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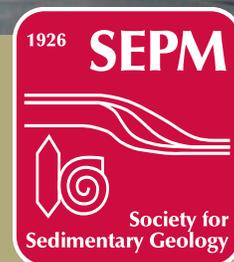
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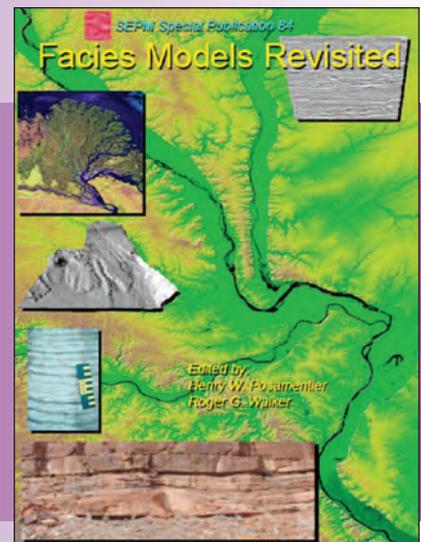
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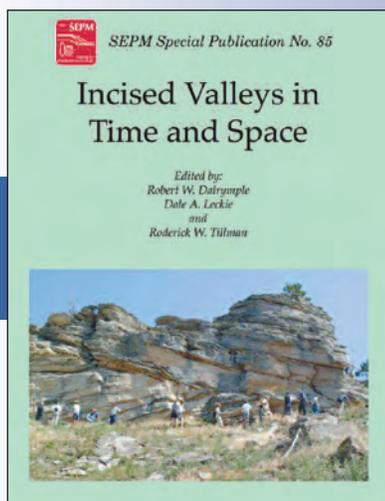
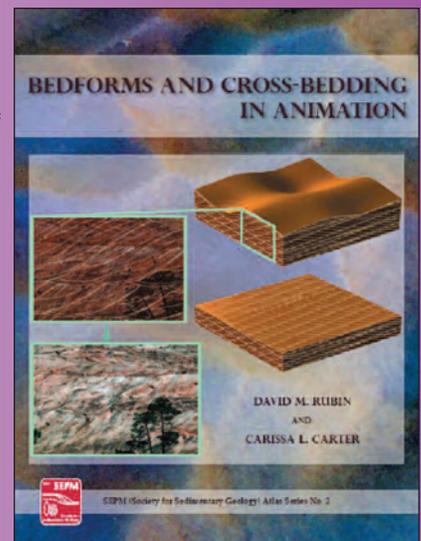
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On the Cover: Carapace Nunatak, formed of Kirkpatrick Basalt, South Victoria Land, Antarctica.

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The “Preservation Paradox”: Microbes as a Key to Exceptional Fossil Preservation in the Kirkpatrick Basalt (Jurassic), Antarctica

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ABSTRACT

Thin sedimentary interbeds within the Kirkpatrick Basalt (Jurassic) of Antarctica harbor exquisitely preserved ‘soft-bodied’ organisms that lived in and around shallow freshwater lakes of the time, some of which were hydrothermally influenced. In the hottest pools, associated with magmatic vents, unusual carbonates were apparently precipitated by Archaea extremophiles adapted to living near active lava flows. In cooler lakes more distant to the vents, fine siliciclastic sediments record other communities of spinicaudatan (“conchostracan”) and notostracan crustaceans, larval insects, fishes, and ostracodes much of which may have been sustained by microbial mats, which are also well preserved in the deposits. Along the lake-edge, carbonized leaves, peat or coal, and silicified logs are often found in association with paleosols. Notably, evidence of carnivory, a primary taphonomic filter, is essentially lacking in these sediments. Exceptional preservation of non-biomineralized or lightly skeletonized organisms, therefore, reflects the original diversity of non-biomineralized or lightly skeletonized organisms present.

INTRODUCTION

One of the most striking and paradoxical observations about the evolutionary record is that the most numerous and diverse animals on Earth are represented by a weak fossil record - among them, insects, spiders, scorpions, mites, myriapods, shrimp, nematodes, “worms” of various kinds, and countless other species lacking hard skeletal parts. Conversely, groups best represented in the fossil record constitute a relatively small fraction of total species diversity, including mollusks, brachiopods, corals, echinoderms, vertebrates, and other animals having hard (biomineralized) shells, bones, or teeth, which today constitute less than 20% of animal species. Compensating for this “preservation paradox,” in which the most abundant and diverse forms on Earth have a weak fossil record, usually involves the discovery of deposits where both biomineralized fossils and non-biomineralized fossils have been preserved. Such deposits are variously referred to as Konservat-Lagerstätten, Lagerstätten, or deposits of exceptional preservation (DEP’s). Well-known examples (see Allison and Briggs, 1991 and references therein) include the Chengjiang deposit (Cambrian of Yunnan, China), the Burgess Shale (Cambrian of British Columbia), the Rhynie Chert (Devonian of Scotland), the Mazon Creek deposit (Carboniferous of Illinois), the Solnhofen

Limestone (Jurassic of Germany), and the Green River Formation (Eocene of Wyoming, Colorado, and Utah). Studying fossils from these and similar deposits provide rare snapshots of organisms and ecosystems otherwise not preserved in the fossil record.

