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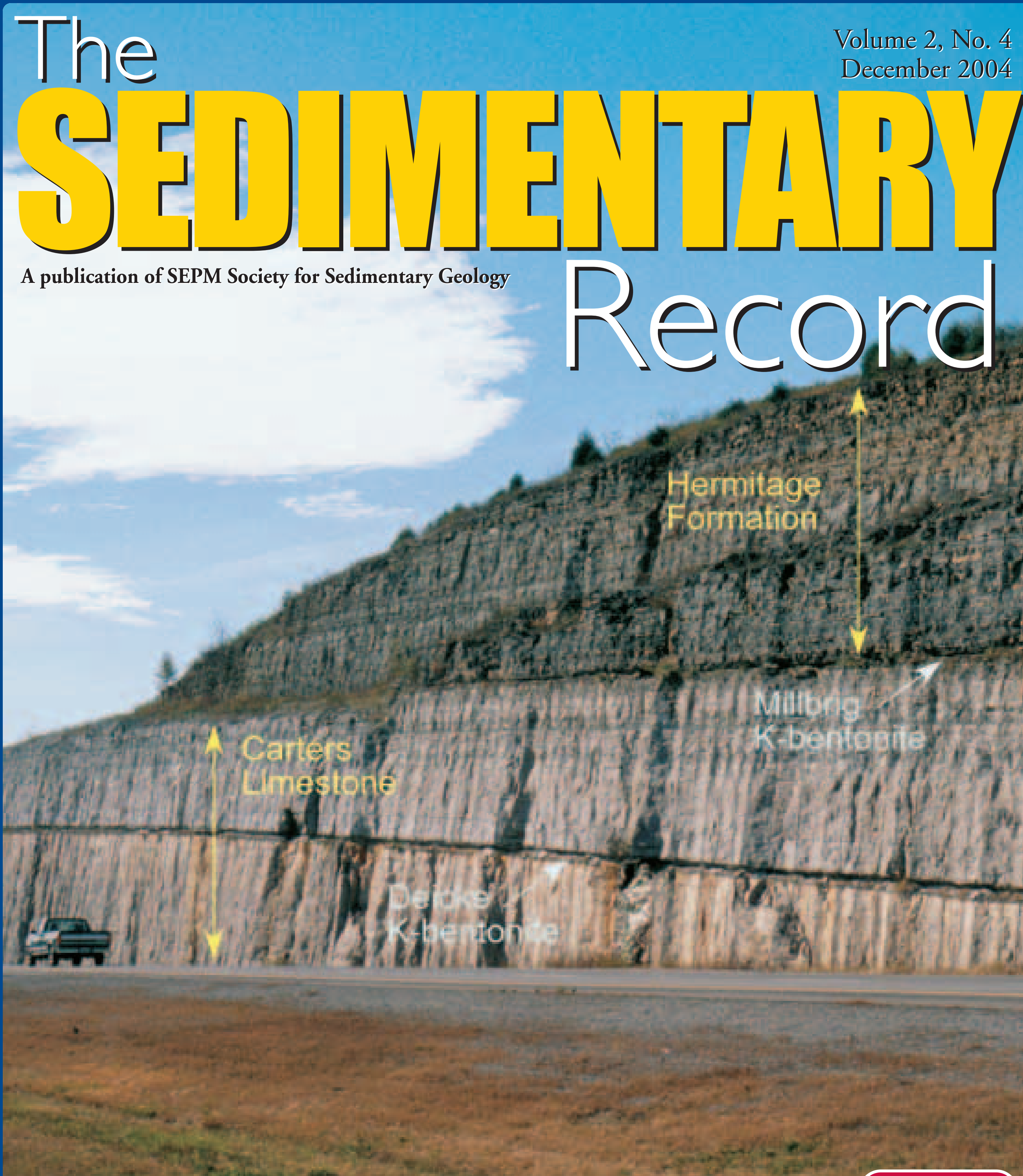

INSIDE: GREAT PHANEROZOIC ASH FALLS

1926 SEPM Society for Sedimentary Geology

On the Cover: *Outcrop along Highway 840 at Gladeville, Tennessee showing the upper Carters and lower Hermitage formations with the Deicke (lower dark bed) and Millbrig (next dark bed) K-bentonites. The Guttenberg $\delta^{13}C$ excursion starts in the lower Hermitage Formation above the Millbrig K-bentonite (see Bergström et al., this issue).*

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Manuscripts to be considered for publication should be submitted to the editors in electronic format, and preferably by e-mail. Upon acceptance, it is anticipated that papers will be published quickly.

