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The SEDIMENTARY Record

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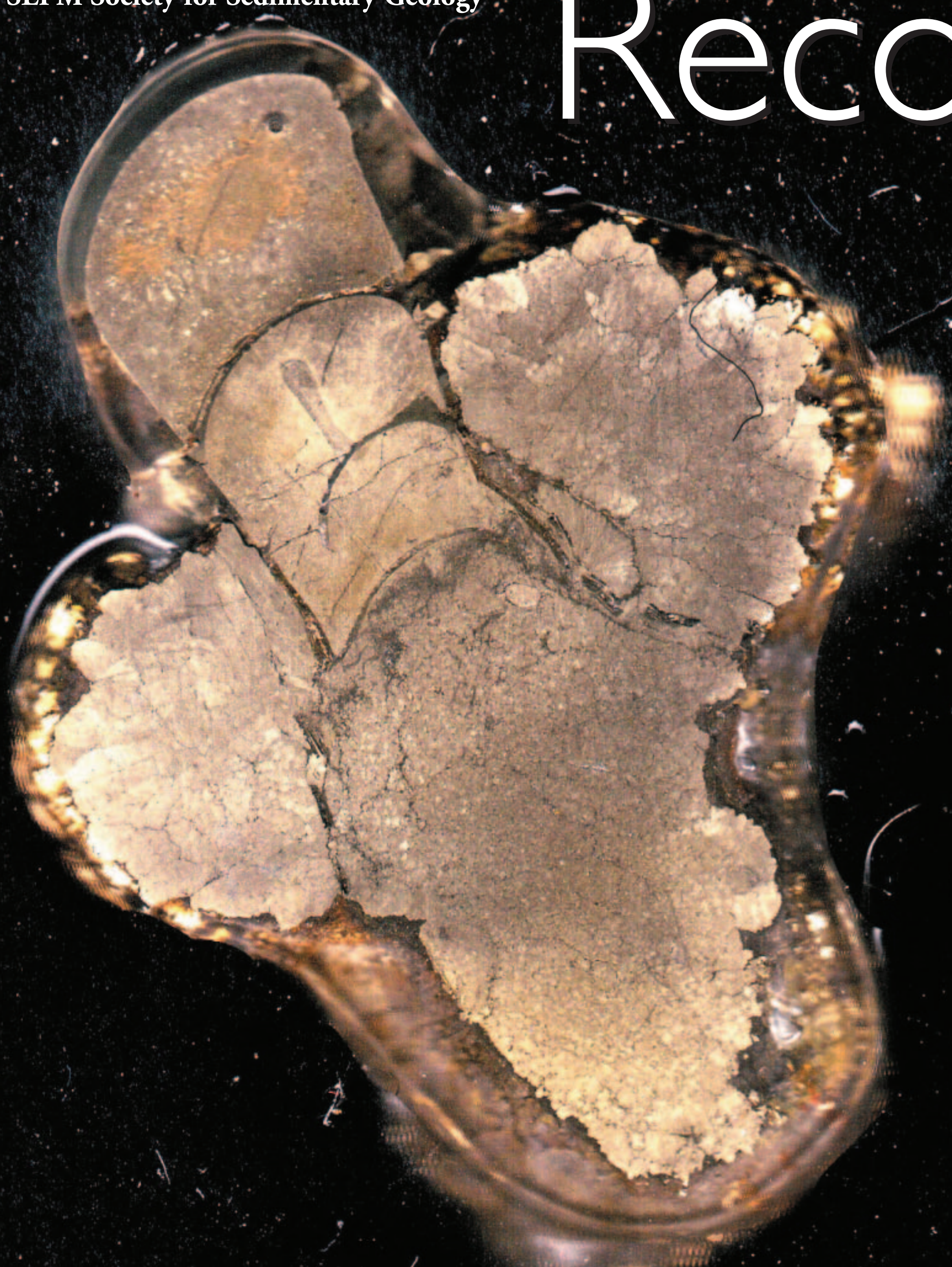

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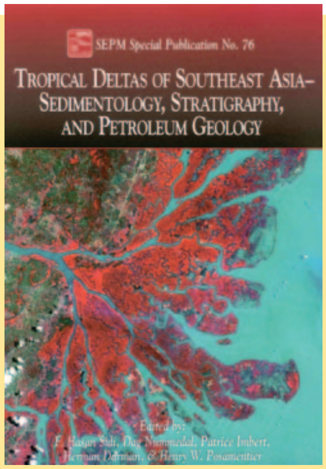

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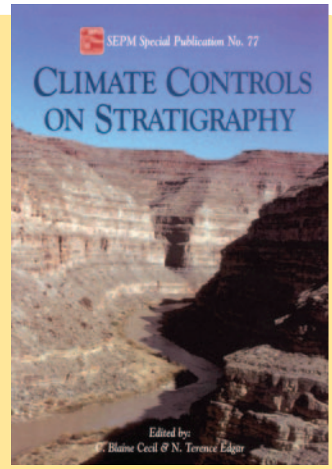

