of carbonate mud in the context of carbonate facies models needs to be re-visited and re-evaluated. The carbonate facies models we teach in geology classrooms in University and industry settings across the country need to be updated to incorporate a broader range of carbonate mud depositional mechanisms.

A REVIEW OF CARBONATE MUD TRANSPORT

Here we focus on a review of carbonate mud transport mechanisms. For a review of both neritic and pelagic carbonate mud generation, see Appendix A. In carbonate platforms with steep slopes that descend to a deep basin floor, platform and/or slope-derived carbonates are re-suspended and deposited on the slope and basin floor (e.g., Eberli et al., 2004). Re-suspended carbonate slope deposits represent a significant volume of sediment deposited on the carbonate platform and have been the focus of renewed research interest, given their relevance for new hydrocarbon targets (Reijmer et al., 2015a). In general, upper slope settings are connected to sediment producers at the platform edge, dominated by high slope angles, coarse-grained deposits, cementation and platform margin failure. Mid slope settings are characterized by a decrease in slope angle, an increase in mud percentage, mud onlap, coarse-grained deposits as a result of re-sedimentation and slope failure, and channel levee development. The lower slope displays similar features with the added impact of contour currents. And finally basin deposits are characterized by high pelagic input, drift deposits and periplatform ooze (Reijmer et al., 2015a). Periplatform oozes occur on modern carbonate platform slopes, like the Bahama platform slopes, and consist of platform-derived neritic mud and sand mixed with pelagic carbonate material, like micro- and nannofossil tests. Recent studies highlight the complexity of Bahama slope processes through time, during sea level lowstand and highstand conditions, with the interaction of slope failure, turbidity and contour currents (Wunsch et al., 2017). Fundamentally, Bahama bank slopes, where periplatform drift sediment is found, reflect the interaction between off-platform sediment export as debris flows and basin-derived contour currents (Betzler et al., 2014).

Channel-levee systems that have long been documented in deepwater siliciclastic systems have only recently been documented on the western carbonate slope of the Great Bahama Bank (Mulder et al., 2014). Their discovery has implications for sediment transport, including carbonate mud, from shallow to deep water carbonate systems.

Study of carbonate turbidite systems is well established. Classical examples are found from the Cretaceous to Paleogene succession of the European Alps and Appenines (e.g., Goldstein et al., 2012). In general, carbonate debris flow deposits are poorly sorted with grains up to cobble or boulder size and include floatstone and packstone facies. Carbonate debris flow deposits, like those from the Miocene of Spain, are mostly defined as carbonate breccias (e.g. Goldstein et al., 2012). Normally graded, skeletal and foraminiferal wackestones to packstones with scoured bases are interpreted to have been deposited by turbidity currents (Goldstein et al., 2012). Sharply based, fining-upwards packages of grainstones to packstones and/or packstones to wackestones, (carbonate mudstones exclusive) interpreted as calcareous turbidites can display incomplete Bouma sequences