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The Greatest Volcanic Ash Falls in the Phanerozoic:

Trans-Atlantic Relations of the Ordovician Millbrig and Kinnekulle K-Bentonites

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ABSTRACT

Beds of altered volcanic ash (K-bentonites) are often widespread geographically, but they generally occur sporadically in the lower Paleozoic geologic record. Most occurrences have been recorded from North America, northern Europe, and Argentina. These ash beds are in most cases less than 20 cm thick but three exceptional beds in the Ordovician, the Deicke and Millbrig in North America and the Kinnekulle in northern Europe, reach thicknesses of 1-2 m or more and can be traced over millions of km^2. Each has an estimated dense rock equivalent volume of around 1000 km^3 or more, and they represent the largest Phanerozoic volcanic ash falls recorded. Various lines of evidence, particularly biostratigraphic and chemostratigraphic, indicate no significant age difference between the Millbrig and Kinnekulle beds but whether or not these originated from the same gigantic eruption(s) is still speculative. At any rate, these ultraplinian eruptions appear to have been derived from a volcanic arc or microplate subduction zone along the eastern side of Laurentia. In view of their enormous size and continent-wide distribution, it is surprising that these ash beds are not directly associated with any notable faunal extinction event or any significant lithologic change in the sedimentary record.

Figure 1: Outcrop of the Millbrig K-bentonite along U.S. Highway 68 at entrance to Shakerstown, Kentucky. The ash bed is about 70 cm thick at this section. Head of top hammer marks the base of the bed.

INTRODUCTION

In terms of destruction of land and life, volcanic eruptions surely rank as some of our planet's most severe catastrophes. In the time interval of human history, some such eruptions have been especially devastating, perhaps the most well-known one being the Vesuvius eruption in 79AD. As vividly reconstructed in Robert Harris' (2003) fascinating novel *Pompeii*, this disastrous eruption destroyed in a couple of days the towns of Pompeii, Herculaneum, and Stabiae and killed virtually all of their inhabitants.

The presence of volcanic ash beds in many geologic successions provides evidence of similar, but in many cases far greater, volcanic ash eruptions in the Earth's pre-human history. The present account centers on beds of altered volcanic ash, known as K-bentonites, in the lower Paleozoic of North America and northern Europe. In the Cambrian K-bentonite beds are apparently rare but more than 60 such beds have been recorded from the Ordovician of North America and more than 150 from Baltoscandia (Kolata et al., 1996). Although Silurian (Bergström et al., 1998; Huff et al., 2000) and Devonian (Ver Straeten, 2004) K-bentonites have been recorded from several regions, such ash beds appear to be less common in those systems than in the Ordovician. Interestingly, concentrations of K-bentonites in the geologic record appear to reflect collisional orogenic episodes, many of the Ordovician and Devonian ones being coeval with the Taconic and Acadian orogenies, respectively.

The thickest and most widespread Paleozoic K-bentonites occur in the Middle Ordovician Mohawkian Stage in North America (Kolata et al., 1996) and in the Keilan Stage in Baltoscandia (Bergström et al., 1995). In North America, there are two particularly thick beds, the Deicke and the Millbrig K-bentonites (Figure 1), which have been traced over most of the eastern and central part of the continent (Huff and Kolata, 1990; Kolata et al., 1996; Fig. 2). In northern Europe, there is one especially prominent ash bed, the Kinnekulle K-bentonite, which has been identified across Scandinavia and the Baltic States and locally in Great Britain (Bergström et al., 1995). The Millbrig, Deicke, and the Kinnekulle are locally 1-2 m or more thick and before compaction, they apparently represented ash layers with an original thickness of at least four times that figure. The Millbrig covers an estimated area of at least 2.2x10^6 km^2 in North America and the Kinnekulle at least 6.9x10^5 km^2 in northwestern Europe. In terms of dense rock equivalent, the silicic magma is estimated to have been 1509 km^3 for the Millbrig and 972 km^3 for the Kinnekulle (Huff et al., 1996). These values do not include the vast quantity of volcanic ash presumably deposited in the Iapetus Ocean between Baltica and Laurentia and subsequently subducted. The truly gigantic size of these ash falls is indicated by the fact that the dense rock equivalent of the 1980 Mt. St. Helens eruption is estimated at 0.2 km^3 (Huff et al., 1992). These enormous ash falls are the largest recorded in the Earth's Phanerozoic history.