Studying exceptionally preserved fossils has a second, and no less important benefit: it provides insight into the processes and timing by which fossilization occurs. Key factors promoting exceptional preservation are the inhibition of tissue degradation by predators, scavengers, and microbial decay agents, and in many cases, rapid diagenesis (commonly preceded by burial). Mounting evidence suggests that microbes (bacteria and fungi) play a central role in the diagenesis process, mediating mineral precipitation within chemical microenvironments inside biofilms generated by decay halos around organic matter (e.g., Schieber, 2002; Borkow and Babcock, 2003; Briggs, 2003).

Here, we describe such an instance of exceptional preservation, and an unusual process of carbonate sedimentation, from the Jurassic of Antarctica. The unusual carbonates were precipitated near a strong hydrothermal source, and nearby cooler and silica-rich hydrothermal waters apparently worked to fossilize organic remains rapidly and produce a “freeze-frame” of macroscopic and microscopic life forms. Microbes seem to have played a vital role in both processes. This example provides an unusual perspective on the fossilization process, and suggests that further insight into taphonomic processes and occurrences of microbial fossils may be gained through expansion of our search strategies, even to igneous-dominated environments.

LOCATION AND STRATIGRAPHY

This paper focuses on thin sedimentary deposits interbedded within lava flows of the Kirkpatrick Basalt (Ferrar Group; Jurassic) of Antarctica, which is exposed in South Victoria Land (Carapace Nunatak) and isolated peaks in the central Transantarctic Mountains (Beardmore and Shackleton Glacier areas; Fig. 1) (Ball et al., 1979; Tasch, 1977, 1987; Barrett et al., 1986; Bradshaw, 1987; Elliot et al., 1991). Two of these sedimentary horizons can be correlated widely and indicate brief periods of relative cessation of extrusive magmatism. The Kirkpatrick Basalt itself forms the cap sequence on tholeiitic rocks of the Ferrar Large Igneous Province (FLIP), which occur in a 3,500 km linear belt along the Transantarctic Mountains from the Weddell Sea region to North Victoria Land (Elliot and Fleming, 2000, 2004). The FLIP was emplaced about 180±3.5 Ma during initial breakup of Gondwana in the Early Jurassic (Toarcian Epoch), from a source

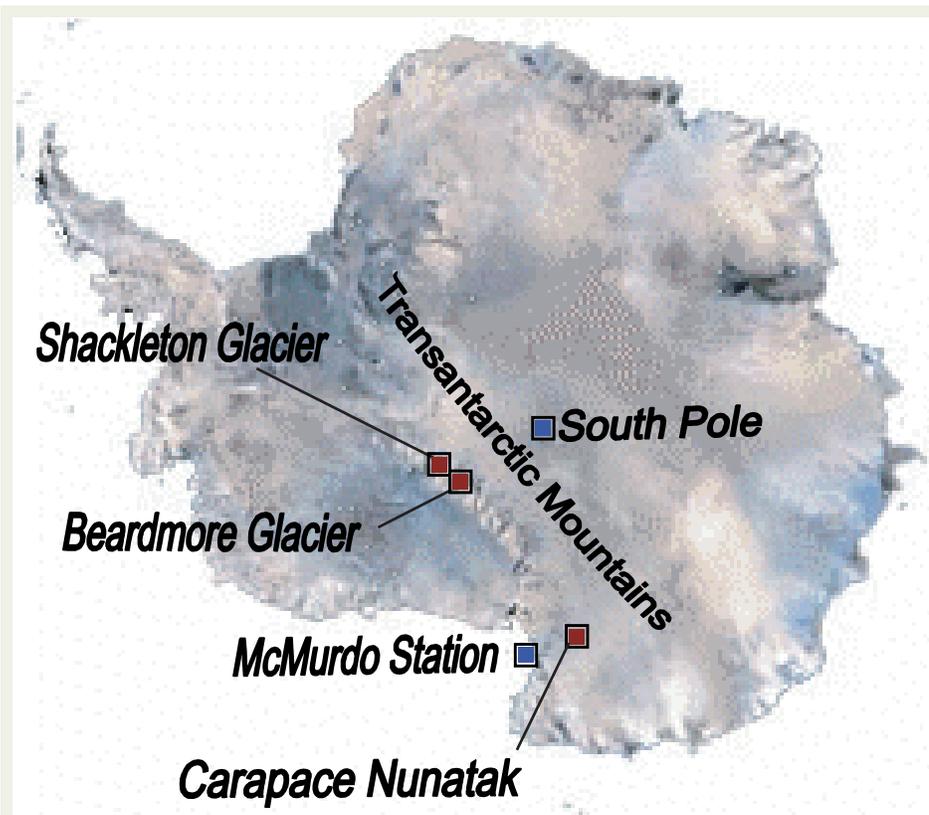


Figure 1. Map of Antarctica showing locations of the Transantarctic Mountains and outcrops of Kirkpatrick Basalt (Jurassic) having sedimentary interbeds. Study localities are Carapace Nunatak (South Victoria Land), and peaks in the Beardmore Glacier area (Central Transantarctic Mountains).

thought to be a triple junction in the proto-Weddell Sea (Elliot and Fleming, 2000, 2004). Radioisotopic dating constrains the duration of FLIP emplacement to a brief interval, less than 1 million years (Heiman et al., 1994). This extrusive magmatism ends with the capping iron-rich lavas of the Kirkpatrick Basalt, which comprises less than 1% of the FLIP rocks that locally exceed 2 km in thickness (Elliot and Fleming, 2004).