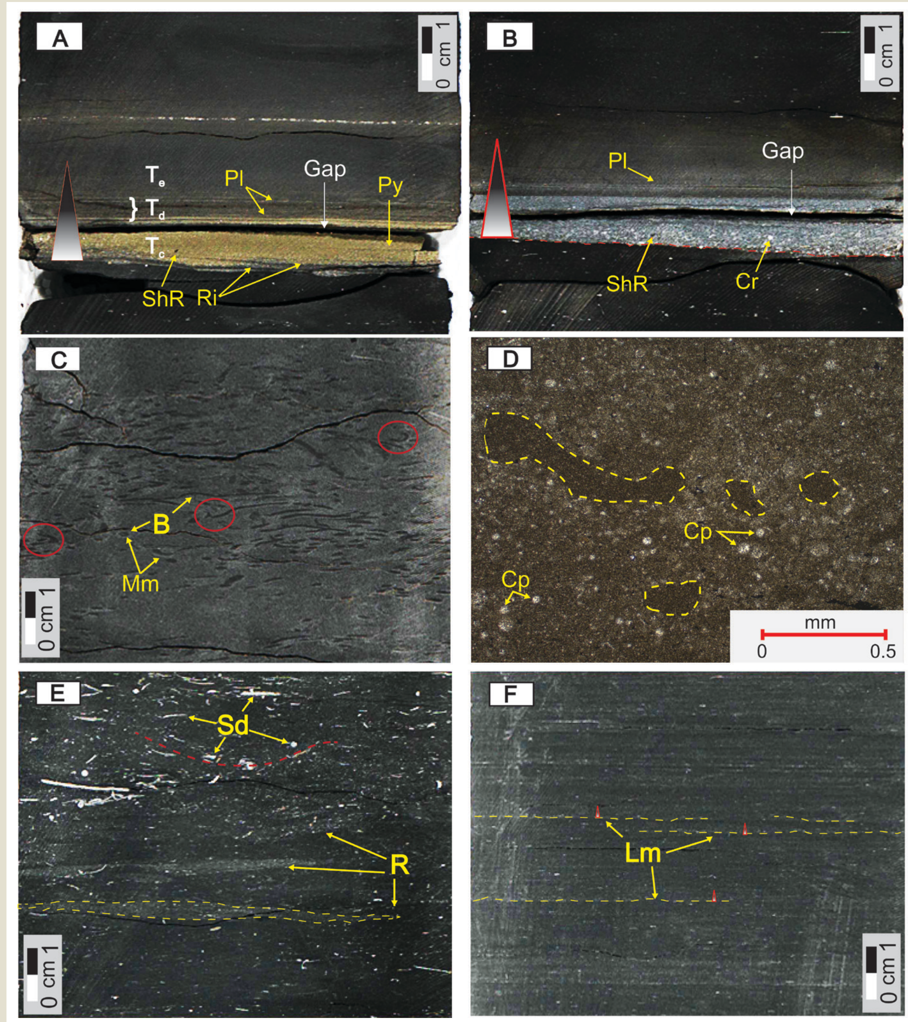

Figure 2: A and B) Partial Bouma sequence in calcareous mudstone of the Wolfcamp Formation (contrast enhanced) interpreted as turbidite deposits. A) Normally graded bed displaying tripartite fining upward succession (grey triangle): coarse siltstone to medium siltstone to fine siltstone. Bouma sequence elements are labeled Tc-Te (after Bouma, 1962). Ri= rippled interval, Pl= planar laminations, Py= pyrite, and ShR=shale rip up clast. B) Same normally-graded bed (grey triangle) as shown in A showing the highly sharp and erosive basal contact (red dashed line) of the base of the turbidite bed. Very faint planar laminations (Pl) occur towards the top of this bed. C and D) Key feature in facies tan, bioturbated, calcareous, medium siltstone (contrast enhanced) interpreted as contourite deposits. C) Example of low diversity high-intensity bioturbation. Burrow traces are largely horizontal ovoid to elongated and sub-horizontal. Red circles mark "fish-hook" structure interpreted as Phycosiphon incertum. *B= bioturbation (yellow arrows), Mm= mantle material (light-gray material surrounding burrow traces). D) Example of bioturbation in contour currents in thin section. Burrow traces are delineated by dashed yellow lines. Burrows are filled with argillaceous material. Cp= calcispheres. E) Example of ripples (R) and horizontal to wavy lamations in hand sample in calcareous mudstone deposits interpreted as contourites. The preferential wavy fabric of skeletal debris (Sd) is delineated by red dashed line. F) Discontinuous laminae in calcareous mudstone. Lm = laminations. Notice the slightly erosive bottom contacts (a few bottom contacts have been marked by a dashed yellow line). Red triangles mark fining upward trends of laminae. Laminations are at a slight low angle to one another, suggesting they may record mud ripples. Interpreted as distal contourite.*