Many aspects of the distribution, mineralogy, bio- and chemostratigraphy, isotope geology, and the eventstratigraphic and paleogeo-

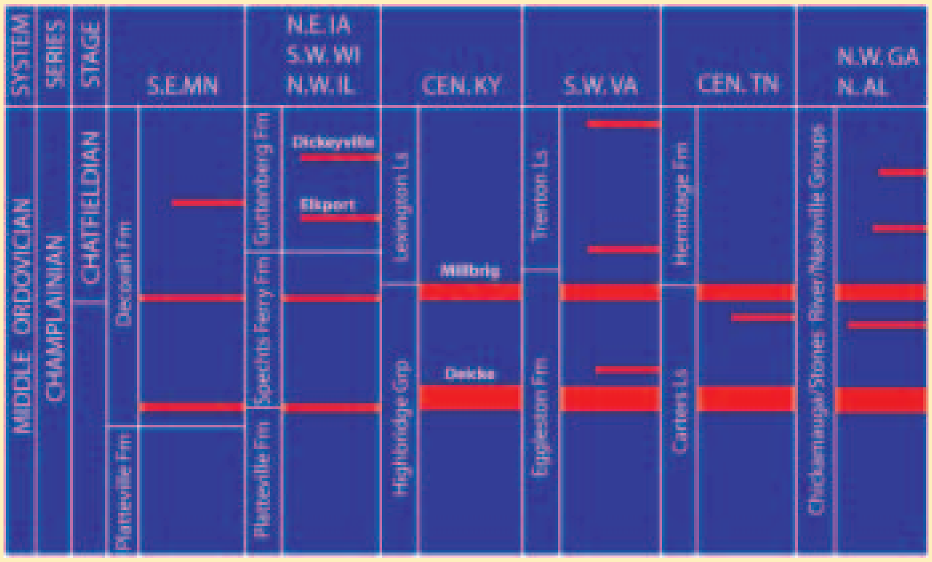


Figure 2: Stratigraphic cross section from Minnesota to Alabama-Georgia showing the stratigraphic position of the Millbrig and Deicke K-bentonites. (Modified from Huff and Kolata, 1990.)

graphic significance of these ash beds have been investigated, particularly during the last two decades (see, e.g., Kolata et al., 1996). One interesting problem that has attracted special attention and some recent controversy is whether the Millbrig and the Kinnekulle beds are equivalent and may represent the same colossal eruption. If that was the case, the combined dense rock equivalent of these beds would be on the order of 2500 km^3. Such an eruption ought to have had profound climatic and biological effects on a global scale. In the present contribution, we summarize various types of data that bear on the consanguinity of these extraordinary ash beds.

