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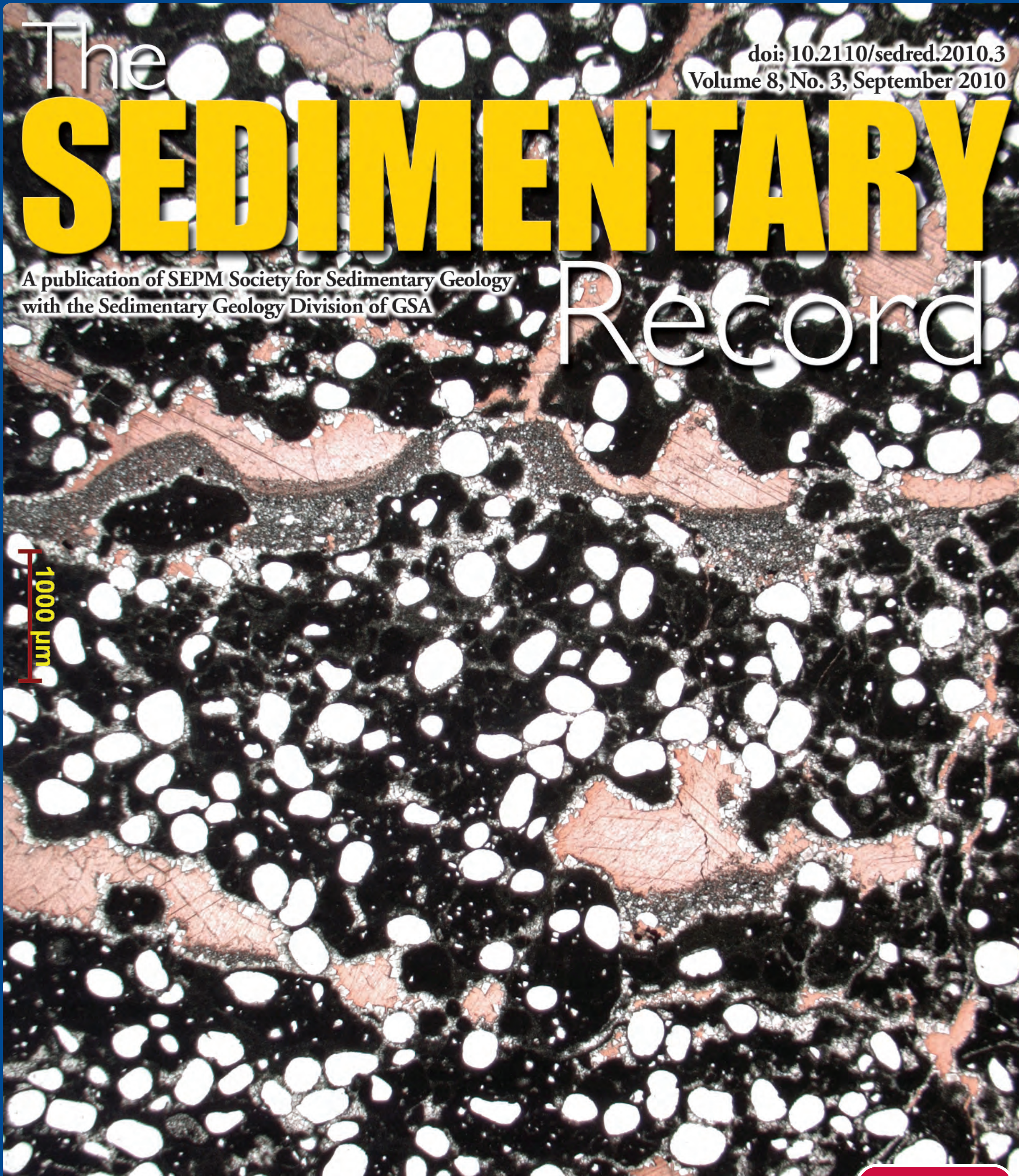

INSIDE: REFLUX DOLOMITE CRYSTAL SIZE VARIATION IN CYCLIC INNER RAMP RESERVOIR FACIES, BROMIDE FORMATION (ORDOVICIAN), ARKOMA BASIN, SOUTHEASTERN OKLAHOMA

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Edited by: Kenneth T. Ratcliffe and Brian A. Zaitlin

Much has been written and debated about the various methodologies applied to modern stratigraphic analysis and the ever increasing complexity of terminologies. However, there exist numerous stratigraphic techniques that are reliant upon precise, quantitative, reproducable data, rather than qualitative interpretative stratigraphic methodologies. Such stratigraphic techniques are applied in an entirely pragmatic non-biased manner within the petroleum industry to provide enhanced stratigraphic understanding of petroleum systems. The petroleum industry is a key driver behind the development of new stratigraphic techniques and a major provider of new stratigraphic data, which has resulted in several of these new techniques having been developed as a requirement to the industry. Furthermore, because techniques, such as isotope chemostratigraphy, elemental chemostratigraphy, magnetic susceptibility stratigraphy, numerical biostratigraphy and heavy mineral stratigraphy are based around precise, quantified and reproducible analytical data, they provide an independent means to test the more interpretative stratigraphic methodologies. This volume attempts an overview of stratigraphic methodologies, but largely focuses on data-generative stratigraphic techniques such as chemostratigraphy, magnetic susceptibility stratigraphy, numerical biostratigraphy and heavy mineral stratigraphy. Where appropriate, each paper discusses data generation methods including sample preparation and analytical methods as well outlining data interpretation methods. This is followed by case histories that demonstarte how those data are used to resolve stratigraphic problems, commonly using material derived from petroleum basins around the World.

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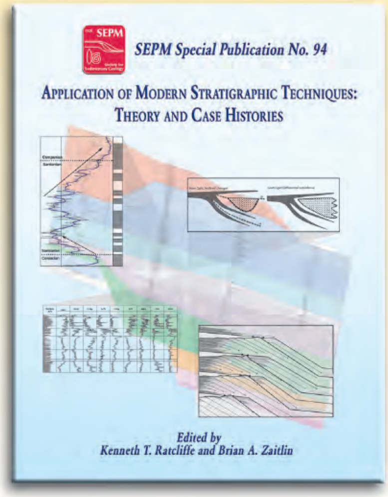

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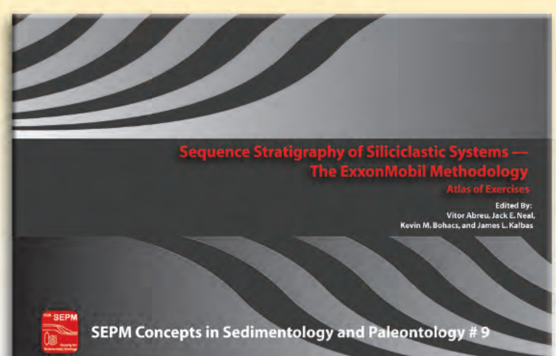
Concepts in Sedimentology and Paleontology #9

Sequence Stratigraphy of Siliciclastic Systems – The ExxonMobil Methodology

Edited by: Vitor Abreu, Jack E. Neal, Kevin M. Bohacs and James L. Kalbas

The stratigraphic concept of a depositional sequence was introduced to the scientific literature by Exxon Production Research Company (EPRco) in the late 70s, building on the shoulders of giants like Chamberlain, Sloss and Wheeler. Since then, several papers compared and contrasted the original Exxon (and later, ExxonMobil) sequence-stratigraphic school with other approaches to subdivide the geologic record, as well as, debating the ExxonMobil model validity and impact on the community. At its core, the ExxonMobil "model" is really a stratigraphic interpretation method, which was never explicitly documented in the literature. The objective of this book is to present the ExxonMobil 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 at EPRco and at the ExxonMobil Upstream Research Company (URC). 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).



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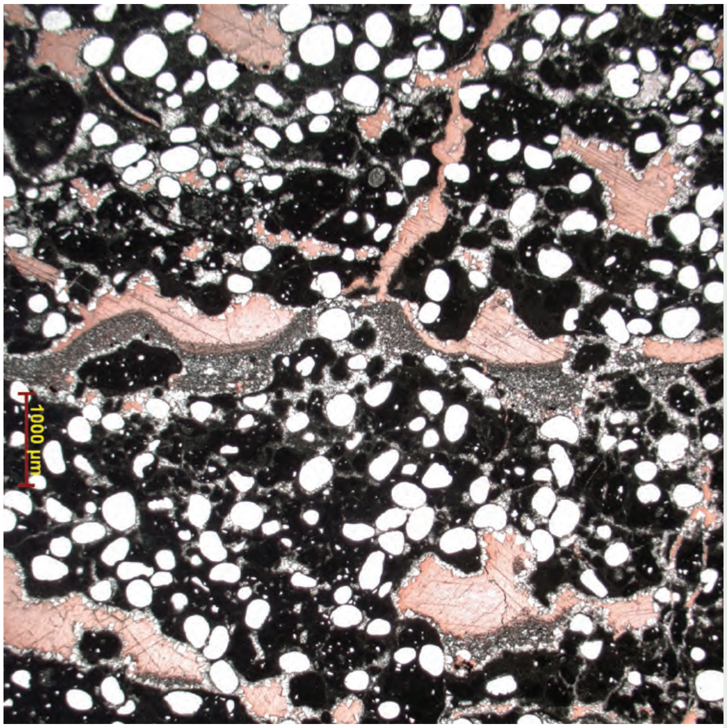

Cover image: Well-preserved fabric of thrombolitic bindstone with fenestral cavities and dessication cracks from dolomitized peritidal facies of updip Bromide Dolomite (Upper Ordovician) in the subsurface Arkoma Basin of southeastern Oklahoma. Matrix consists of dolomicritic peloids and intraclasts, well-rounded (probably eolian-derived) quartz sand grains, and sparse small molluscan shell fragments. Fenestral cavities have geopetal sediment, are lined by dolomite crystals and filled by late diagenetic calcite cements (stained with alizarine red). Under ultraviolet light microspcopy, the dolomicritic peloidal grains show good microporosity. It is thought that the well-preserved sedimentary fabric of the dolostone is the result of rapid dolomitization by refluxing supersaturated fluids near their source of origin.