SEDIMENTARY INTERBEDS IN THE KIRKPATRICK BASALT

The interbeds of the Kirkpatrick Basalt record sedimentary and biotic processes in relatively shallow lakes and ponds, and in surrounding wetlands to upland areas, during two brief intervals when active magmatic activity had slowed along an expanding rift system in high latitude Pangaea. Among these sedimentary interbeds are two dominant types of subaqueous origin: (1) fine-grained, thinly laminated siliciclastic deposits (Fig. 2) and (2) unusual carbonate deposits rimming and filling spaces between basalt pillows (Fig. 3). Both of these subaqueous deposits transition laterally into thin paleosols and poorly consolidated peat deposits, where large permineral-

ized (silicified) logs occur locally in the Beardmore Glacier region (Taylor and Taylor, 1990).

The siliciclastics were evidently deposited in small, relatively shallow, freshwater lakes and pools (Tasch, 1977, 1987). In many places, symsedimentary deformation of the laminations is associated with igneous extrusions. At Carapace Nunatak, for example, large clasts of lithified or semilithified sediment appear to have been rafted by hot magma (Bradshaw, 1987) (Fig. 2b). Elsewhere, numerous thin dark brown to black laminae and crinkled layers with clotted textures are interpreted as microbial mat communities of photosynthetic bacteria and possibly algae (compare Schieber, 1999; Noffke et al., 2001). The fossil assemblage in these environments is dominated by small (1-2 cm) bivalved spinicaudatan (“conchostracan”) arthropods that are today most typical of ephemeral, alkaline pond settings (Fig. 4a) (Tasch, 1987). Other macrofossils include fishes (mostly *Oreochima*), notostracan branchiopods, ostracodes, insect nymphs and wings, and plant leaves (Fig. 4), but macroscopic trace fossils are extremely rare. The animal body fossils are preserved with mineralogies that mimic their original skeletal composition (i.e., spinicaudatan carapaces are pre-

served as calcium phosphate, while those of ostracods are preserved as calcium carbonate), although portions of spinicaudatan carapaces are silicified (Stigall Rode et al., 2005) (Fig. 5). Overall, the preservation of original skeletal composition and the preservation of carapace layers in spinicaudatan specimens indicate rapid burial and preservation of specimens with little or no alteration of regions of their exoskeleton. The silicification of regions within spinicaudatan carapaces (Fig. 5) may have been microbially mediated.

Weak to distinct laminae in the carbonate beds are aligned subhorizontally to concentrically around basalt pillows (Fig. 3b). The carbonates appear to lack the macroscopic body fossils common in the siliciclastic beds. Backscatter SEM-EDS analyses, however, reveal minute, irregular, organic morphologies preserved with a high concentration of carbon. These organic structures are rimmed by thin silica-rich carbonate ‘halos’, and the surrounding carbonate mud lacks needles or other indicators of precipitation by macroscopic organisms. Thermoacidophilic microbes likely occurred in this type of setting and may have mediated carbonate, and perhaps also silica, precipitation in pools closely associated with hydrothermal vents and basaltic extrusion. Another untested possibility is that microbial consortia on the surface of cooler basalt pillows created an alkaline chemical microenvi-



Figure 2. Exposure of the Kirkpatrick Basalt at Carapace Nunatak, South Victoria Land; A) Outcrop showing thick lava flows; B) Siliciclastic interbed.

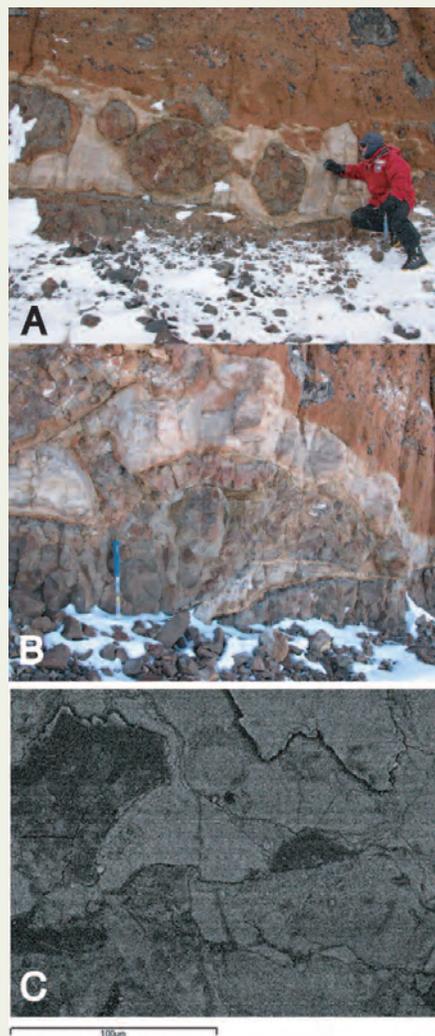


Figure 3. Carbonate interbeds of Kirkpatrick Basalt at Carapace Nunatak; A) View of outcrop showing basalt pillows and limestone interbeds between the pillows; B) Closeup of carbonate interbeds rimming a basalt pillow; C) SEM image of a possible thermophilic archaeon.

ronment in their immediate vicinity, while water elsewhere in the lakes or pools was reducing.