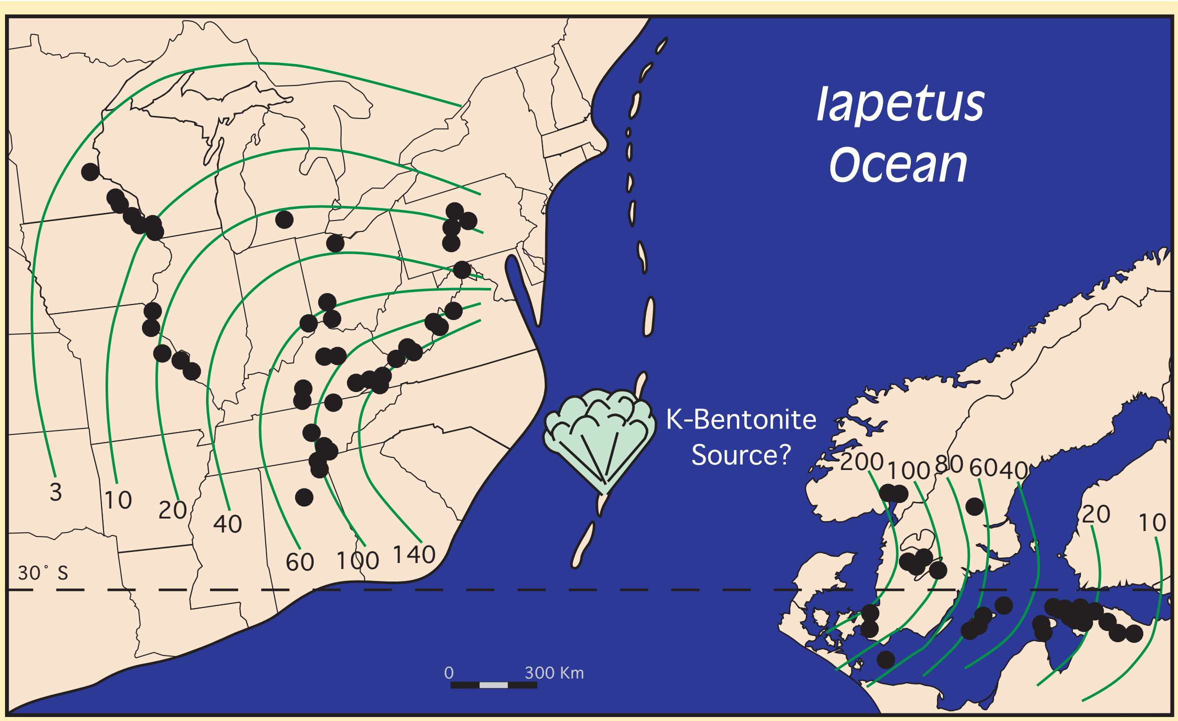
DISTRIBUTION

As noted above, the Millbrig has been identified over much of eastern and central North America, from the Mississippi region and Oklahoma to the Appalachians (Kolata et al., 1996; Figure 2). A maximum thickness map produced by Huff et al. (1996; Figure 3) shows a gradual increase in thickness from a few cm in the Mississippi Valley to 1-2 m in the southeastern portion of the continent suggesting that the source volcano(es) of the ash was located off the southeastern part of the continent (present-day coordinates). A similar map of thickness trends of the Kinnekulle bed (Huff et al., 1996; Figure 3) shows a marked thickness increase from Estonia to southwestern Sweden and southern Norway which indicates that the source of the ash was located southwest of Scandinavia. Both in North America and Baltoscandia, these thickness trends are associated with a general increase in grain size toward the source area. According to Huff et al. (1996), the grain size and distribution patterns indicate that the ash originated from plinian and co-ignimbrite eruptions and that the pyroclastic material was widely distributed by equatorial stratospheric and tropospheric winds. Plotted on widely used paleogeographic reconstructions, the distribution patterns of the Millbrig and Kinnekulle beds (Figure 3) are not in conflict with the idea that they had a common source. Although interesting, these distribution patterns do not provide any conclusive evidence of the direct source relationships of these ash beds.

BIOSTRATIGRAPHY

Of crucial importance for clarifying the relationships between the Millbrig and Kinnekulle beds is obviously to be able to demonstrate that they are of the same age. Possible methods for this include biostratigraphy and radiometric dating but both these approaches have their special problems. Fortunately, both the Millbrig and the Kinnekulle beds occur in successions containing biostratigraphically highly diagnostic fossils such as graptolites and conodonts. In North America, e.g. in the section at Strasburg, Virginia (Finney et al., 1996), the Millbrig is associated with graptolites of the

Figure 3: Sketch map of central and eastern USA and Baltoscandia showing study localities (dots) and thickness trends (cm) of the Millbrig and Kinnekulle K-bentonites, respectively. (Modified after Huff et al., 1996.) The contours are estimated based on the thicknesses recorded at sites marked by dots. Contour estimates far away from data points are less well constrained.