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Reflux Dolomite Crystal Size Variation in Cyclic Inner Ramp Reservoir Facies, Bromide Formation (Ordovician), Arkoma Basin, Southeastern Oklahoma

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ABSTRACT

In the subsurface Arkoma Basin of southeastern Oklahoma, the Bromide Formation (Upper Ordovician) consists of shallow-water inner ramp dolomitized facies deposited on the low-angle South Ozark Platform. The Bromide Formation is composed of repetitive, thin (3-10 ft. thick), shallow subtidal to peritidal, shallowing-upward cycles. Typically, cycles have a basal thin quartz sandstone unit, overlying subtidal dolomitized mudstones to grainstones, and capping peritidal facies. Peritidal dolomitized facies include stromatolitic and thrombolitic bindstones and diverse mudstones to grainstones with fenestral fabrics, dessication cracks, geopetal vadose silt pore fillings, collapse breccias, squared-off crystal molds, and sparse remnant enterolithic bands of former evaporites. Peritidal dolomitized packstones and grainstones are common and composed mostly of dark peloids and small mudstone intraclasts, many of which are microbial in origin. Oolitic grainstones are moderately common.

There is a significant increase in Bromide dolomite crystal sizes and porosity in a downdip direction on the ramp. In the more updip Red Oak Field, the Bromide dolostones are mostly composed of fabric-retentive microcrystalline dolomite, and have only microporosity. In the more downdip Wilburton Field area, the dolostones are composed of fine- to medium crystalline replacive dolomite in which grains are recrystallized beyond recognition or moldic, and have intercrystalline, skelmoldic, vuggy pores.

The dolomite crystal size change downdip is thought to be a result of variation in the reflux dolomitization process. The dolomitization of the updip microcrystalline Bromide by locally-derived supersaturated brines was penecontemporoous to very early diagenetic and was completed relatively quickly. The brines that refluxed through more downdip ramp facies became somewhat depleted (i.e., less saturated with Mg) and dolomitization proceeded more slowly, resulting in coarser planar dolomite crystallization. Later burial diagenesis served mainly to occlude macroporosity, but not the microporosity.

INTRODUCTION

Little sedimentological data are available on subsurface carbonates of the Bromide Formation (lower Upper Ordovician, Simpson Group) in the Arkoma Basin in southeastern Oklahoma (Suhm, 1997; Wahlman et al., 2006). The Bromide Formation is known primarily from open marine ramp limestone and shale facies that outcrop in the Arbuckle Mountains of southern Oklahoma (Longman, 1981) (Figure 1). Bromide sandstone facies also form important hydrocarbon reservoirs in the Anadarko Basin of central Oklahoma (Northcutt and Johnson, 1997) (Figure 1A).

This study is based on Arkoma Basin subsurface cores from Red Oak Field and the slightly more paleogeographically downdip Wilburton Field, Latimer County, Oklahoma (Figure 1B). The fields are about 12 miles (22 km) apart, with no cored wells in between. The Bromide in both fields is composed of cyclic inner ramp, subtidal to peritidal, sandy dolomitized carbonate facies, with subtidal facies increasing downdip and peritidal facies increasing updip and up-section (Figure 2). However, there are significant differences in the dolomite crystal sizes and associated reservoir characteristics between the two fields. Bromide dolostones in the more updip Red Oak Field are composed mostly of microcrystalline dolomite that preserves grain types and depositional fabrics, and essentially all porosity is microporosity (Figures 3-5). Bromide dolostones in the more downdip Wilburton Field are composed of fine- to medium-crystalline planar dolomite in which grains are recrystallized or moldic, and the porosity system is intercrystalline, moldic, and vuggy (Figures 3, 6). This pattern of the downdip increase in dolomite crystal sizes and porosity in inner ramp dolostones is considered largely the result of the downdip reduction of reflux dolomitizing brine saturations and the relative duration time of the dolomitization process, as described by Sibley and Gregg (1987).

GEOLOGIC SETTING AND STRATIGRAPHY

During the Ordovician, southeastern Oklahoma was the eastern shelf of the large Oklahoma Basin whose depocenter was the southern Oklahoma aulacogen (Johnson, 1991) (Figure 1A). Early Pennsylvanian continental collision created the present-day complex of Oklahoma structural basins. The Arkoma Basin is bounded on the north by the Ozark Dome, on the south by the Ouachita Trough, on the west by Anadarko Basin, and on the east by the Plattin carbonate shelf (Johnson, 1991; Suhm, 1997) (Figures 1A, B).

The Bromide Formation (Mohawkian (N.A), ~ Katyan (Global) series, Blackriveran stage) is the uppermost unit of the Middle and Upper Ordovician Simpson Group (Suhm, 1997, Sadler, 2009) (Figure 1C). Within the Arkoma Basin, the Bromide is composed of carbonates and sandy carbonates that are transitional between the sand-rich facies of the Anadarko Basin to the west and the Plattin carbonate platform to the east. According to Suhm (1997) (Figure 1A), the paleoclimate to the west of the Oklahoma Basin was humid, and the area to the east of the basin was arid. Several features of the Bromide dolomites on the South Ozark Platform show evidence of an arid paleoclimate in the study area (Figure 4).

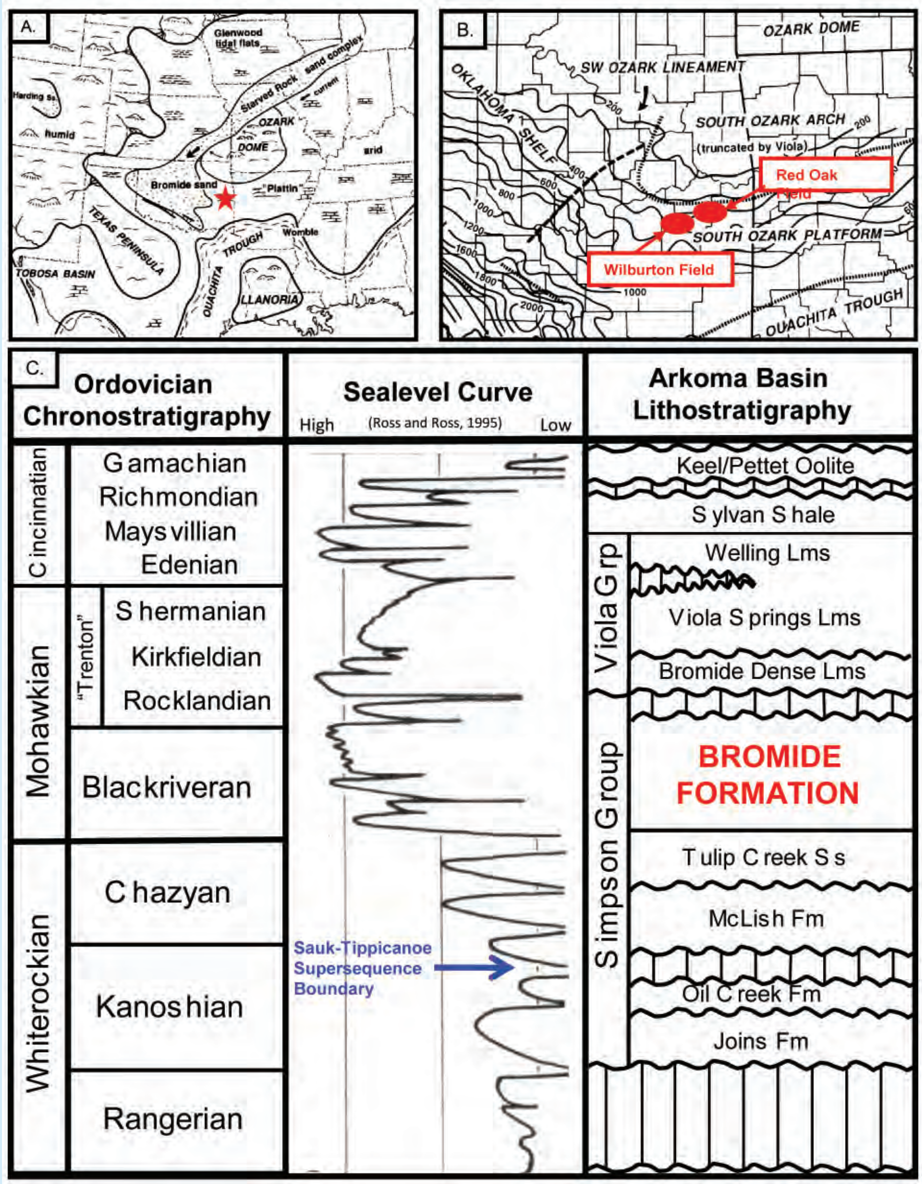

Figure 1. A. Late Ordovician paleogeography of Oklahoma and surrounding area. Red star marks study area. B. Simpson Group isopach map and paleogeographic features mentioned in text. Data are from Red Oak and Wilburton Fields. (Figures A-B from Suhm, 1997). C. Stratigraphic chart for Middle and Upper Ordovician of Oklahoma, with chronostratigraphy, a sealevel curve (Ross and Ross, 1995), and lithostratigraphy.