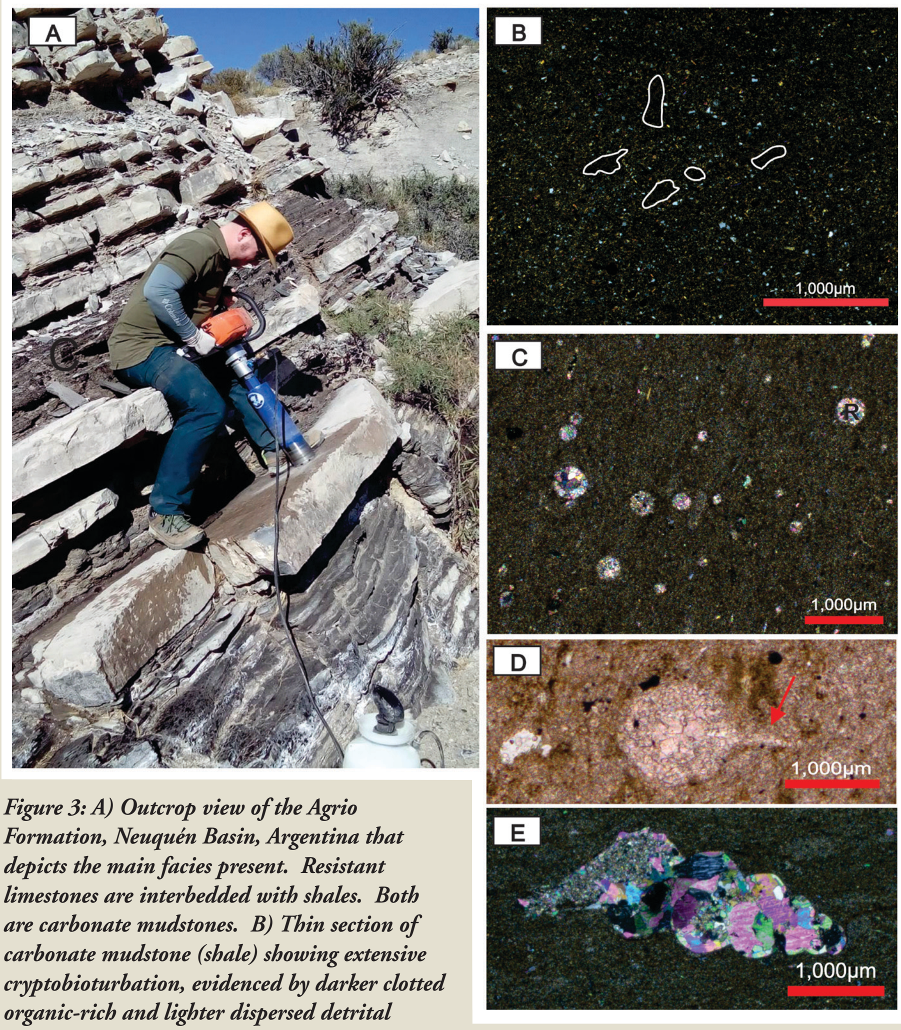

Figure 3: A) Outcrop view of the Agrio Formation, Neuquén Basin, Argentina that depicts the main facies present. Resistant limestones are interbedded with shales. Both are carbonate mudstones. B) Thin section of carbonate mudstone (shale) showing extensive cryptobioturbation, evidenced by darker clotted organic-rich and lighter dispersed detrital silt-rich domains. Several examples of the darker silt-free domains are outlined in white. C) Thin section of carbonate mudstone (resistant limestone) showing blocky spar calcite replaced radiolarians (R). Mottled and massive texture suggests extensive cryptobioturbation. D) Sparry calcite replaced radiolarian with preserved spine (red arrow). E) Blocky spar calcite recrystallized or replaced benthic foraminifera. Note both larger grained sparry calcite and smaller grained micritic cement within the foram, indicating multiple diagenetic events.

with Ta, Tb, and sometimes Tc subdivisions (Eberli, 1991; Playton et al., 2010). There is also a wealth of literature on modern carbonate turbidite deposits in the Bahamas (e.g., Bernet et al., 2000; Swart et al., 2000; Reijmer et al., 2015b).

CASE STUDIES

Here we present two case studies from thick carbonate mudstone dominated successions deposited below storm wave base (Figure 1). Both formations provide evidence that existing carbonate facies models that emphasize suspension settling below storm wave base are insufficient to account for mud deposition. In fact, when both of these carbonate mudstone successions are properly sedimentologically examined, there is ample evidence for current-influenced, rather than suspension settling dominated, deposition.

The first case study from the Upper Pennsylvanian to lower Permian Wolfcamp Formation preserves a deep water carbonate-dominated turbidite system deposited downdip from the shallow marine Central Basin Platform in the Midland Basin of West Texas, a sub-basin of the greater Permian Basin (Handford, 1981; Mazzulo and Reid, 1989). The second, the Lower Cretaceous Agrio Formation, of the Neuquén Basin of Argentina, was deposited on a mixed siliciclastic-carbonate ramp where proximal shoreface sandstone bodies transition to offshore siltstones to distal carbonate mudstones (Schwarz et al., 2018). These two successions represent two different types of deep water carbonate mudstone depositional systems.

Case study 1: Wolfcamp Formation, Midland Basin, TX

Carbonate platform to slope successions from the Permian Basin have been heavily studied (e.g., Tinker, 1998; Kerans and Tinker, 1999). Lower Permian debris flow and turbidite deposits from the Permian Basin in West Texas are cited as a type example a mud-dominated gullied foreslopes associated with broad and/or protected platform interiors (Playton et al., 2010). Slope to basin floor deposits in this Permian system are quantified as roughly half debris- and grain-dominated and half mud-dominated deposits (Playton et al., 2010).