BIOTIC COMMUNITIES AND TAPHONOMY

Two distinct biotic communities developed within the lake environments of the Kirkpatrick Basalt sedimentary interbeds, their differences probably reflecting distance or access to a magmatic source. Hydrothermal pools near igneous vents close to phreatomagmatic centers were evidently too warm to support multicellular life: only high-temperature-adapted microbes are likely to have survived (see Jones et al., 2001). Thus, larger metazoans are found only in the siliciclastic interbeds of

the Kirkpatrick Basalt. Spinicaudatans (dominated by *Carapacestheria*, Fig. 4a) are densely packed in many thin layers at localities in both South Victoria Land and the Central Transantarctic Mountains. Their enormous numbers and nearly uniform lengths presumably reflect a high reproductive (and presumably rapid maturation) rate in pools where they had few predators. The growth lines in the carapaces of *Carapacestheria* in the Kirkpatrick beds indicate that specimens in the individual layers were all of the same age at death. This suggests that each bedding plane represents a single generation of spinicaudatans that hatched simultaneously during the initial spring flooding of the pond, a pattern mimicking that of modern spinicaudatans (Weeks et al., 1997). Carapaces of the fresh-

water ostracod, *Darwinula* (Fig. 4e), commonly occur on slabs with spinicaudatans.

In South Victoria Land, nymphs of ephemeropteran insects (Fig. 4b) are present in certain thin horizons, apparently confined to narrow time intervals, on Carapace Nunatak. Some localities in the Central Transantarctic Mountains yield abundant remains of fishes (Fig 4c) (mostly *Oreochima*) most of them fully or largely articulated. This again suggests that predaceous and scavenging activity in the Kirkpatrick lakes was minimal. Likewise there is little evidence of bioturbation of benthic muds in the siliciclastic-dominated lakes. Lack of an active infauna may have provided an opportunity for microbial mat communities to flourish.

In numerous other instances of exceptional

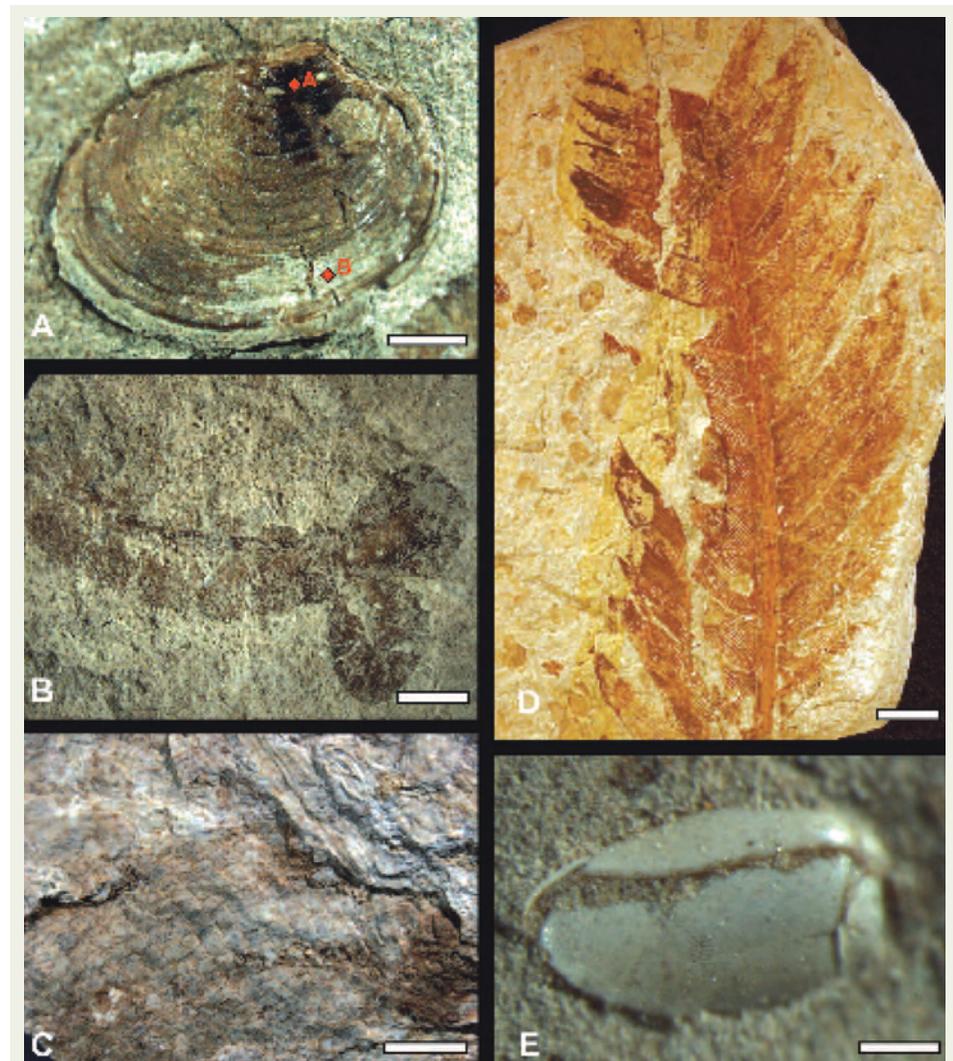


Figure 4. Representative biota from the siliciclastic interbeds. A) spinicaudatan, *Carapacestheria disgregaris*, from Carapace Nunatak, scale bar equals 1 cm; B) ephemeropteran nymph, from Carapace Nunatak, scale bar equals 0.25 cm; C) actinopterygian fish, *Oreochima ellioti*, from lower interbeds at Storm Peak, scale bar equals 0.5 cm; D) bennittitalean, *Zamites sp.*, from Carapace Nunatak, scale bar equals 1 cm; E) ostracod, *Darwinula sp.*, from Carapace Nunatak, scale bar equals 0.25 mm.