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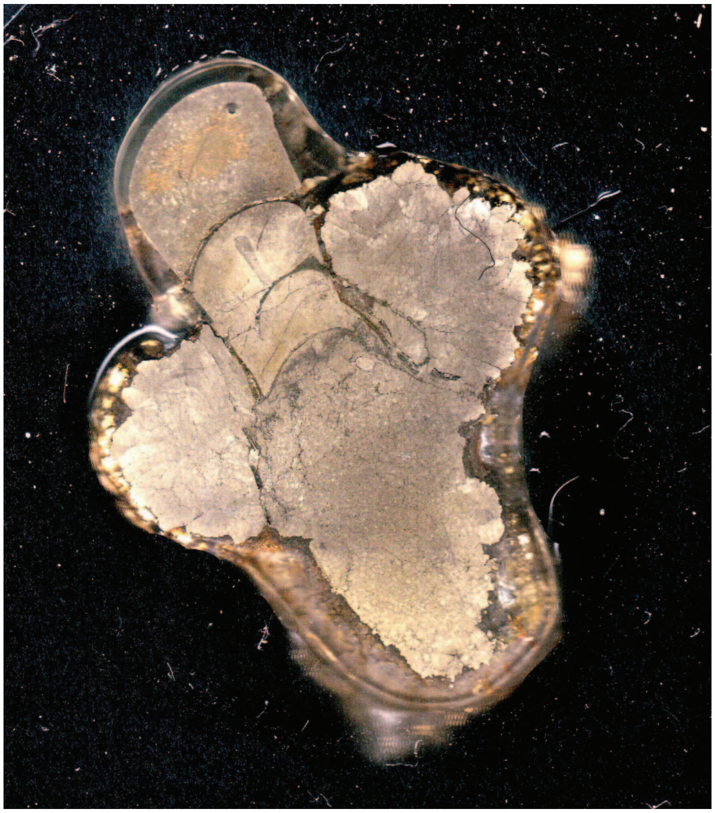

Cover art: *Cross-section of orthocone nautiloid showing pyrite crust on soft parts lining the internal chambers and surrounding the siphuncle, associated with gas blowout structures; length of specimen approximately 5 cm (see Borkow and Babcock, this issue).*

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Turning Pyrite Concretions Outside-In: Role of Biofilms in Pyritization of Fossils

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ABSTRACT: Studies integrating sedimentary geochemistry, diagenesis, and taphonomic experimentation provide new understanding about the development of pyrite concretions around organisms and the exceptional preservation of some nonmineralized tissues by pyrite crusts. As now interpreted, at least three factors influence the preservation of organisms by pyrite: 1) burial in a low oxygen environment or microenvironment; 2) ratio of sulfide ions to dissolved reactive iron in sediment pore waters; and 3) presence of reactive biofilms (microbial assemblages) associated with decaying organic material. Under low oxygen conditions, breakdown of organics allows for the release of sulfide ions into sediment pore waters, where they combine with reactive iron ions to form iron sulfides.

Pyrite often preserves biomineralized structures (primarily shells) through concretionary overgrowths, whereas non-biomineralized tissues (such as internal soft parts) are usually preserved by thin pyrite crusts. The extent of pyrite precipitation and the type(s) of organically produced material(s) preserved by FeS2, seem to be related to the development of either reactive bacterial coatings that were in direct contact with decaying organic tissues or microbial assemblages (including bacteria and probably fungi) that formed halos around decaying organic tissues. Precipitation of pyrite to form a concretion apparently begins at multiple sites within a microbial halo, not just on the surface of the decaying mass.

INTRODUCTION

Among the more intriguing aspects of the fossilization process is preservation of soft tissues, chitinous coverings, or biomineralized structures by pyrite. This type of preservation is rather dogmatically referred to as replacement by pyrite in many geology textbooks. Studies integrating sedimentary geochemistry, diagenesis, and taphonomic experimentation, however, indicate that this notion of replacement is perhaps oversimplified because it fails to account for contrasts in the preservation of different types of organically produced structures. Moreover, it fails to account for factors influencing the formation of pyrite concretions as constrasted with the formation of thin pyrite crusts over organic structures.

Here, we present new information concerning the precipitation of sedimentary pyrite mediated by organic decay. This and other developing information (e.g., Schieber, 2002) provide the basis for an hypothesis that accounts for microbiological and geochemical factors leading to exceptional preservation of non-biomineralized tissues by means of pyrite. Also, preservation of biomineralized shells by means of concretionary pyrite, without preservation of any associated non-biomineralized parts, is discussed. In addition to factors previously determined to play major roles in pyrite preciptation (e.g., burial of organics in low oxygen environments, and ratio of sulfide ions to dissolved reactive iron in sediment pore waters; e.g., Berner, 1970; Raiswell et al., 1988), pyrite precipitation seems to be strongly correlated with the development of microbial biofilms (Schieber, 2002). Such biofilms appear to have two forms that result in different patterns of pyrite precipitation. Bacteria-dominated biofilms apparently result in coating of tissues by thin pyrite crusts. Pyrite concretions (and sometimes pyrite rings) result from microbial assemblages that grow halos around decaying matter. Non-biomineralized parts of organisms are preferentially preserved by thin pyrite crusts, and non-biomineralized structures appear to be preferentially preserved by pyrite concretions.

Characterizing how pyrite has preserved fossils contributes at least two noteworthy advances: 1) a refined understanding of the conditions under which some exceptional preservation of fossils has occurred (i.e., the rather unusual preservation of non-biomineralized tissues or so-called "soft parts;" e.g., Bartels et al., 1998; Stanley and Stürmer, 1987; Briggs et al., 1996; Grimes et al., 2002); and 2) a step toward more complete understanding of the precipitation of concretions in sedimentary strata. This work indicates that concretionary development is the result of rapid formation of an organic matrix surrounding a decaying mass. The presence of this decaying mass created a chemical microenvironment that induced precipitation of concretionary minerals. Crystal growth appears to have begun at multiple sites within the decaying mass, including the margin of the halo. The implication is that a pyrite concretion does not necessarily begin at the center and grow outward.