The mudstone-dominated Wolfcamp Formation was deposited well below storm wave base, with published Midland Basin water depth estimates ranging from between 120 and 490 m (Hobson et al., 1985; Mazzulo and Reid, 1989). Wackestones and packstones, interpreted as debris flow deposits on the platform slope, and grainstones that exhibit Bouma sequences, interpreted as carbonate turbidites, have long been recognized in the Wolfcamp Formation (Handford, 1981). Organic-rich shales or carbonate mudstones in the Wolfcamp Formation have previously been interpreted as deposited from suspension settling (Handford, 1981).

The Wolfcamp Formation also preserves many examples of carbonate mudstone deposits with sedimentary structures, like ripples, that indicate bedload transport. Normally graded calcareous siltstone deposits preserve partial Bouma sequences in a tri-partite succession. A sharp, erosive basal contact is overlain by 1) current ripple-laminated coarse siltstone which grades upwards into 2) plane parallel-laminated medium siltstone, grading into 3) massive fine siltstone (Figure 2A, B). In thin section, plane-parallel laminated siltstones preserve reverse grading between laminations indicative of mud ripples. Based on the sedimentary structures present, these tri-partite layers may be interpreted as the Tc, Td, and Te portions of a Bouma sequence, respectively, even though they are all composed of mud-sized grains. This interpretation diverges from a classical Bouma sequence in which the Tc layer is rippled sandstone, Td is plane parallel laminated siltstone, and Te is massive mudstone (Bouma, 1962). Because mud flocculates, it acts like a coarser-grained particle. Therefore, both the ripple-laminated coarse siltstone (Tc) and plane parallel-laminated medium siltstone (Td) are interpreted as being deposited by active currents. This is in contrast to a traditional Bouma sequence interpretation in which plane parallel-laminated siltstone (Td) is interpreted to represent suspension settling. Thin section petrography reveals silt-size carbonate grains are composed largely of disarticulated bioclasts, like shell fragments, crinoids and fish bones.

A subset of calcareous mudstone deposits in the Wolfcamp Formation are interpreted to have been deposited by contour currents. Variably bioturbated medium to fine siltstone displays ripples, low angle laminations, scours and normally graded lags (Figure 2C - F). Bioturbation is considered a hallmark feature of contour currents, as they provide continuous circulation and oxygenations of the sea floor (Shanmugam, 2008). The presence of ripples, scours and normally graded lags within are consistent with current deposition. Interlaminated claystone and siltstone within these deposits suggests migration of silt and clay floccule ripples during multiple low flow velocity (< 25 cm/s) episodes (Yawar and Schieber, 2017).

Non-laminated massive mudstone deposits that lack petrographic evidence of bioturbation are also found in the Wolfcamp Formation. These facies are interpreted to record classical suspension settling deposition. Importantly, massive mudstone only represents a small fraction of the thickness of the Wolfcamp. Because current indicators in the Wolfcamp Formation are dominant, sedimentation rates were likely much higher than previous suspension-settling dominated models suggested (e.g., Handford, 1981).

Case study 2: Agrio Formation, Neuquén Basin, Argentina

The Lower Cretaceous Agrio Formation contains a total of ~600 m of carbonate mudstone in its lower Pilmatué and upper Agua de Mula Members in outcrop localities from the central to northern Neuquén Basin. These deposits record paleogeographically distal marine environments in the basin (Spalletti et al., 2011; Schwarz et al., 2018). Limestones that are resistant in outcrop are interbedded with shales (Figure 3A) (Spalletti et al., 2011). Both limestones and shales are carbonate dominated and consist of mud-sized grains, hence are carbonate mudstones.

In the Agrio Formation of Argentina, cryptobioturbation, only visible in thin section, obscures original sedimentary structures in carbonate mudstone deposits, making depositional mechanisms difficult to interpret (Figure 3B). Bioturbation is evident from a mottled texture that includes silt-free domains. Furthermore, a complex diagenetic history is evident in the Agrio Formation. Silica tests of radioloaria, which likely underwent Opal A to Opal CT to microcrystalline quartz transformations have been dissolved and replaced with drusy calcite (Figure 3C, D). Similarly, benthic foraminifera tests have been dissolved and replaced with drusy calcite (Figure 3E). Though radiolarian and benthic forams are present in the carbonate mudstone, they do not represent the bulk of the mudstone by volume. Instead, the majority of the mudstone is composed of micrite. Given that many Cretaceous age distal marine carbonate mudstone deposits are chalks composed of coccolithophore tests, it is reasonable to hypothesize a chalk origin for muddy limestones of the Agrio Formation. However, burial diagenesis has also destroyed nannofossil tests in some localities, precluding nannofossil identification and quantification of coccolithophore abundance by sediment volume. And a lack of mineralogical contrast within samples yields poor SEM imaging results. As a result, the origin of the micrite is ambiguous. Due to bioturbation and significant burial diagenesis, direct evidence of current influence from sedimentary structures is largely lacking in this carbonate mudstone succession.