preservation in the Phanerozoic, biodegradation, including predation and scavenging, is minimal and sediment bioturbation largely absent. Non-biomineralized remains often survived long enough in the Kirkpatrick lakes to undergo early diagenesis, especially if it were mediated by microbial decay agents within a few weeks (compare Briggs et al., 1993; Wilby et al., 1996; Borkow and Babcock, 2003). Microbial mediation of silicification likely occurred in the siliciclastic interbeds of the Kirkpatrick Basalt. Microbial influence is suggested by differential replacement along zones of weakness between carapace layers as well the increased silicification of carapaces preserved within microbial-mat-influenced versus other sediments (Fig. 5).

Plant remains, including bennettitalean leaves, silicified trunks of gymnosperms, and peat (or low grade coal), are another important constituent of the fossil assemblage in the siliciclastic interbeds of the Kirkpatrick Basalt. Most of the plants lived in wetlands surrounding relatively cool water lakes, or somewhat upland from them. The sizes of the tree trunks, often 50 cm or more in diameter, provide a minimum duration between lava flows. The large diameter of these trunks suggests that some of the trees were several decades to perhaps a hundred years or more in age. Leaves and peat are preserved as hydrocarbons, whereas the logs are permineralized with silica (Taylor and Taylor, 1990) presumably sourced from Si-rich waters derived from nearby volcanic sources.

Silicification of plant material associated with igneous sources is not uncommon (e.g., Chinle Formation, see Sigleo, 1979 and Creber and Ash, 2004; Rhynie Chert, see Rice et al., 2002 and Trewin et al., 2003), but instances where a nearby hydrothermal source for magmatophreatic interactions can be identified are unusual. The Rhynie Chert (Devonian of Scotland) is perhaps the best-known example (Trewin et al., 2003). Silicification of woody material in the Kirkpatrick Basalt provides a window into paleoenvironments and climate of high-latitude Gondwana during the Jurassic (see Taylor and Taylor, 1990; Parrish, 1990).

CONCLUSIONS

Sedimentary interbeds deposited over lava flows of the Kirkpatrick Basalt during the Early Jurassic splitting of Gondwana represent unusual freshwater paleoenvironments. They illustrate an important means of solving some of the issues related to the “preservation paradox” for a critical paleoenvironmental setting—high latitude Gondwana during the early

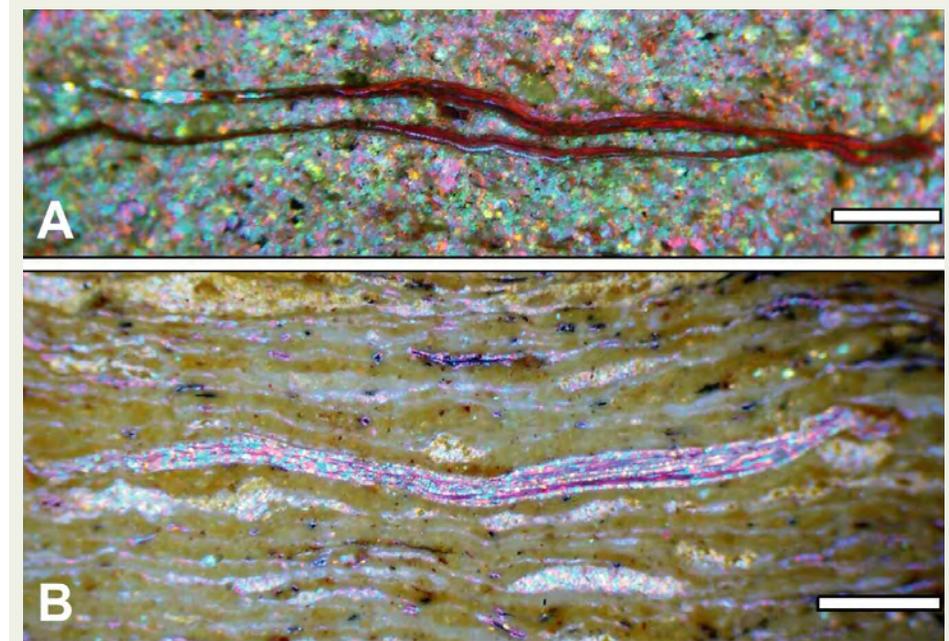


Figure 5. Thin section light micrograph of siliciclastic interbeds; brown coloration of carapace indicates phosphatic composition while purple indicates silica. **A)** Interbed from Carapace Nunatak without discernable microbial textures, note limited silicification of spinicaudatan carapace. **B)** Interbed from Strom Peak (lower bed) exhibiting microbial textures, note extensive silicification of spinicaudatan carapace.

Mesozoic. Hot lakes associated with hydrothermal vents were likely home to thermophilic microbes (archeans) capable of withstanding not only high temperature, but also sulfidic water. They promoted the precipitation of carbonate laminae even around basaltic pillows that extruded into the water. Other freshwater lakes away from direct contact with hydrothermal vents, where water temperatures were cooler, were home to low diversity faunas and microbial mat communities. Vascular plants were rooted beyond the margins of the water. Carnivory was limited, and exceptional preservation of non-biomineralized or lightly mineralized organisms became commonplace. Microbial decay agents contributed to rapid diagenesis.