The Late Ordovician is characterized by relatively high-frequency sealevel changes related to early icehouse paleolimatic conditions (Figure 1C). The Bromide Formation is the uppermost of three 3rd order sequences in the Simpson Group (Candelaria and Handford, 1997), each of which has a basal transgressive quartz sandstone, and later transgressive and highstand marine carbonates and shales. In that scheme, the Bromide 3rd order sequence is composed of the LST to early TST Tulip Creek Sandstone and late TST to HST Bromide carbonates.

The thin Bromide 4th-5th order sequences in the Arkoma Basin cores show the same lithofacies pattern as the larger 3rd order sequences (Figures 2). Those inner ramp high-frequency sequences have thin basal sandstones (<6 inches thick) that grade quickly upward into inner ramp subtidal dolostones that have sparse, mostly molluscan bioclasts, and some burrowing. The subtidal dolostones shallow upward into restricted marine subtidal to peritidal dolostones that consist of shoal/beach, lagoonal, and intertidal-supratidal facies. Many carbonates contain variable amounts of quartz sand. The 4th-5th order cycle model shown in Figure 2 is a typical complete subtidal-peritidal cycle, which is most characteristic of the middle Bromide Formation and in more downdip areas. Updip, and up-section in the Bromide, the proportion of peritidal facies increases.

BROMIDE DOLOMITE FACIES

The Bromide cores from Red Oak and Wilburton Fields represent a range of inner ramp, shallow subtidal to peritidal facies (Figure 5A-B, Figures 4-10). Four general facies associations are recognized: (1) Peritidal and restricted marine lagoon, (2) Shoal, beach, and channel grainstones-packstones, (3) Open marine ramp wackestone-packstones, and (4) Transgressive sandstones. Figure 2 outlines the general Bromide facies associations and the subtle differences between updip and downdip facies. The facies associations are present in both areas, but in general the more updip Red Oak Field area has a higher proportion of peritidal and restricted marine lagoonal facies. Facies contacts within the cycles are mostly gradational, but the contacts of the cycles are usually sharp erosional surfaces.

Bromide dolostones in the updip Red Oak Field area are composed of mostly microcrystalline dolomite. Much of the microcrystalline dolomite is replacing stromatolitic and thrombolitic micrite, micrite peloids and intraclasts, and micritic grain coatings, but many non-micritic bioclasts and oolitic grains are also well-preserved by microcrystalline to very fine-crystalline dolomite. Dolograinstones are common in the updip Red Oak Bromide, and the most abundant grains are microcrystalline dolomite peloids, small rounded micritic intraclasts, and oolites (Figures 3G-H, 5A-C and H). The intergranular areas in those grainstones are generally lined or filled by clear, medium-crystalline planar dolomite cements that can have minor intercrystalline porosity (Figures 5G, H). The microcrystalline dolomites usually have well-developed microporosity, which is visible only in thin-sections impregnated with fluorescent epoxy and viewed using ultraviolet light microscopy (Figures 5C,F,I). The porosities of those microporous dolomites is usually < 5%, and the permeabilities are commonly <0.01md.

The more downdip Wilburton Field Bromide has the same depositional facies, but the dolostones are composed of fine- to medium-crystalline planar dolomite with a porosity system of intercrystalline pores, skelmolds, vugs, and some microporosity. Porosity values commonly range from 5-12% and have relatively good permeabilities (e.g., >1.0md) (Figures 3C-F, 6A-G). Bioclasts are represented by skelmolds, and the coarser dolomite recrystallization has rendered most grains and many fabrics unrecognizable petrographically (Figures 6B-C).

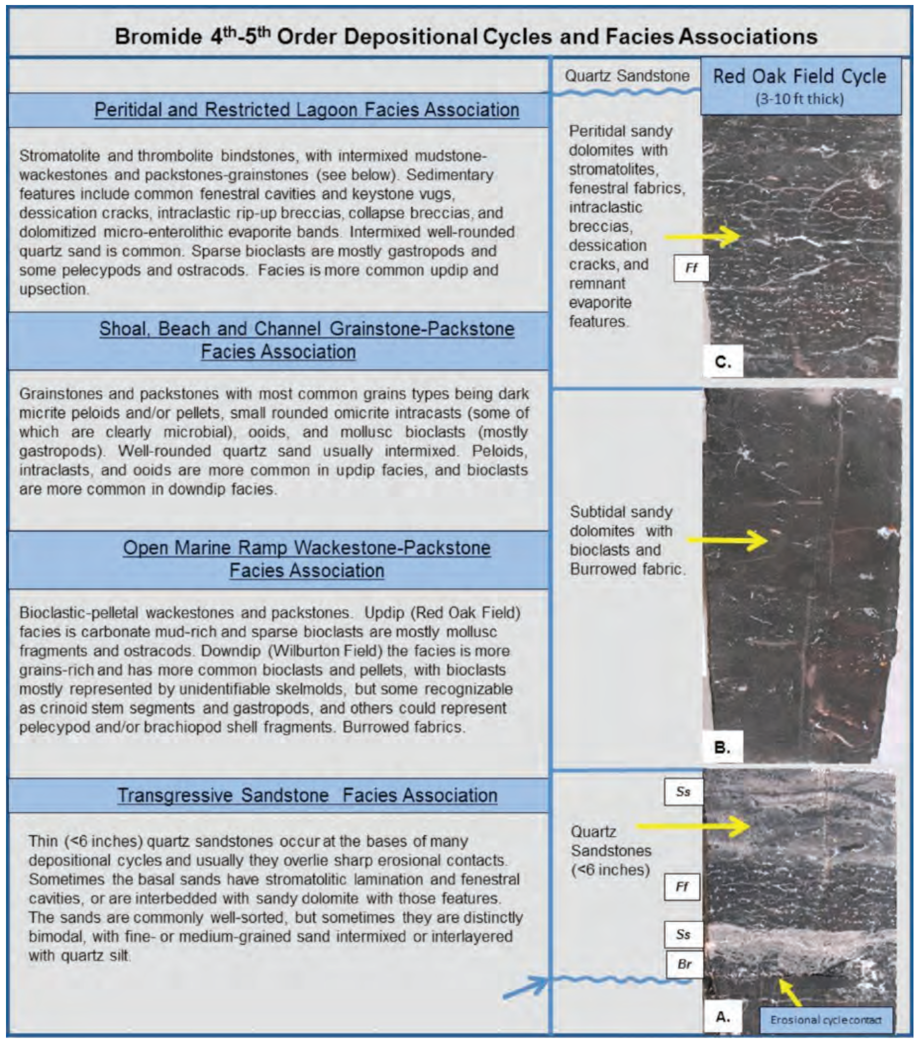

Figure 2. Summary of Bromide facies associations (left), and core slabs from a typical subtidal-peritidal cycle from Red Oak Field core (right). Dark color of dolostones is due to the disseminated bitumen content. A. Erosional cycle base overlain by a thin breccia (Br), quartz sand (Ss), sandy stromatolite with fenestral fabric (Ff), and another thin sand (Ss),12893 ft. B. Subtidal dolowackestone with sparse mollusc bioclasts, 12891.3 ft. C. Peritidal stromatolitic dolobindstone with fenestral fabric , thin intraclastic layers, and sheet cracks, 12888.2 ft. The dolostones have only microporosity values of 1.4-2.8% and permeabilities of 0.07-0.53md.

DOLOMITIZATION AND DIAGENESIS

The Bromide dolostones are interpreted to be the product of reflux dolomitization (Figure 3A) because of their inner ramp depositional setting, and features indicating a probable arid paleoclimate, including dessication cracks, and remnant features suggesting the presence of former evaporites, such as dolomitized micro-enterolithic bands, squared-off crystal molds, and isolated collapse breccias (Figures 4A-G). Reflux dolomitization of cyclic shallow subtidal and peritidal sediments in warm arid settings has been widely described and discussed in modern and ancient settings (e.g., Adam and Rhoads, 1960; Deffeyes et al., 1965; Illing et al., 1965; McKenzie et al., 1980; Hardie, 1987; Zenger, 1988; Mutti and Simo, 1994; Saller et al., 1994; Saller and Henderson, 1998), and results from evaporation of inner ramp, lagoonal and peritidal, shallow marine waters, creating Mg-supersaturated brines that sink and flow downdip dolomitizing the subsurface calcareous sediments. Dolomite textural and crystal size changes have also been attributed to the depositional position of the precursor within the reflux hydrology regime (Saller and Henderson, 2001, Machel, 2004, Saller, 2004).