It is unlikely that pelagic biogenic mud deposition alone was responsible for carbonate mud or micrite deposition in the Agrio Formation. There are robust age constraints on the deposition of the Agrio Formation from extensive biostratigraphy studies that are tied to radiometric tuff dates on the succession. These known age constraints combined with the stratigraphic thicknesses of carbonate mudstone successions suggest 8 cm/ ky sedimentation rates, almost an order of magnitude greater that average calcareous ooze deposition rates from Cretaceous-aged chalks (1.84 cm/ ky, Locklair et al., 2011). Therefore, pelagic carbonate sedimentation was likely not the only mud depositional mechanism at work in the sub-storm wave base portion of the ramp. Bottom currents were likely a prominent feature in the basinal environment. A documented shallow water carbonate factory on the eastern margin of the Neuquén Basin may have sourced carbonate mud (Spalletti et al., 2011). Offshore-directed bottom currents may have transported carbonate mud from proximal to distal portions of the basin.

DISCUSSION

Though we know that carbonate mud can be transported as floccules in bedload as demonstrated by Schieber et al. (2013), we don't know how common bedload transport is as compared to suspension settling across a variety of modern and ancient carbonate settings. This is partly because many ancient thick successions of carbonate mudstone, nominally deposited below storm wave base, have yet to be sedimentologically re-evaluated with an updated understanding of mudstone depositional processes.

There has been a significant advancement in recent years regarding sediment transport, depositional processes, and resulting facies and stratigraphic architecture on platform slopes (e.g., Betzler et al., 2014; Reijmer et al., 2015a; Wunsch et al., 2017). Because the slope is the main environment where neritic mud can be transported to deep water environments, this is valuable research. Yet still, with so many modern case studies from the Bahama platform slope settings, is our understanding of carbonate mud depositional processes in ancient systems bias? What aspects of the depositional mechanisms in modern systems are actually analogous to Mesozoic and younger carbonate systems?

Armed with the knowledge that carbonate mud can be transported as floccules in bedload, ocean currents below storm wave base, like contour currents, should be reconsidered as capable of transporting large volumes of carbonate mud, not just sand, in bedload. Recently emerging studies focused on contour current deposition will help us toward that goal (e.g., Betzler et al., 2014). Assuming contour currents are significant carbonate mud transport agents, is all the mud below storm wave base pelagically sourced? Is some fraction originally neritically sourced and transported via the slope to deep water environments? How do those transport mechanisms vary across different modern and ancient settings?

The realization that carbonate mud can be carried in bedload is significant to the long-standing interpretation that mud only settles out of suspension during the waning phases of a turbidity current. Existing literature on fine-grained turbidites, like Bouma and Stone (2000), focuses heavily on the sand fraction and interprets mud as settling out of suspension, predating most publications in the last decade on mud transport in bedload. This interpretation should be re-visited in light of advances in sedimentologic understanding.

CONCLUSIONS

Carbonate mudstone deposited in sub-storm wave base marine settings are common and can be high quality source rocks and unconventional reservoir rocks. We now understand current-influenced deposition of carbonate mud, even below storm wave base, is significant. As a community, let's challenge ourselves to incorporate a modern sedimentological understanding of carbonate mud deposition and update classical carbonate facies models accordingly.

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PRESIDENT'S COMMENTS

Every 5 years or so SEPM Council holds a strategic planning meeting to consider how the society should be looking forward to the challenges of the coming years. In August we had such a meeting following the International Sedimentology Congress in Quebec and the future challenges that we discussed were mainly digital. When I joined SEPM 35 years ago, to me the society was all about three things: Journals, Special Publications and Research Conferences. All three are still core to SEPM, but now that publications are produced and delivered in digital formats we also need to think about other ways in which the society can serve its members and the scientific community through on-line media. Here's a selection of ideas that were discussed

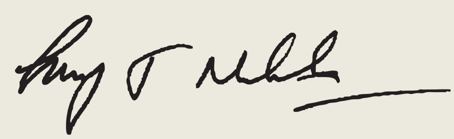
Virtual Conferences. A good conference is as much marked by the opportunities for interaction and discussion as for the science presented in the formal sessions, and a conference convened by participants logging into an interactive webcast cannot provide the 'off-line' element of a scientific meeting. Or can it? Many people are very comfortable with holding conversations through various forms of social media, so it should not be assumed that a 'virtual conference' would lack the social interaction element. The practicalities of meetings in which all, or some, of the participants are at remote locations is therefore something for SEPM to explore.