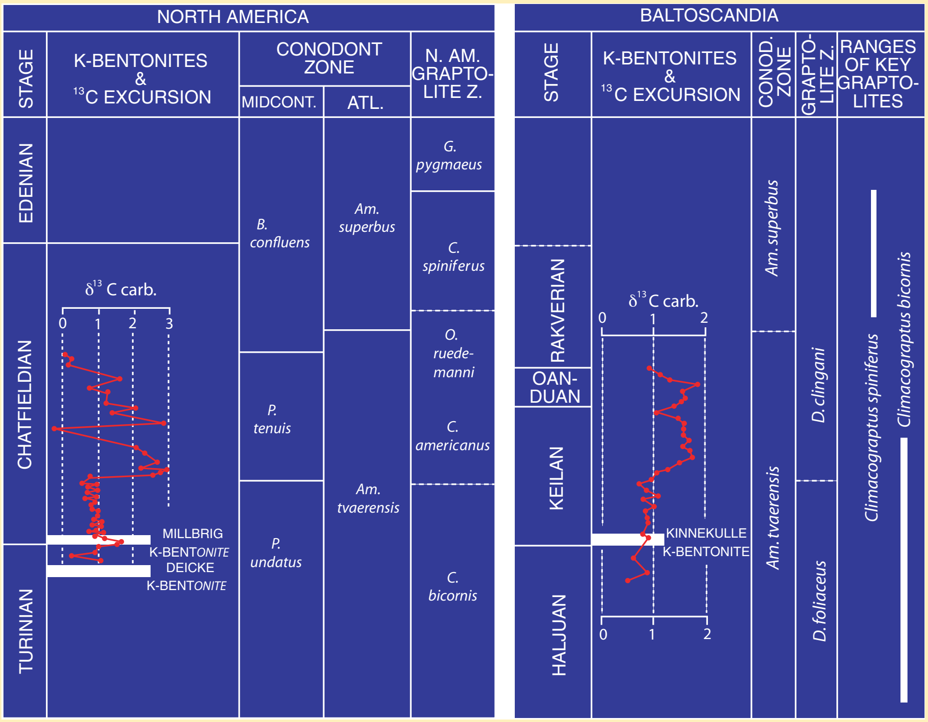


Figure 4: Biostratigraphic classification of the Millbrig and Kinnekulle K-bentonites, position of the GICE $\delta^{13}C$ excursion, and the stratigraphic ranges of some key graptolites. The North American $\delta^{13}C$ curve is from Lexington, Kentucky, and the Baltoscandic one from Fjäcka, Sweden (after Saltzman et al., 2003). Note that these different types of evidence strongly suggest that these K-bentonites occupy a closely similar, or the same, stratigraphic position.

highest part of the *C. bicornis* Graptolite Zone, and at many other localities, such as at Lexington, Kentucky, the Millbrig occurs in the upper part of the North American *P. undatus* Conodont Zone (Richardson and Bergström, 2003), at a level well below the top of the Atlantic *A. tvaerensis* Conodont Zone (Saltzman et al., 2003; Figure 4). Hence, the biostratigraphic position is well established in terms of standard North American zone units. Because of faunal provincialism, different graptolite zones are used in Baltoscandia and in North America and the Kinnekulle bed is in the upper part of the *D. foliaceus* (formerly *multidens*) Zone (Huff et al., 1992). Trans-Atlantic correlations are, however, facilitated by the fact that the Baltoscandic succession contains some North American zone index graptolites such as *Climacograptus bicornis* and *Climacograptus spiniferus*. Similar to its range above the Millbrig in the USA, the former ranges stratigraphically up to somewhat above the Kinnekulle bed, and as in North America, *C. spiniferus* appears slightly higher than the disappearance of *C. bicornis*. Hence, in terms of graptolite biostratigraphy, the Kinnekulle bed occupies a closely similar position to the Millbrig bed. The Kinnekulle bed is just above the top of the *B. alobatus* Subzone of the *A. tvaerensis* Conodont Zone (Saltzman et al., 2003) but because of biofacies differences, it has proved difficult to establish the precise level of the top of the latter conodont zone although it is evidently in the lower part of the Moldå Formation (Saltzman et al., 2003) at a level well above the Kinnekulle K-bentonite. It is concluded that based on the good stratigraphic resolution of these key index fossil groups, there is no recognizable difference in the biostratigraphic position of the Millbrig and the Kinnekulle beds (Figure 4). It might be noted that the correlation of the Millbrig with a level in the lower Pirguan Stage (*D. complanatus* Zone) of Baltoscandia by Kaljo et al. (2004, fig. 5) is improbable and in conflict with all biostratigraphic evidence. As shown by Goldman and Bergström (1997), the *D. complanatus* Zone corresponds to part of the Richmondian Stage of the Upper Ordovician in North America, an interval several stages above the position of the Millbrig in the upper Middle Ordovician Chatfieldian Stage.

CHEMOSTRATIGRAPHY

Extensive research in recent years (see, e.g., Ludvigson et al., 2004; Saltzman et al., 2003) have shown that a prominent $\delta^{13}C$ positive excursion is present in the early Chatfieldian stratigraphical interval just above the Millbrig K-bentonite. This excursion was first recognized in the Guttenberg Member of the Decorah Formation of Iowa (Hatch et al., 1987) and is now known as the GICE (Guttenberg Isotopic Carbon Excursion). It has been identified not only over much of the eastern and central USA but also in the Great Basin (Saltzman and Young, 2005) and has proved to be of extraordinary value as a chemostratigraphic correlation tool. Depending on the local magnitude of net depositional rate, it begins 2-10 m above the Millbrig bed in most sections and ends below the base of the *A. superbus* Conodont Zone. Importantly, recent chemostratigraphic work in Baltoscandia (Saltzman et al., 2003; Ainsaar et al., 2004) has led to the discovery of a very similar, prominent $\delta^{13}C$ excursion one to a few m above the Kinnekulle bed. Apart from the latest Ordovician (Hirnantian) $\delta^{13}C$ positive excursion, this is the most conspicuous such excursion in the Middle and Upper Ordovician of both North America and northern Europe. Because many such excursions have been shown to have a global distribution, there is little doubt that this Baltoscandian excursion is the same as the North American