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Five full days of talks, posters, field trips and core displays

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Submit abstracts to James MacEachern at jmaceach@sfu.ca

Abstracts can be up to 4 pages including figures.

Please submit in MS Word or editable PDF format using Times Roman 12 font with 1" margins

Submit early as this conference has a 50 person limit due to facility restrictions!

Sponsors include: BHP Billiton, Chevron, ConocoPhillips, Hess, Statoil

Conveners

**James MacEachern
Murray Gingras
Kerrie Bann
S. George Pemberton**

Field Trip Leaders

**Janok Bhattacharya
Tom Ryer**

Planned Schedule

- Sun., May 20: Drive Salt Lake City-Price/Icebreaker
- Mon., May 21: Oral Presentations & Discussions
- Tue., May 22: Ferron Field Trip
- Wed., May 23: Core Displays and Posters
- Thu., May 24: Panther Tongue Field Trip
- Fri., May 25: Oral Presentations & Discussions
- Sat., May 26: Return Drive to Salt Lake City

Keynote Speakers

**Christopher Fielding
&
Andy Taylor**

2006 SEPM Sustaining Members

Each year some members chose to support the Society beyond the regular membership fees to show their continued desire to push the science of sedimentary geology forward.

Vitor Abreu
 John B. Anderson
 Sue Ann Bilbey
 John D. Bloch
 Alan L. Bressler
 Richard G. Bromley
 Werner Buggisch
 Marshall C. Carothers
 Kenneth W. Ciriacks
 Marshall C. Crouch, III
 David E. Eby
 Tom Egeberg
 Thomas E. Ewing
 Robert N. Ginsburg
 Wladyslaw P. Karpeta
 George H. Keil
 Mary J. Kraus
 Robert H. Lander
 Timothy F. Lawton
 Benedikt L. Lehner
 R. P. Major
 Christopher G. Maples
 James Ross Markello
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 Alexander Nagy
 Jack E. Neal
 Dag Nummedal
 Neil A. H. Pickard
 Edward B. Picou, Jr.
 Walter C. Pusey, III
 David L. Rodland
 J. Frederick Sarg
 Edward L. Simpson
 John R. Suter
 Julie Therien
 Jon L. Thompson
 Peter R. Vail
 Cynthia Venn
 Ron F. Waszczak
 Jutta Winsemann
 Kenn-Ming Yang
 Dominic K. F. Yap
 Franklin G. Yoris-Villasana

SEPM's New Look

The SEPM Headquarters Staff and the Headquarters and Business Committee has spent many hours over the summer discussing a new SEPM website. Please take a few minutes to go by and take a look at the new look. We are very excited about it and want it to be as "member-friendly" as possible and to add new interactive features to take advantage of the latest developments in online communications.

SEPM
Society for Sedimentary Geology

(918) 610-3361
1-800-865-9765
info@sepm.org

Welcome To SEPM

SEPM (Society for Sedimentary Geology) is an international not-for-profit Society based in Tulsa, Oklahoma. Through its network of international members, the Society is dedicated to the dissemination of scientific information on sedimentology, stratigraphy, paleontology, environmental sciences, marine geology, hydrogeology, and many additional related specialties.

Latest News

Visit the SEPM Booth at the GSA Annual Convention, Philadelphia, PA.
[more info](#)

Announcing the 2007 Award Recipients
[more info](#)

JOIN SEPM...learn more about the benefits of membership
[more info](#)

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Society for Sedimentary Geology
Web design by HostW3

We have crossed the first hurdle with the basic design of the new website and now we need your help. Let us know if you are willing to serve on a special committee that will be formed to ensure that the website meets our members' needs. Please email Howard Harper, hharper@sepm.org if you have website experience and are willing contribute towards SEPM's future.

The Benefits of SEPM Membership

It's that time of year again when we are reminded to renew our membership in the various professional organizations to which we belong. Perhaps it's unfortunate that many of the various reminders (AAPG, GSA, GAC, SEPM, etc.) come at the same time, because we may be put in the position of choosing which one(s) to renew and which one(s) to let slide. Of course I hope you'll choose to renew your membership in SEPM. I believe that there are many good reasons to do so. The purpose of this column is to enumerate these reasons, while bringing you up to date on some changes that you'll see next year. Like membership in any professional organization, the benefits fall into two broad categories, the more general, altruistic benefit of assisting the organization to promote the discipline of which you are a part, and the more personal benefit that you receive in return for the payment of your dues.