On-line Resources. STRATA has been a feature of SEPM's on-line presence for a number of years and it is used as a resource by students, academics and industry professionals. Further development of STRATA and providing access to a wider variety of on-line resources is something for the society to pursue, either by creation of new caches of materials or by linking to resources set up by other groups and organisations – an example of the latter under discussion is a catalogue of 3D outcrop images that have been assembled by a research group at the University of Bergen.

Web-based Activities. There are myriad opportunities and possibilities for advancing communication in our science through podcasts, technical discussion forums, short-format research publications, 'wiki'-type information exchanges, raw research data archives that can be mined and so on. There is a strong drive to make science more 'open' and improve the exchange of ideas and information. SEPM's ambition should be to see itself at the heart of this for the community of sedimentologists, stratigraphers and palaeontologists by providing the enabling platforms.

In order to take further steps into the digital world and achieve these ambitions, SEPM will need to make some investments. Most important of these will be a new member of HQ staff whose responsibility it will be to lead our digital development and on-line activities, and it is hoped that a appointment can be made early in 2019.

By which time I will no longer be SEPM President: the changes to the by-laws that lengthened the terms of office of most members of Council also changed the start/end dates to calendar years from the mid-year changeovers we had in the past. To facilitate this new structure my period of office had to be shortened from 12 months to 6 months, making me the shortest-serving SEPM President. As a colleague pointed out, most presidents want to stay in office for longer, and some change constitutions to do so. I have succeeded in doing the opposite: I guess I've failed to let power go to my head….



Gary Nichols,
SEPM President 2018

SEPM Society for Sedimentary Geology
"Bringing the Sedimentary Geology Community Together"
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Report on the International Sedimentological Congress, Quebec.

By Jamar Bynum[1], Andrew Cummings[2], Autum Downey[3], Rebecca Englert[4], Luke Fritz[5], Maria Sider[6], Alice Stagner[7], Frank Tamakloe[8], Allen Tevyaw[9], Logan West[10], and Spencer William[11]

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INTRODUCTION

Eleven geoscience students received travel grants from an SEPM NSF Award to attend the 20th International Sedimentological Congress in Quebec, Canada, August 13-17, 2018. The awards were made in conjunction with the Sedimentary Geology Division of GSA and covered the student's expenses to attend the meeting. The students come from a wide cross-section of the geoscience community based on gender, ethnicity, age and degree program. This report includes their impressions and experiences at the meeting.

OVERVIEW

Overall the conference was considered a great learning experience by all of the awardees. The conference brought together a different and more diverse group of researchers than other North American-based conferences they had previously attended. Being able to connect with this group was greatly appreciated and helped to build a larger global network. The conference schedule included numerous group activities involving most or all of the attendees such as the icebreaker, daily group lunches, poster sessions, keynote speakers, and a banquet. These events made it easy to meet and socialize with other students and researchers, thereby facilitating discussion and collaboration in a more casual setting. Other opportunities, such as the mid-conference Wednesday break, allowed time to culturally explore Quebec City and the surrounding area or to participate on one day field trips.

The conference was an excellent opportunity to learn from and connect with sedimentologists from around the world. Each day was fully packed and exhausting in a good way. The days were essentially a full 12 hours where even the breaks were opportunities to chat and exchange ideas on research and learnings.

A major aspect of the meeting was the value of interdisciplinary investigation. While a growing trend among top universities is for interdisciplinary work; plenty of work still remains siloed. This can occur not only between disciplines but even just between different research groups in the same building. The study area of sediment transport, in particular deep-water sediment gravity flows, is one where interdisciplinary investigation was highlighted at the meeting and advanced its understanding in the earth science community.

Another takeaway is that as the world of stratigraphy and hydraulics becomes increasingly (and appropriately) linked, the community needs to do its best to educate itself and ensure that hydraulics engineers are teaching and learning from stratigraphers and vice versa.

Finally this conference was a great venue for experiencing the idea of the risks and rewards associated with research and specifically modelling and the evolution of models.

TECHNICAL SESSIONS COMMENTS

Overall hearing and seeing some very different approaches and models is a good reminder to keep an open mind, ask questions, and work from observations to test hypothesis rather than rushing to support anticipated or desired conclusions.

Some of the memorable presentations include:

- Several on mudrocks and shales – their diagenesis and sequence stratigraphic aspects
- What the rock record actually preserves – depositing, eroding or bypassing specific environments
- Carbon storage in deep-water deposits - a single depositional event can bring in carbon from a wide range of ages and sources
- How flows are highly complex and deposits can have wildly different characteristics depending on when and where along the duration or length of a flow they formed.
- Multiple posters and talks that discussed sediment provenance from a variety of ages from Holocene to Mesozoic.
- The impact of bioturbation on reservoir properties and the use of various imaging techniques to evaluate the bioturbation.