In a study of cyclic Permian dolomite reservoirs in the Permian Basin of West Texas, Saller et al. (1994) and Saller (2004) envoked a process through which reflux dolomite porosity decreases in an updip direction toward the origin of the supersaturated refluxing fluids. They demonstrated that updip early dolomites can have a high initial porosity, but continued circulation of supersaturated brines through the updip dolostones results in additional precipitation of dolomite (over-dolomitization; e.g., Lucia, 2002, 2004; Saller and Henderson, 2001) that causes continued dolomite crystal growth and intercrystalline dolomite cementation, which in turn decrease porosity. These results have been confirmed by reactive transport modeling where maximum dolomitization rate is critically dependent on the rate of reflux flow and the reactive surface area of the mineral (Jones and Xiao, 2005, figure 18). In the Saller (2004) conceptual model, original dolomite crystal sizes are essentially the same in updip and downdip sites, but the updip crystals become larger and porosity decreases through the continued dolomite precipitation. When the reactive transport model results are coupled to the conceptual model of dolomite distribution, porosity and crystal size (e.g. Saller 2004) we see a much more transient and spatial differentiated evolution for porosity associated with dolomite.

The Bromide dolomites in the Arkoma Basin demonstrate another process through which reflux dolomite porosities of cyclic inner ramp dolostones decrease in the updip direction. Updip Bromide porosity decrease appears directly attributable to dolomite crystal size decrease, that is in turn thought to be related to the relative saturation levels of the dolomitizing fluids and length of time for dolomitization. Sibley and Gregg (1987), in their discussion of dolomite rock textures, noted that dolomitization and dolomite crystal sizes are a function of fluid supersaturation and nucleation sites. Micritic carbonate sediments have a high surface to volume ratios and dolomitize rapidly. High density of nucleation sites (e.g., micrite) and high supersaturation should produce a finely crystalline dolomite. In their figure 11, Sibley and Gregg (1987) show that at high fluid saturations a wackestone becomes a relatively fine crystalline dolomite and bioclasts are replaced and preserved. But as dolomitizing fluid saturation states decrease, and residence time of the wackestone in the dolomitizing solution becomes longer, dolomite crystal sizes increase and bioclasts become skelmoldic. Sibley et al. (1993) further studied dolomite crystal size distributions and demonstrated the complexity of the subject. The observations and interpretations presented in this brief study do not involve detailed measurements and research data required to support or refute the saturation state, residence time, crystal size model. But observational data presented here illustrate a marked downdip change in Bromide dolomite crystal size that supports Sibley and Gregg's (1987) model, and demonstrates the significant effect such a change in dolomite crystal size distribution can have on reservoir quality.

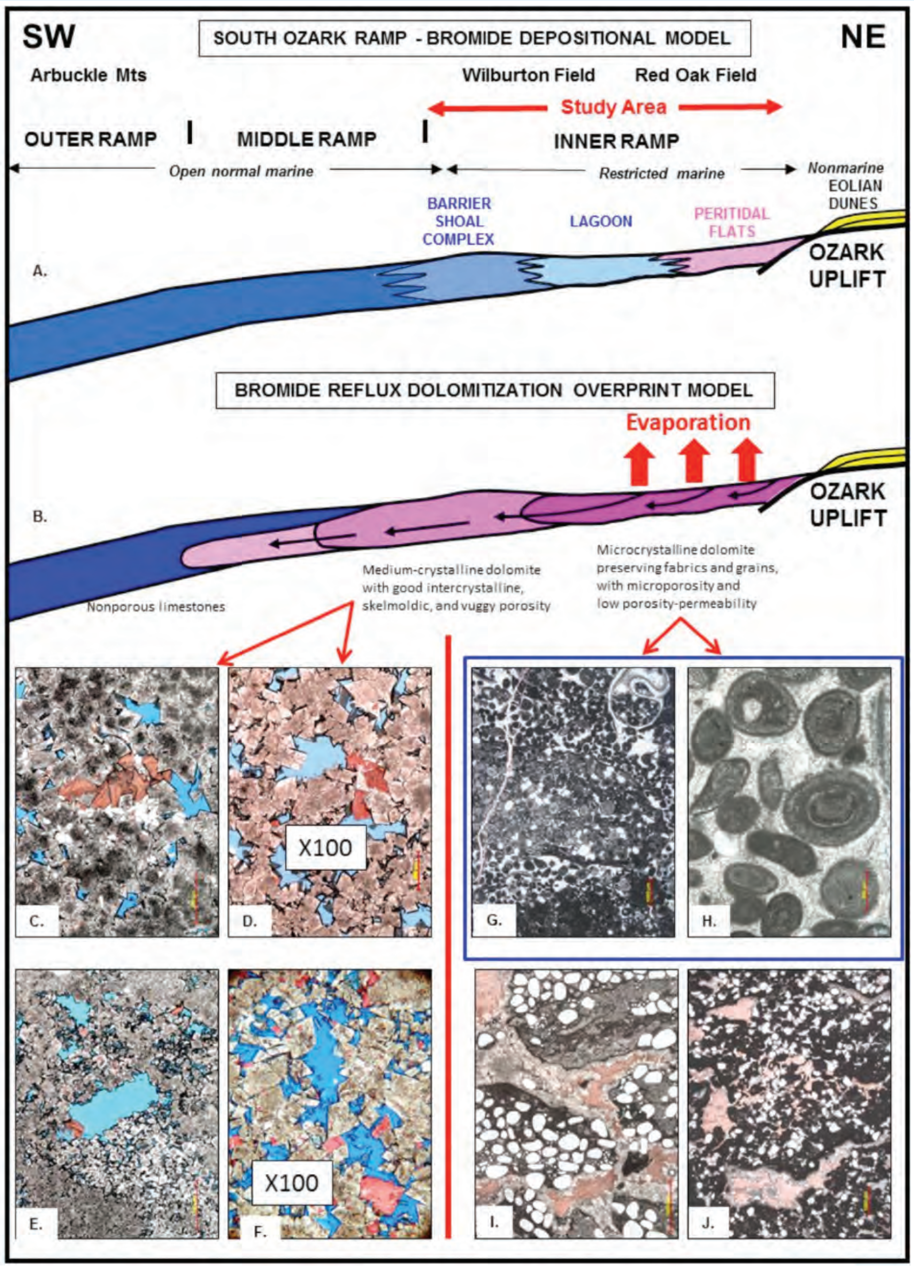

Figure 3. A. Schematic depositional model for Bromide inner ramp facies. B. Model for the reflux dolomitization overprint of carbonate ramp, with evaporative Mg-supersaturated brines flowing downdip through the ramp sediments. Carbonates nearest the source of the supersaturated brines underwent rapid dolomitization resulting in fabric-preserving microcrystalline dolostones with microporosity (dark pink), as seen in the updip Red Oak Field. Downdip brines became depleted, and so downdip carbonates (Wilburton Field) underwent slower dolomitization, resulting in coarser crystalline dolomite with intercrystalline,, skelmoldic, vuggy porosity. C-F. Photomicrographs of Wilburton Field downdip coarser crystalline, replacive dolomites with skelmoldic and intercrystalline porosity. C. Pelletal-skeletal packstone with pellet ghosts (X50). D. Medium-crystalline planar dolomite, and skelmolds lined by bitumen (X100). E. Fine-crystalline pelletal dolomite (X50). F. Medium- to coarse-crystalline dolomite (X100). G-J. Red Oak Field microcrystalline dolostones with microporosity only. G-H. Oolitic-peloidal dolograinstone with preserved gastropods and ooids (X12.5 and X100). I. Brecciated sandy stromatolitic dolobindstone with microbial fabric, and interclast coarse dolomite and calcite cements (X25). J. Thrombolite with fenestral cavities lined by dolomite cements and filled by late calcite cement (X25).

In the Bromide, updip porosity reduction appears to be controlled mainly by an updip reduction in dolomite crystal sizes. Bromide dolomites in the more updip Red Oak Field are mostly microcrystalline and fabric-preserving (mimetic), which is common for penecontemporaneous and very early diagenetic dolomites, especially in micrite-rich settings (e.g., Machel, 2004). The updip Bromide facies have common dolopackstones and dolograinstones composed largely of micritic microbialites, peloids and intraclasts, but other non-micritic grains such as ooids and bioclasts are also preserved as microcrystalline to very fine-crystalline dolomite. It is proposed that near the updip source of the supersaturated refluxing brines, dolomitization was relatively quick, resulting in recrystallization to microcrystalline dolomite and the preservation of recognizable grains and depositional fabrics. As discussed by Lucia (2004), dolomitization of lime mud increases the crystal sizes and thus the porosity, and because dolomudstone undergoes less compaction than lime mud, that porosity is better preserved during burial.

In contrast, within the more downdip Wilburton Field area, the cyclic facies are generally similar (Figures 2 and 6), but the Bromide dolostones are composed of fine- to medium-crystalline dolomite, the dolomite recrystallization rendered many grains and fabrics unrecognizable, and most bioclasts are skelmoldic.. It is proposed that as the supersaturated brines flowed downdip through the inner ramp carbonates, their Mg-saturations were depleted and dolomitization proceeded more slowly, allowing coarser dolomite crystal growth. Both mud-rich peritidal stromatolitic facies and subtidal pelletal-skeletal packstones-grainstones are relatively more coarsely recrystallized and skelmoldic (Figures 3A-F, 6A-G).

The burial diagenetic overprint of the Bromide served mainly to occlude primary and secondary macroporosity, but not the microporosity. Post-reflux dolomitization events that were documented petrographically include: (1) precipitation of coarse clear planar dolomite cements in primary and early secondary macropores; (2) a period of minor solution-enhancement of pores, probably by pre-hydrocarbon front acidic fluids; (3) migration of hydrocarbons into the reservoirs; (4) continued burial resulting in hydrocarbons cracking to gas and leaving a pervasive bitumen residue; and (5) a final stage of porosity occlusion by late diagenetic calcite cements.