METHODS, MATERIALS, AND GEOCHEMICAL MODELS

Detailed study of sedimentary pyrite preserving fossils was carried out principally on specimens from the Alden Pyrite Bed (Ledyard Shale Member, Ludlowville Formation, Hamilton Group; Middle Devonian) of western New York (see Babcock and Speyer, 1987). The Alden Pyrite Bed, which ranges up to about 1.5 m in thickness, is one of the best developed pyrite beds in the Hamilton Group (Dick, 1982), and yields fossils representing a range of shallow marine organisms and body parts. Pyritization of fossils ranges from thin surficial coatings to round concretions that are typically less than 2 cm in diameter. Specimens were studied macroscopically, through sectioning, and via image enhancement (see Schieber, 2003) of sectioned specimens. For comparative purposes, taphonomic experiments were carried out on recently dead or frozen arthropods (horseshoe crabs and centipedes) in marine aquaria inoculated with microorganisms (see Babcock et al., 2000 and references therein). Finally, observational and empirical data were compared with geochemical models for pyrite precipitation.

The interaction of sulfide and reactive iron in controlling pyrite precipitation can be described using a double reservoir model (Helfferich and Katchalsky, 1970; Canfield and Raiswell, 1991; Raiswell et al., 1993). This model for bacterially mediated pyrite deposition describes the interaction between varying amounts of reactive iron and the sulfide released through bacterial sulfate reduction of organic structures having radii up to 50 μm (Raiswell et al., 1993). According to Canfield and Raiswell (1991), two variables

***Figure 1**: Centipede (Scutigera) decaying in water and surrounded by transluscent bacterial-fungal halo. Length of specimen approximately 3 cm*

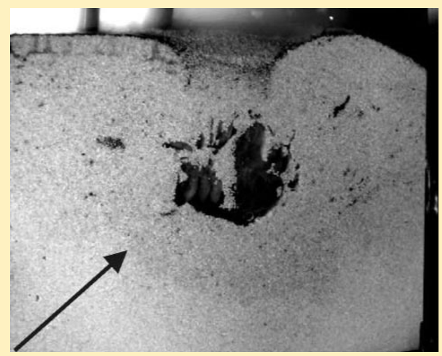
control pyrite precipitation: 1) reactive iron content in the system; and 2) sulfide content in the system. Reactive iron is the amount of iron used in pyrite production as opposed to iron in the system as a whole (Raiswell et al., 1994). This iron may be introduced into a system through bacterially-catalyzed reduction of iron oxides (e.g., hematite) or iron oxyhydroxides (e.g., goethite, ferrihydrite, and lepidocrocite) by organic compounds (Jones et al., 1983; Lovely and Phillips, 1986a,b; Canfield, 1989), and the partial oxidation of iron sulfide minerals (Lord, 1980; Giblin and Howarth, 1984). Sulfide production, which influences the extent of pyrite precipitation around a decaying organism, is the result of bacterial dissimilation (Canfield and Raiswell, 1991). An increase in either of the reservoirs is expected to shift the deposition of pyrite toward the other reservoir. In the case of a decaying organic mass, the sulfide reservoir begins at the decaying organic mass and extends outward, whereas the reactive iron reservoir is in the surrounding sediment and associated pore water (Canfield and Raiswell, 1991). By using the flux of the two reservoirs, Canfield and Raiswell (1991) hypothesized that the three "types" of pyrite preservation outlined by Allison (1988) can be accounted for by: 1) precipitation of pyrite in the cellular pore spaces (permineralization); 2) precipitation of pyrite directly on the surfaces of the non-biomineralized body parts without preserving internal structure (mineral crusts); and 3) precipitation well outside of the boundary of the organic material (mineral casts, molds, and concretions).

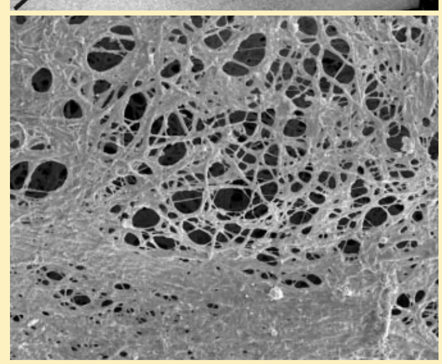
Here, the double reservoir model is emended to include the role of microbionts in mediating pyrite precipitation (Schieber, 2002), especially for decaying masses beyond the size constraints discussed by Raiswell et al. (1993). Biofilms help to explain the formation of both pyrite crusts and pyrite concretions, but not necessarily pyrite permineralization.

MODERN AND ANCIENT MICROBIOTA

The possibility of bacterial-fungal (or other microbial) interaction as a factor controlling pyritic macrostructure is supported based on results of SEM analysis of the cohesive and stable balloonlike structures (referred to here as microbial halos) that envelope decaying arthropods in laboratory experiments (Figs. 1, 2). Three-dimensional microbial halos develop around decaying organisms whether they are floating in water (Fig. 1), at the sediment surface, or buried under sediment (Fig. 2). Scans of a microbial halo surrounding a decaying centipede (Fig. 1) show an anastomosing network of strands representing hyphae of a complex fungal mycelium (Fig. 3). Interspersed among the mycelia are small (0.5-2 ìm) coccoid-shaped, gram-positive bacterial bodies (probably Staphylococcus or Streptococcus; Fig. 4).