Figure 1. Informal discussions with new friends. Photo S. William

Figure 2. Checking out an outcrop on a Wednesday Field Trip. Photo F. Tamakloe

Figure 3. Some of the 'old' Quebec City architecture. Photo L. Fritz

Figure 4. The food. Photo A. Cummings

CULTURE

Opportunities, such as the mid-conference break, to explore Quebec City and the surrounding area allowed time to walk around and watching street performers in Old Quebec, visiting the citadel and the Plains of Abraham, and watching a fireworks show over the St. Lawrence River.

It was important to experience an area where English was not the primary language because it gives perspective on the world as a whole. Language barriers can hold someone up from something as simple as ordering a coffee or having a conversation about sedimentary environments. In regards to global culture the awardees noted that they met and exchanged contact information with professors and students from Spain, Italy, the US, China, Norway, Germany, France, and England among other countries. This was a great networking experience.

Specifically meeting people that have immigrated to Canada was interesting as it is easy to have a US-centric view of the immigrant experience, so it was neat to hear about that experience in Canada from locals in Quebec City.

STRATA – SEPM DIGITAL KNOWLEDGE DATABASE – A NEW LOOK AT A POPULAR TOOL AND ITS' FUTURE

Lesli J. Wood, Colorado School of Mines, Golden, Colorado Email: lwood@mines.edu

I am really pleased to have been asked to serves as Chief Editor of our SEPM STRATA Digital Knowledge Database. It was a gift to SEPM by very fore thinking professors that could see the future of education in sedimentary geology. Today, students, academics and industry professionals are turning in ever increasing numbers to STRATA as a knowledge database and training tool. They draw upon STRATA to assist in prepping courses, for assistance during publishing on a variety of topics and to assist in learning techniques and methodologies for research in both basic and applied science. As such a popular tool that is backed by the science strength of the SEPM organization, it is imperative that STRATA be a strong knowledge database, with frequent consideration of modifications as our dynamic science changes and grows. These are some of the reasons for my decision to accept this position. I hope to work with a dynamic and knowledgeable group of colleagues of all ages and interests to ensure that STRATA contains useful and accurate information. In part due to its origins as a gift from a legendary carbonate stratigrapher, Dr. Christopher St. Kendall, STRATA carbonate systems' content is currently much stronger than similar content in clastics. One of my first tasks is to bring our clastic content up to par with the carbonate content. A larger project will be to consider an ongoing process by which to modify and update all content that exists in STRATA, as well as consideration of new content streams such as digital outcrop models, subsurface visualizations, or quantitative data sets on a variety of physical system properties. I will report progress on the clastic systems knowledge upgrade in early summer. Throughout the year, we will be considering how to include community input and community volunteers to establish content. Certainly, if you are interested in being involved in this community effort please contact me! I look forward to working with all of you to create an incredible SEPM Community Tool in STRATA (www.sepmstrata.org)

CALL FOR POTENTIAL 'LOCAL' SPEAKERS

The SEPM Council is initiating a new program to encourage sedimentary geology as a discipline across the globe and to help geoscientists and students be more aware of the Society and what it has to offer. To this end, the Council wants to create a list of potential speakers and topics that can be made available to requesting schools in the same general region as the speakers, hence the 'local' aspect of this initiative. SEPM would help with some local financial support and will also supply content as needed to the speakers. This program may also test creating video recordings of speakers so that the presentation may be archived and shared at other times and outside of the local area. Some speakers may already have videos of various presentations, such as course lectures, and those may also be considered to be included in this initiative.

Please contact Howard Harper (hharper@sepm.org) if you are interested in being a participant of this initiative.

UPCOMING MEETING!
SEPM International Sedimentary Geosciences Congress – 2020 26-29, April, 2020 – Flagstaff, AZ, USA
'The Past is the Key to the Sustainable Future'

The "Past" of sedimentary geosciences being the Sedimentary Record. SEPM, in conjunction with IAS and SGD/GSA, invites you to plan to attend the International Sedimentary Geosciences Congress in Flagstaff, Arizona (SEPM2020). In addition to fantastic field trips and workshops and to foster continued interaction between the many sub-disciplines of sedimentary geosciences, technical sessions will be under the umbrella of two broadly designed themes:

Theme 1: Geodynamic and tectonic evolution of the continents and their margins: implications for ancient depositional systems.

Theme 2: Ocean-atmospheric controls on surface processes: evolution of life, landscapes, and the sedimentary record.