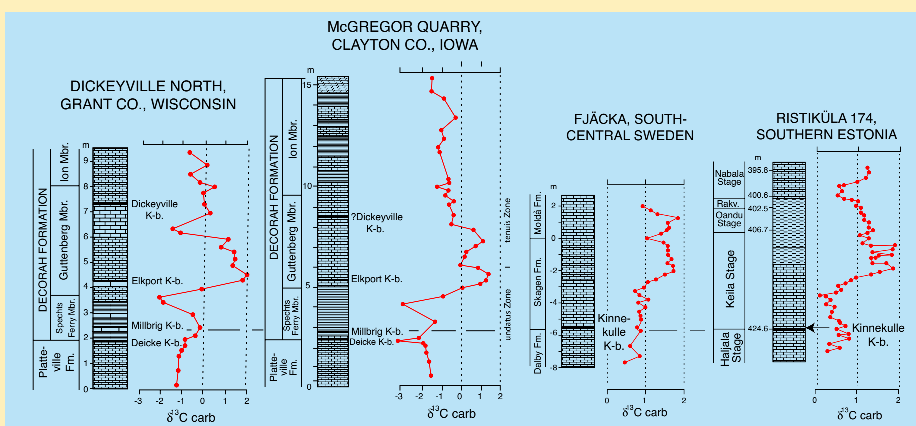


Figure 5: Comparison of the GICE carbon isotope excursion at some North American and Baltoscandian localities and its relation to the Millbrig and Kinnekulle K-bentonites, respectively. See Ludvigson et al. (2000) for data in Iowa and Wisconsin. See Ainsaar et al. (2004) for Estonia data.

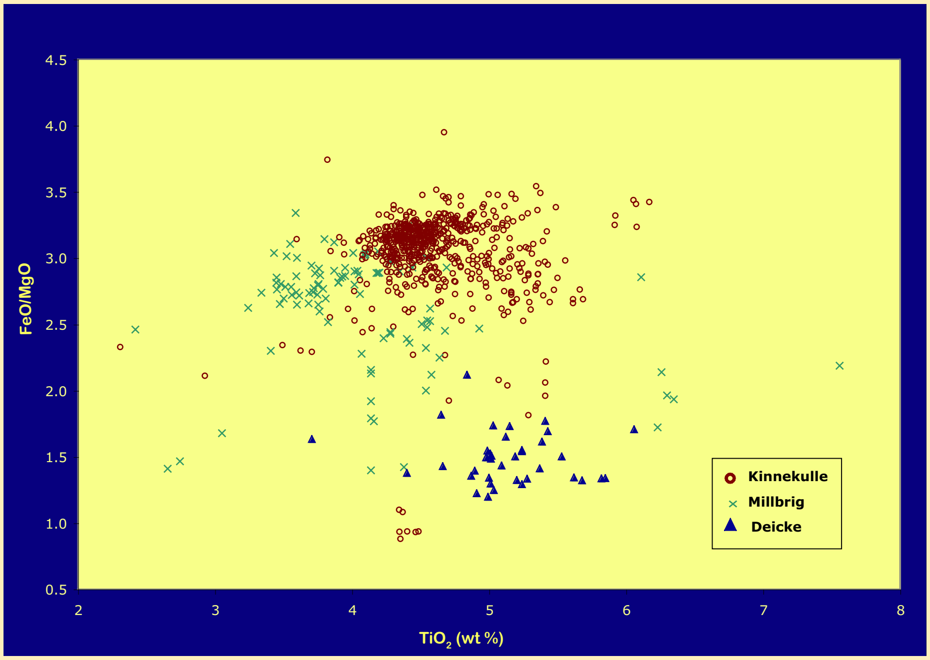


Figure 6: Bivariate plot of TiO_2 vs. FeO/MgO from more than 800 biotite analyses from the Deicke, Millbrig, and the Kinnekulle K-bentonites. Note that most of the Deicke samples plot separately whereas those of the Kinnekulle and Millbrig show considerable overlap suggesting that the Deicke bed is a single event deposit whereas the two other beds represent more than one eruptive event (from Huff et al., 2004).