Fungal mycelia that surround decaying organic matter in aqueous environments act as stabilizing media and substrates for the growth of interdependent, coherent microbial communities referred to as consortia (Cullimore, 2000). Modern microbial consortia can assume various forms, including crystallized structures such as nodules, crusts, rusticles, iron pans, stalactites, and stalagmites (Cullimore, 2000). An important product of microbial consortia is the accumulation of extraceullar polymeric substances (EPSs), commonly referred to as "slime" (Cullimore, 2000). This slime acts as a three-dimensional pathway for the transport of recalcitrant accumulates such as ferric iron and nutrients such as nitrogen. Iron is a key component of EPSs





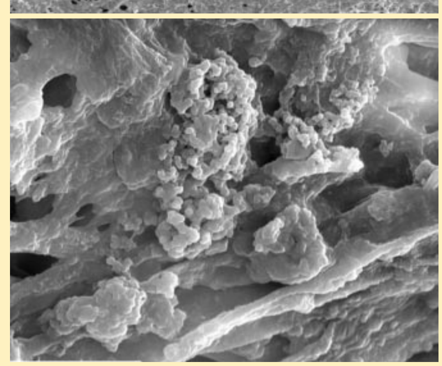


***Figure 2** (top): Horseshoe crab (Limulus) decaying in sand and surrounded by dark bacterial-fungal halo (arrow). Length of halo approximately 8 cm.*

***Figure 3** (middle): SEM image of network of fungal mycelia with interspersed bacterial cells extracted from halo surrounding specimen in Fig. 1. Length of bar scale 100 μm.*

***Figure 4** (bottom): SEM image of bacterial cells within the microbial consortium illustrated in Fig. 3. Length of bar scale 10 μm.*

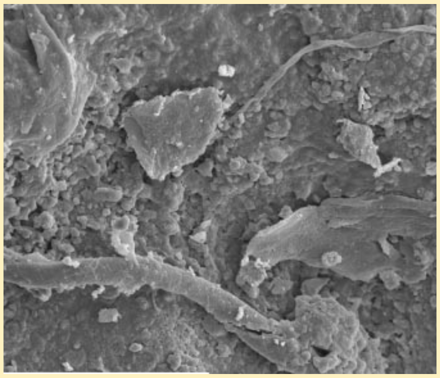


Figure 5: SEM image of pyrite crust over soft parts associated with the siphuncle of an orthocone nautiloid showing probable fungal hyphae (strandlike structures) and bacteria (round structures); from the Alden Pyrite Bed (Ledyard Shale Member of Ludlowville Formation; Devonian) of western New York. Length of bar scale 70 μm.

because some bacterial respiration mechanisms rely upon it. The presence of iron-binding agents, called siderophores (Madigan et al., 1997), in some bacteria make the formation of a consortium beneficial to those bacteria lacking in efficient iron-binding proteins. They allow iron to be transported throughout microbial communities (Madigan et al., 1997), which is an important prerequisite for the formation of FeS2.

We interpret microbial halos that surround decaying organic matter within sediment as precursors of concretions. Darkened halos observed to surround decaying horseshoe crabs (Fig. 2) consist of fungal hyphae that surround and ensconce grains of sediment. The halos are so cohesive that extracting samples without disturbing the surrounding sediment can be difficult. Under SEM and EDX analysis, the dark halos appear to be largely bacterial in composition and not due to the presence of iron monosulfide or manganese hydroxide.

SEM analyses of pyritized mollusks from the Alden Pyrite Bed reveal minute strands and beadlike structures (Fig. 5) that closely resemble microbionts observed in the halos surrounding organisms decaying in aqueous laboratory experiments. The strands are inferred to be pyritized fungal hyphae (although the possibility that some may be cyanobacterial strands cannot be ruled out at present), and the beadlike structures are interpreted as coccoid bacteria. Similar structures observed previously from sedimentary rocks (e.g., Southam et al., 2001; Schieber, 2002; Grimes et al., 2002; Schieber and Arnott, 2003) likewise have been associated with the decay of animals or plants. Preservation of bacterial cells, and by implication, also soft internal tissues in pyrite tends to occur in rather sheltered areas (e.g., linings of the chambers of orthocone nautiloids; cover photo). Pyritized areas have a honeycomb texture that is different from the surrounding pyritic matrix. This texture is similar to that observed in carbonized Oligocene feathers and interpreted as having a biofilm origin (Davis and Briggs, 1995).

BIOFILM RESPONSE PATTERNS IN PYRITIZED FOSSILS

The composition of microbial consortia involved in the decay of organic tissues seems to play a major role in the style of pyritization of fossils. Bacteria-dominated consortia lead to pyrite crusts and are preferentially associated with non-biomineralized tissues, whereas microbial consortia dominated by extensive networks of microbes (presumably fungal hyphae and bacteria) lead to pyrite concretions. Also, a relationship exists between the types of microbial consortia and the extent to which integrity of the decaying organisms is maintained within the resulting fossils: tissues preserved by crusts seem to have been more susceptible to development of blow-out structures resulting from gas release during decay than were structures preserved by network-supported microbial consortia.

Bacteria-dominated (fungi-depleted) sheets surrounding decaying organic matter probably responded differently to gas release than did larger, presumably mycelium-supported, microbial consortia. In order to study the different effects of biofilms influencing preservation style, images of cut and polished pyritized fossils were enhanced using Adobe Photoshop (see Schieber, 2003). In examples where points of rupture associated with gas release have been studied, pyritization was evidently associated with bacterial sheets lacking significant strands or networks of microbes. Pressure associated with gas buildup in response to decay was not well accommodated in the relatively non-elastic bacteria-dominated sheets. The more elastic, network-supported microbial halos were better at accommodating gas pressure. As a result, rupture was more common in decaying organisms covered by bacteria-dominated sheets (cover photo). In specimens having more extensive microbial networks, biofilms were probably more stable and able to distribute gas release more evenly over the circumference of the consortium. This may have been an important step in the formation of a concretion (Fig. 6) around a decaying organic nucleus.