Keep up dated at https://www.sepm.org/SEPM2020
https://www.facebook.com/SEPM2020/
#SEPM2020

SEPM NEWLY ELECTED COUNCIL MEMBERS

Please congratulate the new members of the SEPM Council and thank them for becoming involved with SEPM governance. Under the revised Bylaws, these council members take office January 1, 2019.

President-Elect: Michael Blum, University of Kansas

Sedimentology Councilor: Zane Jobe, Colorado School of Mines

Paleontology Councilor: Murray Gingras, University of Alberta

Student Councilor: Kristina Butler, University of Texas-Austin

Co-Editor of PALAIOS: Patrick Orr, University College Dublin

SEPM Foundation President: Rick Sarg, Colorado School of Mines

APPENDIX A

A review of carbonate mud generation

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Carbonate settings have historically been subdivided into platform-slope-basin floor or ramp systems. Within these systems, carbonate mud has either a neritic or pelagic origin. In modern neritic tropical to sub-tropical environments, like the Great Bahama Bank and Florida Shelf, green codiacean algae, like *Penicillus*, are thought to be responsible for much of the shallow water mud generation since these algae break down into micron-sized aragonite needles (Stockman et al., 1967; Neumann and Land, 1975). Secondarily, biomicritization of grains by boring organisms, as well as fecal pellet production, play a role in shallow water micrite generation. There is a long standing debate over the organic versus inorganic origin of Bahamian mud (Shinn et al., 1989). Milky water column events consisting of suspended aragonite needles, termed whitings, are a common occurrence in both the Bahamas and Florida Shelf (Robbins et al., 1997). Whitings may be inorganic precipitation events or biologically induced and may be responsible for a significant volume of shallow water mud generation over time (Shinn et al., 1989; Robbins and Blackwelder, 1992; Purkis et al., 2017). Recent studies link precipitation events to ocean circulation patterns, specifically off-platform ocean currents that periodically reach the platform (Purkis et al., 2017).

Temperate carbonate seafloors host coarse-grained carbonates and generally lack mud producing organisms. The origin of carbonate mud in temperate, non-tropical settings is less common and more enigmatic. Studies of modern settings like South Australia suggest mud is composed of macerated shell fragments, rather than from aragonite precipitation in seawater documented from tropical to sub-tropical settings (O'Connell and James, 2015).

Pelagic biogenic production is an important source of carbonate mud. In Mesozoic and younger open water systems, pelagic biogenic production by calcareous organisms has resulted in the deposition of micro- and nannofossil tests and calcareous ooze deposition, preserved as pelagic limestones and chalks in the sedimentary record (Ekdale, 1984). Microfossils, like foraminifera, make up pelagic limestone units, like those found in the Cretaceous aged Eagle Ford, which are interbedded with organic and clay-rich shale beds (Denne et al., 2014; Hentz et al., 2014; Denne et al., 2016; Denne and Breyer, 2016; Fairbanks et al., 2016). Nannofossils, specifically coccololithophores, make up chalk deposits. Jurassic-age chalks preserved in the North Sea and across portions of Europe are among the most heavily cited geologic examples (Herrington et al., 1991). Chalks deposited in the Cretaceous Western Interior Seaway, like the Niobrara represent typical pelagic biogenic coccolithophore-rich mud deposition (Longman et al., 1998; Sonnenberg, 2011). Average calcareous ooze deposition rates from Cretaceous-aged chalks is 1.84 cm/ ky (Locklair et al., 2011). Where clay dilution was locally high, marls instead of chalks are preserved (Longman et al., 1998; Sonnenberg, 2011).

Large volumes of carbonate mud also occur in mud mounds. Mud mounds are carbonate buildups with depositional relief that are composed dominantly of carbonate mud, peloid mud, or micrite (Bosence and Bridges, 1995). Mud mounds may be microbial or biodetrital in nature (Bosence and Bridges, 1995). Microbial mounds are relatively in-situ features, constructed from the trapping and baffling of sediment by microbial mats (Bosence and Bridges, 1995; Lees and Miller, 1995; Monty, 1995), whereas biodetrital mud mounds are composed of broken and transported skeletal debris (Bosence, 1995; Bosence and Bridges, 1995; Bridges, 1995; Taberner and Bosence, 1995). In biodetrital mud mounds, mud may be generated locally or transported significant distances (Bosence and Bridges, 1995). These two types of mounds may or may not be mutually geographically exclusive. In some cases, microbial facies transition to biodetrital facies within one mound (Bosence and Bridges, 1995). Mud mounds can be found in a variety of settings ranging from deep basinal, to lower slope, to shelfal or lagoonal environments (Bosence and Bridges, 1995; Pratt, 1995).

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