GICE (Saltzman et al., 2003; Ainsaar et al., 2004). The very close similarity in stratigraphic position of the GICE to the Millbrig and Kinnekulle beds (Figure 5) provides powerful chemostratigraphic evidence of the coeval nature of these ash beds.

GEOCHEMISTRY

Recent comprehensive studies have shown that chemically, including both major and trace elements, the Millbrig and Kinnekulle K-bentonites are quite similar (Huff et al., 1992, 1996; Kolata et al., 1996). Chemical fingerprinting methods have been used to identify the Millbrig regionally in North America (Kolata et al., 1987; Mitchell et al., 2004) and corresponding work has been carried out on the Kinnekulle bed in Sweden and Estonia (Bergström et al., 1995; Kiipli et al., 2004). In a study of the chemistry of volcanically generated biotite phenocrysts from the Millbrig and the Kinnekulle beds, Haynes et al. (1995) recognized a difference between these ash beds in terms of their content of FeO, MgO, Al_2O_3, MnO, and TiO_2 that they interpreted as indicating separate eruptive events. Recent more comprehensive studies (Huff et al., 2004; in review) show that both Millbrig and Kinnekulle include multiple ash beds that apparently represent separate, in time very closely spaced, eruptions. In terms of chemical composition, some of these layers in the Millbrig and the Kinnekulle are indistinguishable (Figure 6) and they may be the products of the same eruption(s). Other layers are compositionally slightly different and may be the record of separate eruptions. Clearly, the compositional variations through these ash beds are more complex than suggested by previous work and their relations to different eruptions and perhaps different eruptive centers need further study.

RADIOMETRIC DATING

During the last 50 years, about a dozen different isotopic age dates have been published for each of the Millbrig and the Kinnekulle beds. They show a considerable spread (more than 10 million years for each bed) which at least partly reflects the use of different isotopic methods. However, there is no obvious trend toward concentration of even the recent datings to more precise isotopic ages. The problems with dating these ash beds are illustrated by the data in Min et al. (2001) who, using the $^{40}Ar/^{39}Ar$ method, not only found an age difference of about 7 m.y. between the Millbrig and the Kinnekulle but also dated the Millbrig as being about 447 Ma. In terms of recently published time scales (e.g., Webby et al., 2004) the latter date would place the Millbrig high up in the Upper Ordovician (Richmondian) which, as indicated above, is in drastic conflict with biostratigraphic and chemostratigraphic data, as well as with other isotopic dates for this bed. Accordingly, we conclude that the precision of current radiometric datings is currently not good enough to successfully assess whether or not the Millbrig and the Kinnekulle beds are equivalent.

PALEOGEOGRAPHY

Geochemical studies of the trace elements of the Millbrig and Kinnekulle beds (Huff et al., 1992; 1996; Bergström et al., 1995) indicate that their source volcano(es) was associated with an active subduction zone, possibly along an island arc or a microplate. Because the western side of Baltica is thought to have been a passive margin, Huff et al. (1996) considered it more likely that the source of the volcanic ash was located on the North American side of the Iapetus Ocean (Figure 3), possibly a region such as the Oliverian Terrane (McKerrow et al., 1991). Although such a position of the source volcano(es) is in general agreement with the distribution patterns of the Millbrig and Kinnekulle volcanic ashes, no potential source volcano(es) has been identified and the precise location of the ash eruption site(s) remains speculative. It is quite possible that this volcanic source region subsequently was subducted.

CONCLUSIONS

A review bearing on the consanguinity of the these two giant ash falls shows that based on biostratigraphy and chemostratigraphy, they are closely similar, if not identical, in age. At least parts of these huge ash deposits are also indistinguishable chemically and their geographic distribution patterns are in agreement with the idea that they originated from the same region and even shared the same source volcano(es). Radiometric datings are considered inconclusive regarding the possible age equivalence of the Millbrig and Kinnekulle beds. Regardless of whether the ash accumulations represented the same eruptions, or separate eruptions closely spaced in time, the formation of these deposits represent mega-catastrophic events of a unique magnitude in the Earth's Phanerozoic history. In view of this, it is highly notable that the rock record shows no relation to any marked climatic effects and to any general extinction event in the marine faunas as one would expect from such a large-scale catastrophe.