Although the microporous dolostones in the more updip Red Oak Field generally have <5% microporosity and very low permeabilities, they produce moderate amounts of natural gas and provide secondary producing zone in the field. As pointed out by Wahlman (2009), such microporosity-dominated carbonate reservoirs generally need other associated macroporosity types (e.g., vugs, fractures) in order to be economic primary reservoirs. The coarser crystalline Bromide dolostones in the more downdip Wilburton Field commonly have porosities in the 5-12% range and good permeabilities, and so the Wilburton Bromide serves as a primary gas reservoir.

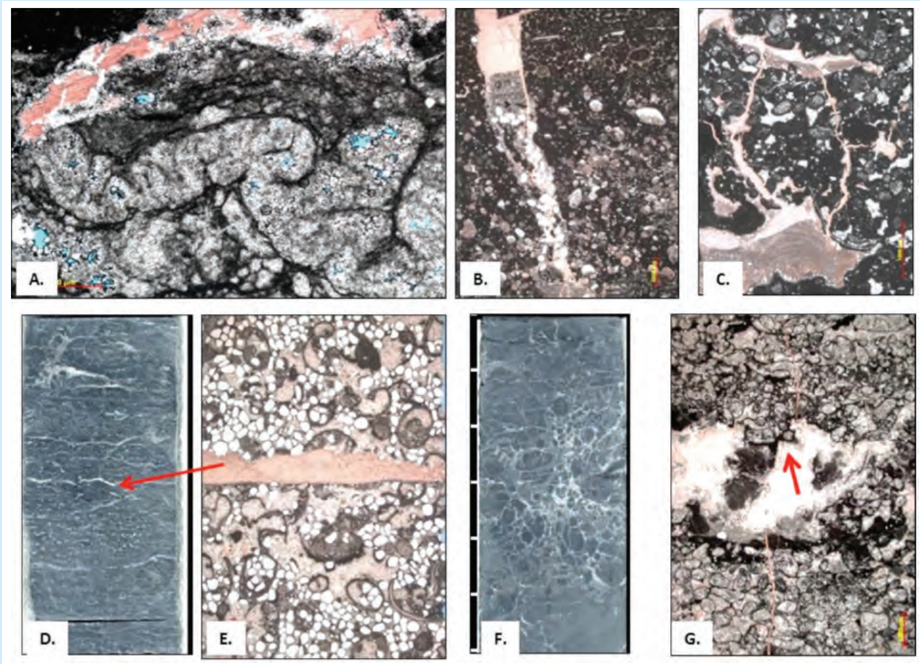

Figure 4. Photomicrographs showing dessication and evaporitic features from the Bromide Formation. A. Dolomitized remnant of enterolithic evaporate (X50). B. Dessication crack with geopetal filling (X12.5). C. Fenestral cavities with geopetal vadose silt and dessication cracks (X12.5). D-E. Core slab and photomicrograph (X25) of sheet cracks in sandy bioclastic grainstone. F. Core slab of collapse breccia in peritidal stromatolitic bindstones. G. Photomicrograph showing squared-off margin of fenestral cavity that might represent former halite crystal (X25). In photomicrographs, white cements are dolomite and red cements are calcite stained with alizarine red.

CONCLUSIONS

The Upper Ordovician Bromide Formation in the subsurface of the Arkoma Basin consists of thin, inner ramp, shallow subtidal-peritidal depositional cycles. The entire section is dolomitized, and the dolomites display a marked spatial variability in their replacement textures and dolomite crystal size. Reflux dolomitization of Bromide carbonates resulted in an increase of dolomite crystal sizes downdip. In the more updip Red Oak Field, the Bromide dolomites are microcrystalline, preserving grains and depositional fabrics, and are dominated by microporosity of generally <5%. In the more downdip Wilburton Field, dolomites are fine- to medium-crystalline, grains are recrystallized or moldic, and the pore system includes intercrystalline, skelmoldic and vuggy porosity that is commonly 5-12%. The downdip increase in dolomite crystal size and porosity are thought to be the result of reflux dolomitization, where updip facies near the source of the supersaturated brines are quickly dolomitized to microcrystalline dolomite, and downdip facies are more slowly dolomitized by Mg-depleted brines resulting in coarser replacive dolomite crystals, and skelmoldic and vuggy porosity. This study highlights the importance of fluid saturation and fluid flow efficiency and reaction kinetics in the early dolomitization process, which are not currently well understood or quantified. Such observational datasets provide a starting point for more detailed geochemical and numerical modeling analyses.

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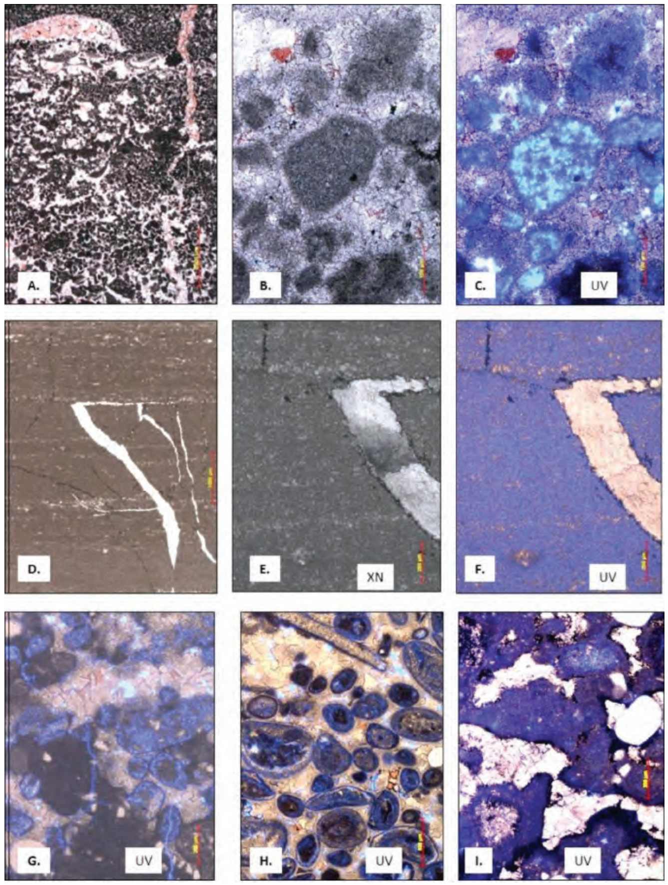

Figure 5. Photomicrographs of Red Oak Field Bromide dolostones with microporosity shown with ultraviolet (UV) microscopy. A-C. Fine-grained peloidal dolograinstone with sparse mollusc bioclasts. A. Peloidal dolograinstone with pelecypod shell and fracture filled by dolomite (white) and late calcite (red) cements (X25). B. Same at X100 under plane light showing microcrystalline peloids. C. Same at X100 under UV light showing microporosity in peloids and cements. D-F. Stromatolite with dessication cracks. D. At X25 under plane light. E. At X100 under cross-polarized light showing pelleted mud matrix and saddle dolomite in fracture. F. Same at X100 under UV light showing 10% microporosity. G. Peloid-intraclast dolograinstone under UV light showing 2.0% microporosity and microfracture (X100). H. Oolitic-skeletal dolograinstone under UV light showing 4.5% microporosity (X100). I. Thrombolitic micrite under UV light showing 1.1% microporosity (X100).

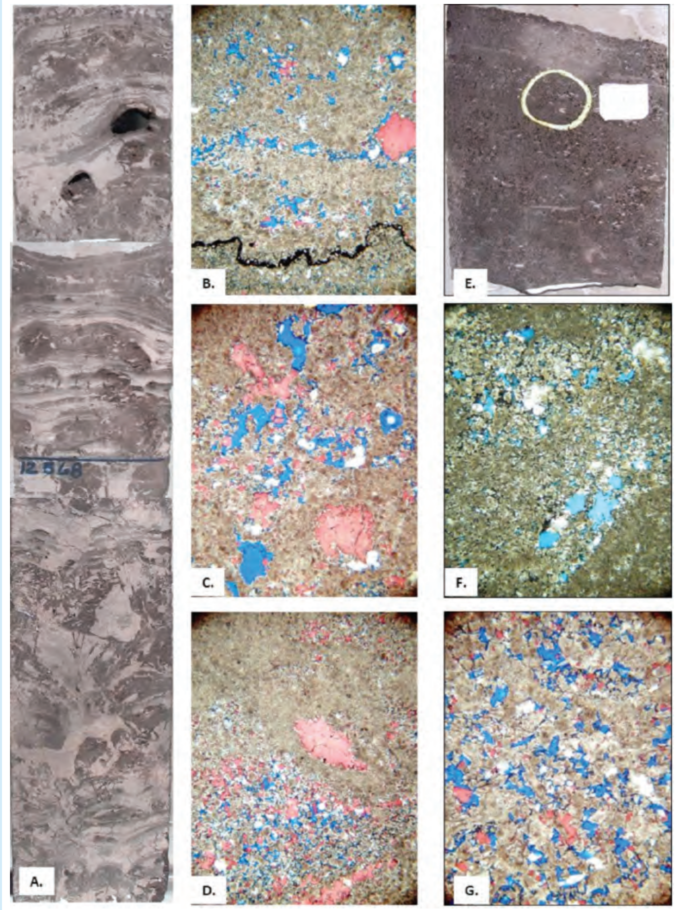

Figure 6. Wilburton Field dolostones. Core slabs (A) and photomicrographs (B-D) of stromatolitic peritidal facies. A. Core slab (2 ft) of stromatolitic dolobindstone with breccia in lower part. Vugs near top probably anhydrite molds. B. Photomicrograph of medium-crystalline dolomite with open fenestral cavities and fine intercrystalline porosity (por = 13.1%, K = 18.3 md) (X25). C. Fenestral cavities and small vugs (X40). D. Patchy intercrystalline and small vug porosity in disrupted breccias (por 6.5 %, K = 0.71 md) (X25). E-G. Wilburton subtidal facies. E-F. Core slab and photomicrograph of burrowed pelletal-skeletal medium-crystalline dolopackstone with skelmolds and intercrystalline porosity (por = 9.5%, K = 1.69 md) (X25). G. Burrowed pelletal-skeletal dolopackstone with skelmolds, small vugs, and intercrystalline porosity (por = 12.2%, K = 25.8 md) (X25).