On the altruistic side, SEPM depends on its members for a significant proportion of the revenue that it uses to advance the science of sedimentary geology. Your dues help the Society to publish two of the premier scientific journals in the field, the *Journal of Sedimentary Research* and *PALAIOS*, both of which provide, on a dollar-per-page basis, the best value of any journal in their particular specialization. Their scientific quality is in the top rank. A recent survey of the "most influential" papers in sedimentology found that 8 of the 10 most-cited papers (excluding self citations) in the period from 1996-2003 were published in JSR (G. Racki, 2003, IAS Newsletter, No. 187). Thus, SEPM's journals should be an indispensable part of the library of any individual sedimentologist or their institution. (Make sure that your university or company library is encouraged to retain or take up a subscription to JSR and/or PALAIOS!) In addition, your dues help SEPM to organize cutting-edge Research Conferences at which the newest ideas in our discipline are interchanged, discussed, argued and refined. Without such Conferences, scientific progress would be slower and more fraught with unnecessary misunderstandings. SEPM is also one of the most significant publishers of books, such as its highly regarded Special Publication series, as well as Short Course Notes and Field Guides. All of these publications help to disseminate the latest ideas. Without all of these many activities, our discipline of sedimentary geology would be poorer. SEPM, and its sister organizations, the International Association of Sedimentologists and GSA - Division of Sedimentary Geology, undertake all of these

activities on a non-profit basis, thereby making knowledge available at an affordable cost, something that the commercial publishers cannot do because profit, rather than the betterment of the discipline, is their ultimate bottom line. Supporting the activities of professional societies such as SEPM is an altruistic investment that benefits all of us, whether we are the creators or users of the ideas and information.

As if that wasn't enough reason to belong to SEPM, there are many individual benefits of membership. On the most crass level, **individual full membership** is cheap at \$85. This represents a cost of 23 cents (US) a day; what else of comparable value on a professional basis is this inexpensive? For this trivial cost, an SEPM member receives a journal of his/her choice (including electronic access to the complete archive of that journal from Volume 1) at a fraction of the amount that it actually costs to produce: approximately half of your dues (\$45) goes toward journal publication, whereas the cost to prepare and print one copy is of the order of \$175 (the difference being born by the higher subscription price charged to libraries because of the multi-person usage of the library's copy)! The value of this member benefit will also increase dramatically next year, because SEPM Council has approved significant increases in the number of pages to be published in JSR and PALAIOS: JSR will increase from 1060 pages in 2005 to 1400 pages in 2007 (a 32% increase), whereas PALAIOS will increase from 600 pages in 2006 to 700 in 2007 (an 17% increase), all for a normal (6%) increase in SEPM dues of \$5.

Furthermore, every member is entitled to ~40% discount on the price of any SEPM publication, and to similar discounts for registration at any SEPM Research Conference or other meetings (for example, membership in SEPM allows you to pay a reduced registration fee for AAPG and GSA meetings, whether you are a member of those organizations or just SEPM). Therefore, at the typical cost of a single Special Publication (which is less than a comparable book produced by a commercial publisher), a member would recoup the entirety of their membership dues through the savings on the purchase of just two books per year, or the purchase of one book and attendance at one Research Conference! Greater participation means even greater savings! Of course, membership also gives you an automatic free subscription to *The Sedimentary Record*, the full-color news magazine in which you are reading this column.

The indirect benefits of membership and active participation include the access to the latest ideas in sedimentary geology, which may translate into value in your job. The chance to network with like-minded professionals is a substantial benefit, especially for students. SEPM is unique among sedimentary organizations in bridging the "gap" between the academic and applied aspects of sedimentary geology. As noted in this column in the last issue of *The Sedimentary Record*, SEPM also serves as a home for a wide range of sub-specialties within sedimentary geology, thereby allowing you to be exposed to a wide range of ideas easily, all for a few cents a day.

I hope that the preceding arguments convince you that membership in SEPM represents enormous benefit, and at an incredibly low cost. I encourage you to renew your personal membership. I also encourage you to promote SEPM to individuals who are not members, but whose professional activities fall within the broad scope of SEPM. Their participation in SEPM will enrich them, professionally, and, indirectly, the entire community of sedimentary geologists. Students are especially welcomed and receive substantial savings on membership (a **student membership** is only \$25 and gets them electronic access to both journals!! A membership application form is available online and can be copied for distribution to your colleagues and students. Please also make sure that the library at your university or place of work subscribes to JSR and/or PALAIOS; this ensures that the excellent science published in these journals gets maximum exposure. The relatively inexpensive cost of an institutional subscription goes a long way toward subsidizing the good work that SEPM does. Individuals who are in a position to do so and wish to give something back to SEPM and their discipline can also subsidize SEPM's activities by becoming a **Sustaining Member** at a cost of US\$300. Such membership entitles the individual to receive both journals, and the opportunity to provide advice on matters of interest to the Society. Appropriate recognition of this generosity is made in *The Sedimentary Record*. A more concise listing of the benefits of each of the three types of membership described here is in your renewal materials and of course online at www.sepm.org. Help SEPM advance the discipline of sedimentary geology. Join and encourage others to join.

Bob Dalrymple, President
<dalrymple@geol.queensu.ca>

Benefits of SEPM Membership

Full Membership - \$85

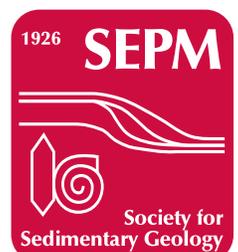
- ◆ Participate in a vibrant international community that is active in its promotion of the full spectrum of sedimentary geoscience
- ◆ Networking with peers to stay abreast of current science
- ◆ Opportunities to introduce students to the world of sedimentary geoscience
- ◆ Opportunities to work with your peers to shape the future of sedimentary geology, or for professional development, through attendance at meetings, conferences, short courses, and field trips
- ◆ Easy online access to the world-class science in the SEPM journals (*JSR* and *PALAIOS*)
- ◆ Easy online access to the entire archives of SEPM journals
- ◆ Free option for printed copies of your chosen journal(s) or a year-end CD
- ◆ Receive news and timely topics presented in *The Sedimentary Record*, the Society's full-color print magazine
- ◆ Discount pricing for SEPM Book Publications (~ 40%)
- ◆ Discount registration fees for SEPM activities including Research Conferences and Annual Meetings (includes AAPG and GSA Annual Conventions)
- ◆ Vote for or hold office on SEPM Council