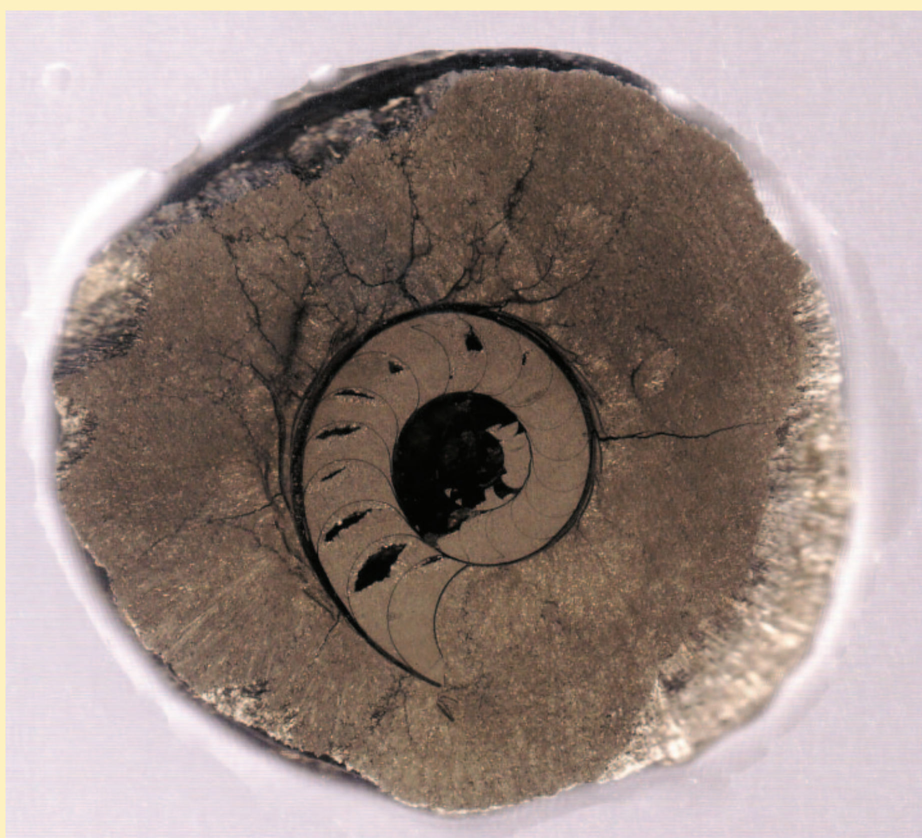


Figure 6: Cross-section of pyrite concretion formed around ammonoid shell; from the Alden Pyrite Bed (Ledyard Shale Member of Ludlowville Formation; Devonian) of western New York. Diameter of concretion approximately 2 cm.

Under anaerobic conditions, halos composed of sulfate-reducing bacteria attached to fungal mycelia (or possibly cyanobacterial strands) formed around decaying organic matter, and the bacteria released pockets of sulfide into slime. The pockets could extend into the surrounding matrix. Bacteria deficient in microbial networks would, in contrast, form mats along organic surfaces. Sulfide produced at sites of bacterial colonization in network-stabilized EPSs would promote the deposition of pyrite throughout the consortia; this explains the precipitation of pyrite in concretions. By contrast, the lack of network-supported consortia would restrict bacteria to positions close to decaying organisms, thus causing pyrite precipitation close to nuclei of decay. In such cases, pyritization of bacterial sheets would occur through microbe entombment (Schultze-Lam et al., 1996).

IMPLICATIONS

The implications of microbial consortia for influencing fossilization are far reaching. In addition to accounting for variation in the ways that pyritization of fossils occurs, the biofilm consortium hypothesis suggests a mechanism by which other types of concretions (e.g., carbonate and silica) may form. Preservational differences within beds containing sedimentary pyrite seem to record variability in the composition of microbial species involved in decay. It is conceivable that there was also some environmental varibility in the composition of microbial communities, and that may help to explain some differences in style of pyritization among different sedimentary strata.

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The Fairmont Hotel, 11:30am-1:30pm

Tickets are $30 and can be purchased through the registration form for the convention.

This year's SEPM luncheon speaker is Dr. John C. Van Wagoner, Senior Research Advisor at ExxonMobil's Upstream Research Company. Dr. Van Wagoner specializes in stratigraphy and sedimentology. His principal areas of research have been in the development of sequence stratigraphy concepts, especially as applied to siliciclastic outcrops and subsurface data sets; and facies architecture, especially in fluvial and shallow-marine strata.

The title of Dr. Van Wagoner's talk is "Energy Dissipation: Origin of Structure and Organization in Siliciclastic Sedimentary Systems."

FIELD NOTES

View from a State Survey

My name is John Harper. I am Chief of Oil, Gas and Subsurface Services of the Pennsylvania Geological Survey, and head of the Pittsburgh office. I hold a PhD in Paleontology and have a Professional Geologist license (PG). My responsibilities, like those of my staff, are varied, but our primary responsibility is to collect and disseminate information about oil and gas and subsurface geology in Pennsylvania to the oil and gas industry, geologic consultants, government officials, academics, and the general public. We also provide information on a wide variety of geologic topics for western Pennsylvania. We are, for all intents and purposes, THE geological survey in western Pennsylvania.