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COUNCIL'S COMMENTS

The SEPM Foundation - Contributing to the Future of Sedimentary Geology

First things first, the Society and the Foundation want to express a thank you to the many contributors to the SEPM Foundation over the last 27 years. With this short note, we want to remind you of the invaluable role the Foundation plays and provide a glimpse of the breadth of its activities.

In 1983, after SEPM became an independent scientific organization, the SEPM Foundation, Inc. was established to raise and grant funds for scientific activities related to sedimentary geology. Through 20 funds, the Foundation provides a variety of fund development initiatives for the benefit of SEPM's outstanding programs and more importantly to advance the science of all aspects of sedimentary geology. The Foundation has provided over $519,000 for purposes including the support of publications and conferences, moving our legacy publications in to the digital era, student research and travel, and, of course, support for the five medal awards bestowed each year by SEPM for excellence in sedimentary geology. Today the foundation has a net value of just over $700,000, which is an amount to be proud of but one that is down significantly from the peak in 2006 due to the challenging conditions in the financial markets.

The Foundation has made extra efforts to increase available funding for the support of student research, as students are the future of our science and our Society. The first funds established specifically for geoscience student activity were the Grover E. & Sally M. Murray Endowment and the Ken Hsu Fund, both of which were started in 1987. Additional student assistance was provided in 1995, when Robert and Ruth Weimer established the Weimer Student Research Fund to specifically support graduate student research. In 1998, the Mobil Foundation began funding the Mobil Geoscience Student Travel Grant to provide support for student travel to the SEPM Annual Meeting to present a paper or poster. Each year the awardees, chosen by the Foundation and each SEPM Section, receive a grant for their travel expenses. As part of the SEPM Diamond Jubilee two additional endowed student funds were initiated. The John Sanders Fund, established with donations from Naresh Kumar and Gerald and Sue Friedman, provides funds to support graduate student research in the areas of coastal or environmental geology. NAMS (North American Micropaleontology Section) began a successful endowed fund drive as a memorial to Garry Jones and Brian O'Neill to support graduate research in the area of micropaleontology. The latest fund to be established recognizes Gerry Friedman's many significant contributions to sedimentary geology and will provide support to graduate students in sedimentary geology.

In 2010, in addition to support for digitizing the last of our legacy publications, the Foundation provided travel support for 23 students to present papers at the SEPM annual meeting in New Orleans, and over $20,000 in grants to support ten graduate students to undertake their research. These students hail from universities across the globe and across the many fields of sedimentary geology. The names and affiliations of these young scientists are available on the Foundation link at the SEPM web site (www.sepm.org).

We hope you will accept this short note as a reminder of the value we place on the Foundation to SEPM and its future, and join with us in pledging your support to insure its role as an active and viable partner of SEPM. Each year the funding requests to the Foundation for student research and travel support and other needs greatly exceed available funds, so the Foundation continually depends on the financial contributions from SEPM members. For your convenience, an envelope is included with this newsletter or you can go directly to the Foundation donation website (see the SEPM Foundation link on the About menu at www.sepm.org). With your assistance, SEPM and the SEPM Foundation working together have the opportunity to support the sedimentary science and scientists of the future.

From SEPM Council Members
Paul (Mitch) Harris and Tim Carr

SEPM Society for Sedimentary Geology
"Bringing the Sedimentary Geology Community Together"
www.sepm.org

Sedimentary Geology Division

Geological Society of America

The Annual GSA Meeting is just around the bend!

It's time again for that grand fall tradition, the GSA Annual Meeting. We will meet in Denver this year from October 30 to November 3. In the spirit of the ever increasing links between our two organizations, I bid a hardy welcome to all SEPM and GSA Sedimentary Geology Division (SGD) Members. This year will see a continuation of the strong presence of the sedimentary geology community at the annual meeting, reflecting the pivotal role of sedimentology in the geosciences. In this issue, I'd like to summarize the many activities our division has to offer. I would also like to offer a few words about the emerging role of sedimentary geology in the GSA, and maybe in general.

2010 Laurence L. Sloss Award Recipient

The GSA SGD is pleased to announce that Dr. Hugh Crawford Jenkyns of the University of Oxford is the 2010 Laurence L. Sloss Award recipient. Dr Jenkyns is a pioneer in the study of marine pelagic sediments. His early work in marine strata of the Tethys Sea led to lasting impacts on our understanding of the development of the Mediterranean, modern deep marine sediments, and global anoxic events, all of which he has studied vigorously throughout his career. He has served on the editorial board of *Eclogae Geologicae* and *Geodinamica*, and most recently as co-editor of *Geology*. Please plan to join us at the SEPM-sponsored SGD and Limnogeology Division Joint Business Meeting and Awards Reception scheduled for Tuesday, November 2nd, to bestow Dr. Jenkyns with this fitting honor.

2010 Laurence L. Sloss Award winner Hugh Jenkyns

2010 SGD Student Research Award Recipient

Congratulations to Jennifer Cotton, this year's winner of the Student Research Grant! Coming from a true "Arts & Sciences" undergraduate background of Chemistry and sculpture from Brandeis University, Jennifer is starting her third year of graduate work in Geology at the University of Michigan. Her research focuses on isotope proxies (particularly Carbon) for assessing ancient vegetation, climatic, and atmospheric conditions. Her proposal deals with development of a new proxy for soil respired CO_2. Jennifer aspires to be a professor and to pass on her findings to the next generation.

Jennifer Cotton at Chaco Canyon archaeological site, New Mexico.

Please join us at the SEPM-sponsored SGD and Limnogeology Division Joint Business Meeting and Awards Reception as we recognize Jennifer's efforts as well as those of the SGD student poster and student travel award recipients.

The Stephen E. Laubach Structural Diagenesis Research Award

We welcome with great appreciation this newest award opportunity. The Stephen E. Laubach award is a truly interdisciplinary award that promotes research combining structural geology and diagenesis. The award is given jointly by the Sedimentary Geology and Structural Geology and Tectonics divisions and is presented at our respective awards ceremonies. This first year, SG&T won the toss. Please check out the SG&T awards ceremony to meet the inaugural winner of this award. The award will be presented at the SGD awards ceremony at GSA 2011.

The winner this year is Christopher Thissen of Yale University. Chris strives to understand the governing dynamics of orogenic wedges and the development of deformation and structure in wedge settings. He uses diagenesis to this end thorough his interest in development of pressure solution textures. Overgrowths and truncations that affect diagenesis of siliclastic rocks also record deformation associated with the kinematics of orogenic wedges.

Christopher Thissen, 2010 winner of the Stephen E. Laubach Award

Do you know a colleague who would be particularly deserving of the Laurence L. Sloss Award for Sedimentary Geology?
Please forward nominations to John Holbrook at holbrook@uta.edu.

2010 GSA Annual Meeting Denver, Colorado

Sedimentology has a strong presence at the GSA Annual Meeting. The GSA SGD and SEPM are sponsoring or co-sponsoring eight field trips, two short courses, sixteen topical sessions, and two Pardee symposia (all of which are listed below). As well, through our cooperative agreement with SEPM, we are offing our first "Confluence," a mini conference offered in conjunction with a larger meeting. This will be the jointly offered SEPM and GSA SGD Pardee Symposia (Pardee #5) and field trip (Field Trip #421) "Rapid Environmental/Climate Change in the Cretaceous Greenhouse World" by Chengshan Wang; Robert W. Scott; Michael Wagreich; Bradley B. Sageman; William W. Hay; and Kirk Johnson.

If you are in Denver on Saturday the 30th of October, the "Seds and Suds" town hall meeting will be held in the evening approximately 6-9 pm just before GSA Saturday October 30th in the Hyatt Regency CCC in Granite A. This is the annual open discussion for anyone and everyone sedimentary geology. This is your opportunity to help develop a research agenda for the sedimentary community. It's also a good time to meet your colleagues and enjoy a cool beverage. We will include a discussion on the "New media and geology Google, i- apps and video streaming, what should we attempt to change in the way we present and publish geologic data?"

However, any and all topics are open for discussion. If you are interested in having any particular topic added to the agenda, please feel free to contact Richard Langford (SGD Vice Chair) and we'll make time available. Please plan to join us for light hors d'oeuvres and beverages, and contribute to this notoriously lively discussion group.