Sustaining Membership - \$300

- ◆ An opportunity to direct some of the fruits of your professional success towards securing the future of Sedimentary Geology and to the activities of scientists, both young and established, who are devoted to this field
- ◆ All benefits of Full Membership plus:
 - ◆ Online access to both SEPM journals and journal archives with year-end CD
 - ◆ Recognition in *The Sedimentary Record*
 - ◆ Visual recognition at annual meeting (ribbons, badges, emblems)
 - ◆ Recognition gifts during year such as SEPM Post Card sets and Address labels
- ◆ Act as an advisor to SEPM Council for strategic input
- ◆ US Tax deduction letter for a portion of the membership fee

Student Membership - \$25

- ◆ Your entrée into the lively global community of sedimentary geoscience
- ◆ Networking with established scientists for advice and mentoring
- ◆ Meet people with similar interests and build a network of colleagues that will last for a lifetime
- ◆ Ability to apply for SEPM Foundation Student Grants
- ◆ Special rate for online access to both SEPM Journals (*JSR* and *PALAIOS* and Journal Archives)
- ◆ Special discounted surcharge rate for printed journals
- ◆ Special student pricing on all SEPM Publications (~50% list)
- ◆ Heavily discounted registration fees for SEPM activities including meetings, research conferences, short courses and field trips
- ◆ Opportunities to obtain classic SEPM publications for the cost of shipping and handling only (Free Books for Student events)





SEPM SHORT COURSES AND FIELD TRIPS

Sponsors

(as of October)

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Course #7 (SEPM)

Sequence Stratigraphy for Graduate Students

Dates Saturday, March 31 – Sunday, April 1, Time: 8:00 a.m. – 5:00 p.m.

Instructors: Vitor Abreu and Jack Neal (ExxonMobil Exploration Company)

Fee: No cost – Graduate Students Only

Course #8 (SEPM)

3-D Seismic Interpretation for Geologists

Dates: Saturday, March 31 – Sunday, April 1, Time: 8:00 a.m.–5:00 p.m.

Instructor: Bruce Hart (McGill University)

Fee: Professional: \$325; No cost – First 20 Graduate Students; Student: \$150

Course #9 (SEPM)

Applied Ichnology: The Use of Trace Fossils in Sequence Stratigraphy, Exploration and Production Geology

Dates: Saturday, March 31 – Sunday, April 1; Time: 8:00 a.m. – 5:00 p.m.

Instructors: S. George Pemberton (University Alberta), and James MacEachern (Simon Fraser University)

Fee: Professional: \$325; Student: No cost – First 5 Graduate Students; Students: \$150

Contact
Howard Harper
about Sponsorship

Trip #10 (SEPM)

Baja, California – Volcanic Arcs and Related Sedimentation

Date: Monday, March 26, 6:00 a.m. – Saturday, March 31, 9:00 p.m.

Leader: Cathy J. Busby (University of California–Santa Barbara)

Fee: Professional: \$865; Student: \$434 (limited number)

Unique chance to
see remote outcrops!

Students need to register early
to secure sponsored seats

Trip #11 (SEPM)

Sand Injectites in the Western San Joaquin Valley

Date: Thursday, March 29, 7:00 a.m. – Saturday, March 31, 8:00 p.m.

Leaders: Andrew Hurst, Mario Vigorito (University of Aberdeen & Hilde Schwartz (University of California, Santa Cruz)

Fee: Professional: \$650; Student: \$325 (limited number available)

Compare two famous injectite deposits!

Trip #12 (SEPM)

Santa Cruz Island – Sedimentation and Deformation of a Tertiary Continental Margin

Date: Saturday, March 31, 7:00 a.m. – 8:00 p.m.

Leaders: James R. Boles and Grant Yip (University of California, Santa Barbara, CA)

Fee: Professional: \$635; Students: \$318 (limited number available)

See an extremely limited access area
of the California Channel Islands!

Trip #13 (SEPM)

Sedimentology and Facies Architectures of Channelized Slope System: Capistrano Formation, San Clemente, Southern California

Date: Saturday, March 31, 7:00 a.m. – 8:00 p.m.

Leaders: Kirt Campion & Anthony Sprague (ExxonMobil Upstream Research Co.) and Morgan D. Sullivan (Chevron Energy Tech. Co.)

Fee: Professional: \$145; Student: \$73 (limited number available)

Great trip if you have only one day!

Trip #22 (SEPM)

Tectonic Controls of Facies Distribution and Stacking Patterns, Ridge Basin, Southern California

Date: Wednesday, April 4, 7:00 a.m. – Friday, April 6, 8:00 p.m.

Leaders: Kenneth Ehman (Skyline Ridge, Inc.) & Morgan Sullivan (Chevron Energy Tech. Co.)

Fee: Professional: \$685; Students: \$343 (limited number available)

See it all in one basin!

Get details at
www.sepm.org
or
www.aapg.org