Because 99% or more of western Pennsylvania's bedrock above the crystalline basement (16,000 feet beneath Pittsburgh) is sedimentary (there are two known kimberlite dikes in the area), sedimentary geology plays a vital part in our day-to-day efforts. All of Pennsylvania's oil and gas reservoirs consist of conglomerate, sandstone, siltstone, shale, limestone, dolostone, and/or coal. What makes them special are the characteristics of the rock that were imparted to the original sediment and altered through diagenesis over the past 250 to 500 million years. All of these characteristics allowed the hydrocarbons to be emplaced, stored for hundreds of millions of years, and released during and after drilling. As such, the types of geologic studies we undertake typically involve interpreting depositional environments, diagenetic processes, fluid migration pathways, current porosity and permeability, and other physical, chemical, and engineering characteristics. Although some of these characteristics can be determined using geophysical logs and geochemical analyses, in the long run you need to study the rock to get a good picture of what really happened over geologic time. For example, we are currently engaged in a multi-state study of the Upper Ordovician Trenton and Black River carbonates in the Appalachians. These rocks, which are normally limestones, recently have been shown to provide gas in great quantities as a result of localized dolomitization. Hot fluids penetrated the limestone in the geologic past along faults and other fractures and turned the low porosity, low permeability limestone to vuggy, porous dolostone. The hydrocarbons were emplaced at about the same time. A small team of Survey geologists is currently studying outcrops, cores, and drill cuttings both macroscopically (hand samples, outcrops) and microscopically (thin sections) to try to determine why some of the limestone was dolomitized and some was not. In addition, the Survey is continuing its efforts to investigate landslides and landslide potential, direct people to local fossil and mineral collecting sites, explore the geochemistry of natural gases, trace the history of western Pennsylvania drainage and landscape development, educate the public about groundwater issues, map mineral resources, and many other sedimentary geology topics. In fact, the only non-sedimentary geology topic anyone in this office has undertaken during my tenure was collecting specimens of one of the kimberlite dikes for study by graduate students at Penn State University.

I am, and have always been, a sedimentary geologist in one form or another, even when I was an invertebrate paleontologist. The study of these rocks is very important. Not only do they exist as matrix holding my beloved fossils in place and protecting them from the ravages of time, but they also contain much of the geologic history of our planet. Much of our water, most of our oil and natural gas, and many of our metallic and non-metallic mineral deposits can be found in sedimentary rocks. Most sedimentary rocks, in fact, have been used as a mineral resource at one time or another - limestone for cement and blast furnace flux, dolostone for agricultural lime, shale and siltstone for fill, claystone for bricks, sandstone for sand in the making of glass and refractories, to name a few uses. And all of them have been used for building material such as aggregate and dimension stone. In Pennsylvania, the use of sedimentary rocks for construction provides more capital to the state than does oil, gas, and coal combined. And since there will always be a need for construction material, energy minerals, groundwater, and other geologic resources, sedimentary geology will remain an important topic of study here and elsewhere.

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The Hand Lens—a student forum

SEDIMENTARY GEOLOGY AS KEY TO CONSERVATION

Sedimentary rocks preserve the only record of the history of life, environment, climate, and deposition through the history of the earth. As our sole historical record, they offer great promise for unlocking both the secrets of the past and constraining the possibilities for the future.

This wealth of information has provided the basis for much of our understanding of the evolution of the earth and its inhabitants over the past 4.6 billion years. Deciphering the history locked in sedimentary rocks was a crucial step in the establishment of modern geology. Hutton (1788) espoused the use of modern analogs to understand the processes that formed the strata within the sedimentary record, and Lyell (1830) based his entire Principles of Geology on uniformitarianism. Thus "the present is the key to the past" became perhaps the best known phrase in geology. While this concept certainly also applies to other aspects of geology, interpreting sedimentary units requires the use of analogs within modern depositional systems. The study of modern analogs to sedimentary deposits progressed dramatically during the 20th century including, for example, studies of modern carbonate systems (e.g. Purdy, 1963), turbidity currents (e.g. Kuenen, 1967), and modern marine traces (e.g. Seilacher, 1967). Studies incorporating modern analogs to better characterize idealized sedimentary geometries (e.g. Best et al., 2003), taphonomy (e.g. Duncan et al., 2003), and ichnofaunal assemblages (e.g. Hastiotis and Mitchell, 1993) continue and are providing increasingly detailed understanding of ancient depositional systems. Each additional study allows for further characterization of ancient environments, stratigraphic architecture, or biotic interactions. Continuing and expanding analyses of modern analogs is critical for developing increasingly accurate estimates of ancient sedimentary environments for both scientific and economical purposes.

The increased precision and detailed work of recent studies also allows today's sedimentary geologists to take the inverse of Hutton's oft-repeated phrase and examine the past as the key to the modern (or future). Much of modern biology and environmental science focuses on identifying ways to mitigate the negative changes being wrought by a variety of causes including global warming, habitat destruction, increased coastal sedimentation, etc. Fortunately for historical geologists, most (if not all) of these scenarios have already been played out at some time in the geologic past. Their secrets are preserved in fossils, bedding planes, and stacking patterns just waiting for a daring geoscientist to uncover.

The purpose of this forum is to present a student's view on the field of sedimentary geology and to inform both current students and professionals of developments within the field. I would submit that the conservation arena is an area where sedimentary geologists can make both significant and exciting contributions. Certainly a portion of the current sedimentary literature already falls within this area; in general, however, this is an under developed realm in which we can have dramatic impact. This is an exciting area that graduate students (and professionals alike) should consider seriously when identifying project ideas. Graduate students currently building their base of expertise are particularly well suited to adopting research strategies that combine several areas of sedimentary geology with pertinent modern problems.

The arena of conservation geology requires an innovative research program. The ability to link disparate fields of study, such as biology, geochemistry, and sedimentology, into a cohesive project is required for tackling these multifaceted problems. Sedimentary geologists are perhaps uniquely qualified to undertake this type of project since we have been engaging in this type of comparative and integrative research for years, albeit usually with somewhat differently stated objectives. The scope of conservation questions that can be examined within a framework of sedimentary geology is almost unbounded. Studies examining changes in sediment supply within individual river sheds can provide evidence of the impact of human intervention in damming specific rivers, while core data from oceanic shelves can help determine patterns of ancient oceanic circulation. Applying stratigraphic and paleontologic principles to these types of problems can help to produce more informed policy decisions.