We plan to have the 2010 SGD and Limnogeology Division Joint Business Meeting and Awards Reception on Tuesday evening, November 2nd, to avoid overlap with alumni parties that are scheduled for Monday night. The meeting will be in the Colorado Convention Center. Please plan to join us for the celebration with light hors d'oeuvres and cash bar. The first 100 attendees will receive a ticket for a free beer, wine, or soft drink.

We welcome additional sponsors for the SGD and Limnogeology Divisions Joint Business Meeting and Awards Reception at GSA in Denver.

I) PARDEE SYMPOSIA

5. Rapid Environmental/Climate Change in the Cretaceous Greenhouse World
Sponsored by Society for Sedimentary Geology (SEPM); International Geoscience Program 555
Chengshan Wang; Robert W. Scott; Michael Wagreich; Bradley B. Sageman; William W. Hay
Wed., 3 Nov., 8 a.m.

6. Seeing the True Shape of Earth's Surface: Applications of Airborne and Terrestrial Lidar in the Geosciences
Sponsored by GSA Engineering Geology Division; GSA Structural Geology and Tectonics Division; GSA Quaternary Geology and Geomorphology Division; GSA Sedimentary Geology Division; GSA Geoinformatics
Ian P. Madin; Kurt L. Frankel
Sun., 31 Oct., 8 a.m.

II) TOPICAL SESSIONS

T24. Sediments and Settlements
GSA Archaeological Geology Division; GSA Sedimentary Geology Division; GSA Quaternary Geology and Geomorphology Division
Cynthia M. Fadem, Katherine A. Adelsberger

T27. Frontiers in Coal Science: Basic Research to Applied Technology
GSA Coal Geology Division; GSA Sedimentary Geology Division
Sharon M. Swanson, Ronald H. Affolter

T32. Seeing the True Shape of Earth's Surface: Applications of Airborne and Terrestrial LiDAR in the Geosciences
GSA Engineering Geology Division; GSA Structural Geology and Tectonics Division; GSA Quaternary Geology and Geomorphology Division; GSA Sedimentary Geology Division; GSA Geoinformatics Division; GSA Geophysics Division
Ian P. Madin, Kurt L. Frankel

T97. Temporal Trends in Anthropogenic Contaminants from Lacustrine, Coastal, and Marine Sediment Cores: The Good, the Bad, and the Future
GSA Limnogeology Division; GSA Geology and Health Division; GSA Quaternary Geology and Geomorphology Division; GSA Sedimentary Geology Division
Michael R. Rosen

T98. African Lakes and Paleolakes: Processes, Paleoenvironments, and Paleoclimate
GSA Limnogeology Division; GSA Sedimentary Geology Division; GSA Quaternary Geology and Geomorphology Division; GSA Archaeological Geology Division; GSA International Section; Paleontological
Daniel Deocampo

T105. Impact Cratering: From the Lab to the Field; from the Earth to the Planets
GSA Planetary Geology Division; GSA Geophysics Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division; GSA Sedimentary Geology Division; GSA Structural Geology and Tectonics Division; GSA Quaternary Geology and Geomorphology Division; International Continental Scientific Drilling Program (ICDP); Geological Society of America Bulletin
Christian Koeberl, Jared Morrow

T112. Paleontology, Paleobiogeography, and Stratigraphy of the Late Cretaceous North American Seas: A Tribute to Bill Cobban
GSA Sedimentary Geology Division; Paleontological Society; Society for Sedimentary Geology (SEPM)
Richard A. MacKenzie, Corinne Myers

T115. The Precambrian-Cambrian Ecosphere (R)evolution: Insights from Chinese Microcontinents
GSA Geobiology & Geomicrobiology Division; GSA Sedimentary Geology Division; Paleontological Society
Christoph E. Heubeck, Maoyan Zhu, Shaoyong Jiang

T117. Lagerstätten through Time: An Examination of Exceptional Preservational Pathways from the Terminal Proterozoic through Today
Paleontological Society; GSA Geobiology & Geomicrobiology Division; GSA Sedimentary Geology Division
James D. Schiffbauer, Marc Laflamme

T118. Filling the Hole: Sedimentary Geology and Paleontology of Caves and Karst
Paleontological Society; Karst Waters Institute; Society for Sedimentary Geology (SEPM); GSA Sedimentary Geology Division; GSA Archaeological Geology Division; GSA Quaternary Geology and Geomorphology Division; GSA Geobiology & Geomicrobiology Division
Roy Plotnick, Ira D. Sasowsky

T119. Holocene Paleoclimate Records from Western North America: Exploring Pacific Influences
GSA Quaternary Geology and Geomorphology Division; GSA Sedimentary Geology Division; GSA Limnogeology Division
Lesleigh Anderson, John A. Barron

T120. New Developments in Permian-Triassic Paleoceanography
GSA Sedimentary Geology Division; Society for Sedimentary Geology (SEPM)
Thomas J. Algeo, Margaret Fraiser

T121. The Western Interior Seaway Revisited (Posters)
Paleontological Society; GSA Sedimentary Geology Division
Dee A. Cooper, Roger W. Cooper

T141. Ancient Floodplains and Rivers: Unraveling the Mysteries of Colorado's Conglomerates
Colorado Geological Survey; Colorado Scientific Society; GSA Quaternary Geology and Geomorphology Division; GSA Sedimentary Geology Division
Matthew L. Morgan, Peter E. Barkmann

T143. Stratigraphic Standards: Where Have They Gone, What Should They Do, Where Should They Go?
GSA Sedimentary Geology Division; North American Commission on Stratigraphic Nomenclature (NACSN); International Subcommission on Stratigraphic Classification (ISSC); Association of Earth Science Editors (AESE); Paleontological Society
Arthur Donovan, Brian R. Pratt, L.E. Edwards

T156. Controls and Consequences of Continental Rifting: From Heat Flow, Stress, and Strain to Magmatism, Landscape-Basin Evolution, and Development of Natural Resources
GSA Structural Geology and Tectonics Division; GSA Geophysics Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division; GSA Hydrogeology Division; GSA Sedimentary Geology Division; GSA Quaternary Geology and Geomorphology Division; GSA International Section
Yilderim Dilek, Benjamin J. Drenth, Ren A. Thompson, Harald Fernes, Jonathan Saul Caine

III) FIELD TRIPS

404. Behind Colorado's Front Range-A New Look at Laramide Basin Subsidence, Sedimentation, and Deformation in Central Colorado
Fri.-Sat., 29-30 Oct. US$179 (L, R, 1ON).
Cosponsor: GSA Sedimentary Geology Division.
Leaders: James C. Cole, USGS; James H. Trexler Jr.; Patricia Cashman

Fluvial, arkosic sandstones in the Paleocene Coalmont Formation, North Park basin, eroded from uplifted Precambrian terrane in Colorado's Park Range. *Image © Jim Trexler.*

408. A Hike through Geologic Time at Red Rocks and Dinosaur Ridge
Sat., 30 Oct. US$93 (L, R).
Cosponsor: Friends of Dinosaur Ridge, GSA Sedimentary Geology Division.
Leaders: Chris Carroll, Friends of Dinosaur Ridge; Tim Connors.

409. Garden of the Gods at Colorado Springs: Paleozoic and Mesozoic Sedimentation and Tectonics
Sat., 30 Oct. US$69 (L, R).
Cosponsor: GSA Sedimentary Geology Division
Leaders: Timothy L. Clarey, Delta College; John H. Whitmore; Marcus R. Ross; William A. Hoesch; Steven A. Austin.

413. Historic Dinosaur Quarries within a Newly Interpreted Paleoenvironmental Context
Sat., 30 Oct. US$118 (L, R).
Cosponsors: Colorado Scientific Society, Morrison Natural History Museum, Colorado Geological Survey, GSA History of Geology Division, GSA Sedimentary Geology Division, Escalante Mines, Inc.
Leaders: Thomas R. Fisher & Lisa R. Fisher, Escalante Mines, Inc., Matt Mossbrucker; Libby Prueher.
This trip also runs before the meeting (see trip 418), and is presented in conjunction with Topical Session T94.

414. Old and New Geologic Studies along the Front Range between Golden and Morrison Including Structural, Volcanic, and Economic Geology and Paleontology
Sat., 30 Oct. US$114 (L, R).
Cosponsor: Friends of Dinosaur Ridge, GSA Sedimentary Geology Division.
Leader: Tim Connors, National Park Service Geologic Resources Division.
This field trip also runs after the meeting (see trip 419) and as a family trip during the meeting (see trip 415).

415. Geology of the Dinosaur Ridge, Red Rocks, and Fossil Trace Areas (FAMILY Trip)
Mon., 1 Nov., US$94 (L, R)
Cosponsor: GSA Sedimentary Geology Division.
Leaders: Tim Connors, Geologic Resources Division, National Park Service, Norb Cygan, Harald Drewes, Chris Carroll.
Versions of this trip also run before (trip 414) and after (trip 419) the meeting, but they are not specifically designated for families.

421. Rapid Environmental/Climate Change in the Cretaceous Greenhouse World
Thurs.-Fri., 4-5 Nov. US$235 (B, L, D, R, 1ON).
Cosponsor: GSA Sedimentary Geology Division.
Leaders: Bradley B. Sageman, Northwestern University, Robert Scott; Kirk Johnson.