One example of this type of integrative, conservation-centered approach concerns the role of invasive species in mediation of mass extinctions. Invasive species are species that originally occupied restricted geographic ranges but rapidly expanded their ranges following the breakdown of barriers. The modern spread of invasive species, attributable primarily to humans, is one of the primary causes of the current biodiversity crisis (Enserink, 1999). Species invasions also occurred in the geologic past and can be studied as analogs of modern events to characterize the long-term effects of species invasions, which cannot be studied otherwise. Research focusing on changes in geographic range associated with species invasions during the Late Devonian Frasnian-Famennian biodiversity crisis has revealed a structural change in speciation mode during this interval (Rode and Lieberman, 2003). This type of information can be incorporated into predictive models for the modern biodiversity crisis, but could not be discerned from the modern biota alone.

Conservation approaches, however, need not be limited to paleontologic questions. Differentiating historical and post-disturbance (development) rates of sedimentation and erosion can help determine sustainable coastal policy for costal regions including beaches and wetlands. Core data from peat bogs, ancient lakes, and continental shelves can aid in the reconstruction of paleoclimate and estimation of potential future warming trends. Distinguishing differences in stratal stacking patterns in various paleoclimatic and tectonic regimes can aid in predicting areas of erosion and deposition within fluvial and shallow marine systems. Assessing the timing and spatial scale of sedimentologic and paleoenvironmental variations could provide constraints on the areal extent required to preserve threatened ecosystems.

Understanding these types of conservation questions and acquiring pertinent data to predict long-term trends in the modern environment will become increasingly important as global population continues to rise and natural areas decrease. Geoscientists can play an important role in promoting sustainable solutions to environmental problems by drawing on the rich historical data preserved within the sedimentary record.

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DIRECTOR'S CHAIR

Non-Technical Session Activities at GSA

Having just returned from the GSA Annual Meeting in Seattle, I thought I would share with you some very interesting things that occurred but cannot be found in the abstracts. The most significant of these, to me, is an effort to begin organizing the community of sedimentary geologists. A first step is to identify the current basic research questions driving our field. In the first issue of *The Sedimentary Record*, I discussed predicting the future of Sedimentary Geology, now there is an effort to shape the future and each of us should be part of it. The effort is timely because NSF is reorganizing the Geology and Paleontology Program and is seeking input from sedimentary geologists concerning research directions in the upper crustal interval. This presents an opportunity to revise the perception that Sedimentary Geology is an "old" or "applied" science. Another contributing factor is the ever-increasing need for sedimentary geology specialists to work together, tackling some of the grand challenge problems that cannot be addressed by small groups with limited funding.

About a dozen people had an informal discussion at GSA about how to begin a sustainable process of getting community input on the future of our field. The consensus was to have a series of workshops, starting with the big picture and then dealing with http://serc.carleton.edu/earthworkshop02/.

A parallel effort in the sedimentary geology community will begin with the first Sedimentary Geology basic research forum in Dallas, in April 2004 around the time of the next AAPG/SEPM Annual Meeting. The workshop, co-sponsored by NSF, SEPM, and the National Center for Earth-surface Dynamics (NCED), is open to anyone interested in shaping the future of sedimentary geology. More information will be distributed as details are set, but please mark your calendars for the day just before the Dallas meeting, Friday, April 16.

Additionally, a small working group of ISES (Vladimir Davydov, Boise State; Rebecca Dorsey, University of Oregon; and Tim Carr, Kansas Geological Survey) has started an effort to understand the cyberinfrastructure (CI) needs of the stratigraphic and sedimentary geological community. In addition, a variety of data and tools are already available to work on stratigraphic information, as well as some ongoing CI efforts in this direction. This working group is planning an informal workshop at the Spring 2004 AAPG/SEPM meeting, so keep checking the SEPM website for its schedule (probably Monday evening, April 19).

CHRONOS is another major push forward that benefits all areas of stratigraphy and earth history and is funded by NSF. This effort was born out of combining several individual research efforts into a joint enterprise. Again, NSF helped to develop the collaboration with support for workshops, which helped focus the earth history community. CHRONOS's mission is to build a network of stratigraphic databases, tools and information, all centered on the goal of linking all of the data to geologic time. That is easy to say but to get involved with the details that need to be done check out the CHRONOS website at www.chronos.org.

Two more examples of recent efforts within sedimentary geology can be found at: **EarthTime** — website — http://www-eaps.mit.edu/earthtime/ and **National Center for Earth-surface Dynamics** — website — http://www.nced.umn.edu/