425. Alternative Sequence Stratigraphic Model for Channel-Shallow Marine Sandstones, Desert Member to Castlegate Sandstone Interval, Book Cliffs, Eastern Utah
Thurs.-Sat., 4-6 Nov. US$307 (L, R, 2ON). Begins and ends in Grand Junction, Colorado.
Cosponsors: GSA Sedimentary Geology Division; Society for Sedimentary Geology (SEPM).
Leader: Simon A.J. Pattison, Brandon University

IV) SHORT COURSES

506. Sequence Stratigraphy for Graduate Students.
Fri.-Sat., 29-30 Oct., 8 a.m.-5 p.m. Fee: US$25. Limit: 60. CEU: 1.8.
Cosponsors: *British Petroleum; ExxonMobil Exploration Company; Chevron Energy Technology Company; GSA Sedimentary Geology Division.*
Art Donovan, BP; Morgan Sullivan, Chevron Energy Technology Co.; Kathryn Lamb-Wozniak, ExxonMobil Exploration Co.

507. Structural and Stratigraphic Concepts Applied to Basin Exploration.
Fri.-Sat., 29-30 Oct., 9 a.m.-5 p.m. Fee: US$25; includes continental breakfast and lunch. Limit: 30. CEU: 1.6.
Cosponsors: *ExxonMobil Exploration Company; ExxonMobil Upstream Research Company; GSA Sedimentary Geology Division.*
Lori L. Summa, ExxonMobil Upstream Research Co.; Bob Stewart, ExxonMobil Exploration Co.

Just who do you think you are?

Sometimes shouted and sometimes murmured, but often duely asked, "Just who do you think you are?" Though not in the usual context of audacity, I put that question to all of those with affinity for sedimentary geology. Maybe more accurately, just what does our field entail? We learned from our days as geo-pups that there are indeed only three types of rocks on earth, igneous, metamorphic, and of course SEDIMENTARY! the rocks all good rocks one day aspire to be. By that logic, we are 1/3 of all geology after all. On the other hand, we may be considered more like the soy beans of geology. We seem to be in most everything, but not so often eaten alone. In truth, we span a diversity of fields, and there seems to be a sedimentologist/stratigrapher involved in most every geologic venture. Sedimentology is perfect for the ADHD scientist like me as you can bop around between fossils, fens, fuels, and fumerals, particles, planetoids, pixels, and plants without ever having to leave your sedimentological home.

So what brings on this introspection anyway you may ask? It's the enormous amount of sedimentology presented this year at GSA. There is a lot from which to choose, from sand transport to isotopes. In reality, however, much of this is harbored under the banner of other fields. There is exciting and topical science presented in sessions steered toward geomorphology, geochemistry, climate, etc. that we would find indistinguishable from classic sedimentology that are not particularly credited to us. This is namely because those who proposed did not seek us first when deciding how they should be flagged. At one level, I revel in the acknowledgement that the work of generations of sedimentologists is being put to good use. At another level I can't help but want my chosen field to see a bigger citation. It can be a little frustrating to see the climate-change wagon depart without a big "sedimentology was here" banner stretched along the side. On the other hand maybe the limelight shouldn't be our goal. (By the way, it's called the limelight because base components of early stage lights were made from limestone. Another sedimentology rip-off if you ask me.)

If being the soy beans of science is not your thing, and you would like to see a little more acknowledgement of the many sedimentologic wonders that permeate geology, there is a simple grass-roots solution. Propose a session for the next GSA through the Sedimentary Geology Division. We would be happy to offer our sponsorship. The innovative and unconventional should consider themselves welcome. After all, no matter where your sedimentologic science may venture, you can always come back home.

JH

SGD Personnel and Committee Assignments for the 2009-2010 Year.

- **John Holbrook** is the Chair.
- **Richard Langford** is the Vice-Chair.
- **Linda Kah** is the Secretary/Treasurer.
- The Joint Technical Program Committee (JTPC) representatives for SGD are **Troy Rasbury** and **Brenda Beitler Bowen**.
- **Kelly Dilliard** is the web manager.
- The Sloss Award Committee comprises: **Mike Arthur (Chair)**; **Janok Bhattacharya**; **Pete Decelles**; **Maya Elrick**; **Ray Ingersoll**; **Judy Parrish**
- Stephen E. Laubach Structural Diagenesis Research Award Committee comprises: **Brenda Beitler Bowen**; **Nancye Dawers**; **Peter Eichhubl**; and **Linda C. Kah**

If you have any suggestions regarding information that the SGD web site should contain or useful links for the sedimentary geology community, please contact **Kelly Dilliard** at kedilli1@wsc.edu.

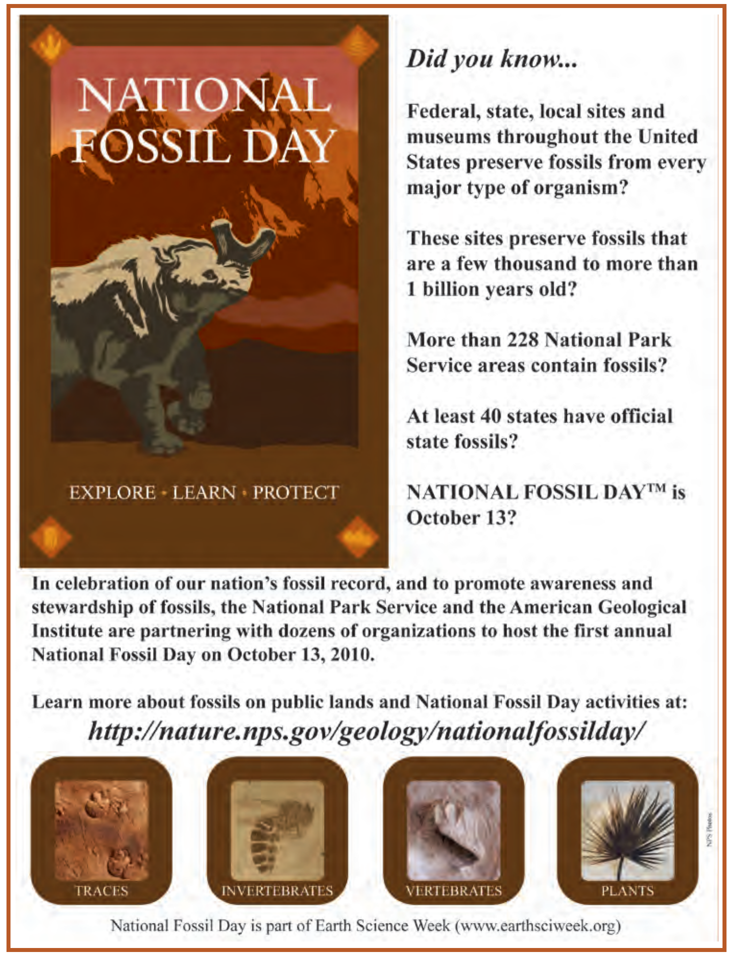
For more links to societies and organizations of interest to sedimentary geology, visit http://rock.geosociety.org/sed/SGD.html.

SEPM Membership Fees Changes for 2011

SEPM members have for many years had to include at least one journal (*JSR* or *PALAIOS*) when they paid their membership fees. Beginning with 2011 memberships there are three significant changes. The first is that a member no longer has to subscribe to one of the SEPM journals. There is a 'dues only' level of membership which still includes all of the advantages of membership but without the added cost of at least one journal. This is a response to many member comments that they get access to our journals from their school or company library. The second change is an additional member subscription option to access the SEPM Books Online archive. This archive represents almost all of our previously published Special Publications, Concepts in Sedimentology and Paleontology, Short Course Notes and Core Workshop Notes. They are archived along with our two journals and in a similar format of PDF files for each chapter. With this new option each member has three subscription options to consider. The final change is an increase in the print surcharge from $25 per journal per year to $50. This increase is an unfortunate result of ever increasing costs of printing our journals. SEPM will continue to investigate ways to deliver a printed copy as the lowest price possible.

The table below shows the pricing for our basic memberships (Full/Associate; Student; Developing Country Full/Associate and Developing Country Student). The overall increase for any specific set of choices compared to 2010 is only $10 but the ability to make choices may increase or decrease each member's actual fee. Please note there is a discount for subscribing to all of those options and that Sustaining Members will receive any or all of the options and Emeritus member fees are variable.

2011 Membership Fees	**Full or Associate**	**Student**	**Developing Country Full or Associate**	**Developing Country Student**
Dues:	**$50.00**	**$10.00**	**$10.00**	**$5.00**
Subscription Options:				
JSR Online	$50.00	$10.00	$10.00	$5.00
PALAIOS Online	$50.00	$10.00	$10.00	$5.00
Books Online Archive	$50.00	$10.00	$10.00	$5.00
Total with all Options	**$180.00**	**$35.00**	**$35.00**	**$15.00**
Additional:				
JSR Print Surcharge	$50.00	$50.00	$50.00	$50.00
PALAIOS Print Surcharge	$50.00	$50.00	$50.00	$50.00
Sustaining Member	**$300.00**			
Emeritus Member	**Variable**			



ACS Petroleum Research Fund Research Grants for 2011

The ACS Petroleum Research Fund has supported "fundamental research in the petroleum field" in the geosciences, chemistry, materials science, and petroleum engineering since 1954. ACS PRF is an endowed fund administered by the American Chemical Society and there is no connection between ACS PRF and the petroleum industry. To see about grants go to (www.acsprf.org) or contact the Program Manager for geosciences, Dr. Dean A. Dunn, by email d_dunn@acs.org or telephone (202-872-4083).