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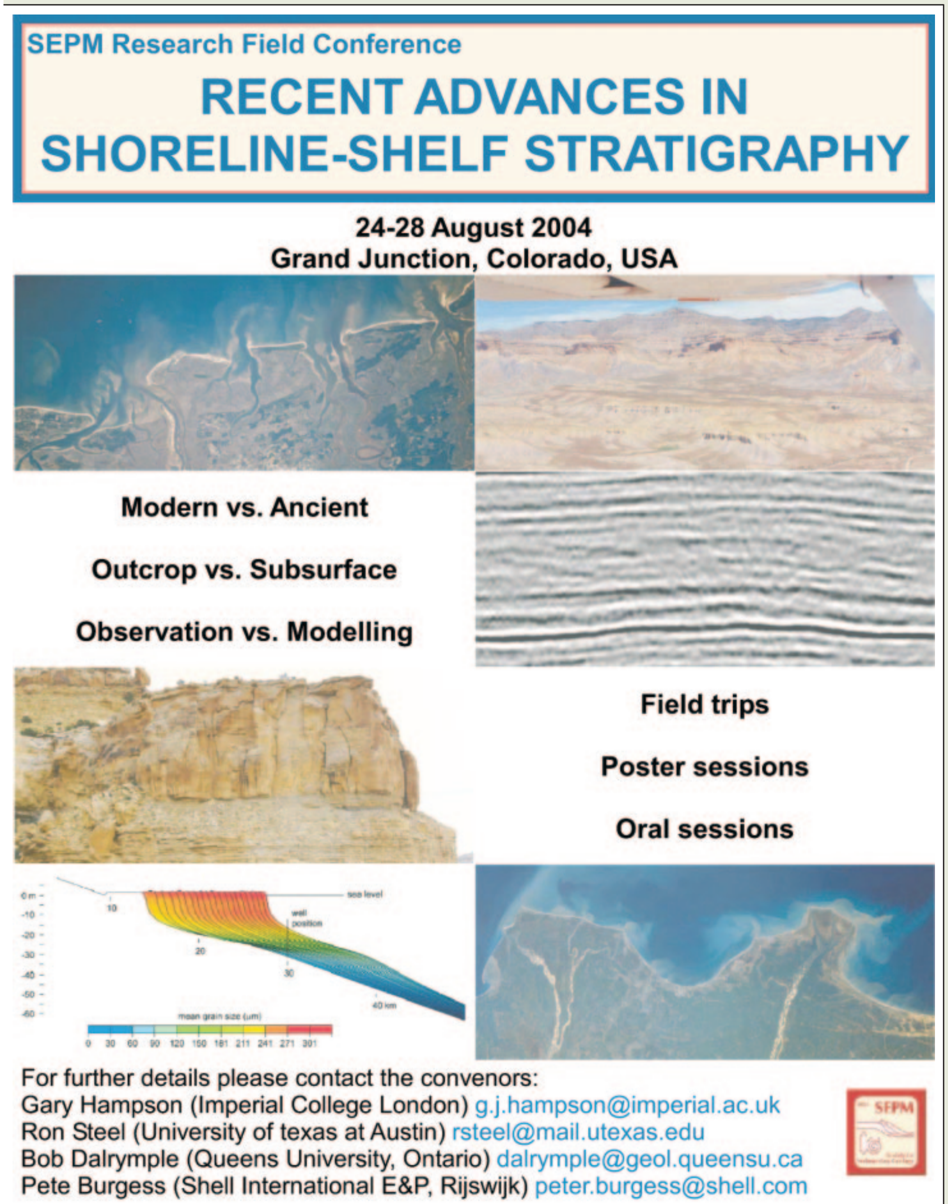

PRESIDENT'S OBSERVATIONS

A Letter to Geology Students

First, let me apologize to the old timers in the field. This letter is directed toward our younger colleagues who are still struggling to find their way through the gauntlet of higher education. To undergraduate students, hang in there. You have chosen an exciting field and, if you work hard, you will never regret your decision. Sedimentology, sedimentary geochemistry and paleontology are the frameworks on which Earth's changing environments are slowly being revealed. We are the true time bandits; capable of walking up to an outcrop and reconstructing the environment in which rocks were deposited millions of years ago. This is what lured me to geology and I have never regretted that decision. But be careful in your academic journey, there are some potential wrong turns.

Sedimentary geology, like every other field of Earth Science, is becoming increasingly more quantitative. We are now faced with trying to understand such complex problems as how quickly mountains are eroded and sediments are delivered to basins, the role of bacteria in sediment production and alteration, global climate change and its causes, pathways of contaminated sediments through surface and groundwater, and how strata record changing sea level, climate, and tectonic activity. As sedimentary geologists we are uniquely trained to determine if changes that are occurring on Earth today are due to human influence or part of natural cycles. These endeavors require strong backgrounds in the allied sciences: mathematics, physics, chemistry and the biosciences. It is a shame that some schools still do not require these supporting science courses as part of the Earth Science curriculum. Those students who follow that path will find their career options very limited. Indeed, the first major obstacle they will face will be that of gaining admission to graduate school, a critical point in one's career.

Undergraduates, you would be well advised to research the web sites of grad schools while you are still sophomores or juniors. Don't wait until your senior year to begin making this important decision. Learn now about standards for admission and research opportunities. If you have the opportunity to attend a society meeting, visit the graduate school booths. Choosing the right graduate school is one of the most important decisions you will make in your career. Choosing a specialization is another and you will need help with this one. Try to pick a graduate school where you will have options.

Graduate students, you will find many mentors who are eager to help you through the next stages of your career. Don't simply rely on your advisors to help you along the way. Become involved in professional societies and you will be delighted to discover geologists from both academia and industry who will share their experiences and knowledge with you. We are talking about your career, don't rely on advice from only a few to help guide you along your way. Professional societies provide vast opportunities for networking with senior colleagues. You will be welcomed into these societies.

I recently returned from the Geological Society of America meeting in Seattle. On Sunday there was a student breakfast, hosted by GSA and other societies, including SEPM, and sponsored by ExxonMobil. I was delighted to discover that there were no fewer than 500 students at the breakfast. I could not help but smile as I watched my colleagues don aprons and began serving the students. What a magnificent idea, but what a change from when I was a student. My first GSA meeting was in New Orleans and I was able to enter the icebreaker only after I found a nametag, which turned out to be that of a rather famous sedimentologist, lying on the floor. Back then students didn't get much of a break in registration fees, there were no student travel grants for meetings or student sessions, and there certainly was no student breakfast where one could meet and talk with leaders in the field. The profession has changed a lot since I started. Students have many opportunities to become engaged in the profession at an early phase of their career.

Undergraduates, work hard. The road to success and happiness is not an easy one to follow. Young sedimentary geologists who have made it to graduate school, you are very lucky. You have chosen an exciting profession. Your senior colleagues do care about you and will encourage you to succeed. Take advantage of these opportunities. You will never regret your involvement. Join a society and become engaged with your profession.

John Anderson*; President, SEPM*
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