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AN INTERNATIONAL COMMUNITY

SEPM is an international society, committed to being a leader in the global sedimentary geology community. We have members in many countries and the majority of our new members are international. Currently, 35% of our total membership (1328 of 3752) come from outside the U.S. These members are distributed around the globe and occupy every continent except Antarctica, although I am sure we have temporary residents there during the summer field season. Members in North America reside in the U. S., Canada, Mexico, and the Caribbean. Our African members occupy the length and breadth of that continent, from Algeria, Morocco, and Egypt in the north to Namibia and South Africa in the south, to Nigeria and Ghana on the west, and Sudan in the east. We have 661 European members representing almost every nation in that region, including Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, and Switzerland. Our Asia contingent is 217 strong and reside from India on the west, to Japan on the east, to Australia and New Zealand in the south, and include representatives from Brunei, Indonesia, Malaysia, Philippines, Singapore, Sri Lanka, Taiwan, and Thailand. South America includes members from Argentina, Brazil, Columbia, Ecuador, Peru, and Venezuela. Our Middle East members come from throughout the region including Iran, Iraq, the Gulf States, Saudi Arabia, Jordan, and Turkey. Our Society truly does connect a global community.

SEPM's mission as a Society is to exchange and disseminate knowledge in Sedimentary Geology. Our primary means to do this are our meetings, research conferences, and publications. Meetings and conferences are conducted in partnership and collaboration with AAPG, GSA, and the IAS. Our partnership with AAPG, is a particular focus, and involves contributing our expertise at the annual meeting, as presenters at technical sessions, sponsors and leaders of technical sessions, short courses, and field trips. Our publications continue to enjoy strong support around the world, and our research conferences target leading edge topics across the wide range of our discipline. Although our efforts to fulfill our mission draw on a variety of venues, Sedimentary Geology is a global science, and we must increase our efforts to engage the international community. We must include, in more direct ways, the wealth of talent and science of our global membership.

It seems evident that SEPM needs to increase participation in international conferences and meetings. Let me throw out some ideas that I have been gathering in discussions with members and officers of our Society. Potential venues for increased engagement include broadening our sponsorships to focus on meeting sessions and research topics where we have common interests with IAS; and partnering with AAPG in their international meetings. To test new ideas and emerging concepts in our field and facilitate scientific exchange, SEPM could also co-sponsor field seminars to classic field areas around the globe. We could encourage and sponsor new regional sections that would allow increased participation by our international members. We currently have international sections in South America, and Central Europe. Other regions with a critical mass of members include Japan, and Australia-New Zealand. Perhaps we should also think about defining and electing regional international counselors. Possible regions are Austral-Asia, Europe/Africa, and the Middle East. In addition, we could include in the Sedimentary Record, news from around the world on advances in our science, and updates on upcoming research conferences. This would enhance communication among our members and ensure that our science is spread widely around the globe. All of the above are just a number of possible ideas for advancing our mission. We will be discussing our international strategy at our fall Council Meeting at the GSA meeting in Denver. I'd like to hear from you, the members. Let me know you're ideas, and I hope to see many of you in Denver.

Rick Sarg, President SEPM
rick.sarg@exxonmobil.com

COMMENTS FROM THE COUNCIL

SEPM Research Committee Activities

Scientific societies are an essential part of the research environment. In my opinion, one of the main goals of a scientific society is to promote the understanding and technical interaction in a particular field. In the case of SEPM, the challenge is to promote the integration of a much diversified collection of earth-sciences disciplines grouped under the umbrella of "Sedimentary Geology." Many of these disciplines have common language and tools, being directly related to industry and broad research lines in academia. They often are the main themes of national and international meetings (e.g., sequence stratigraphy, sedimentology, and paleoclimatology). Other disciplines are more specialized (e.g., numerical modeling of sedimentary processes), or are at early stages of development (e.g., planetary geology), and normally involve a smaller number of specialists in their meetings. The SEPM Research Conferences were designed to offer the specialists an opportunity to have scientific meetings with a more focused scope and more limited attendance (30 to 75 participants).

Research Conferences are designed to stimulate new research areas. SEPM tries to promote up to 4 conferences a year, in the US and abroad, and also to encourage the organizers to prepare a SEPM Special Publication volume after the meeting. The main responsibilities of the SEPM Research Committee are to generate ideas for Research Conferences and to propose topics for SEPM Special Publications. The committee is also responsible to evaluate proposals for Annual Meeting Research Symposia, Short Courses, and Research Groups. The committee has representation from different disciplines that are part of the society: clastic and carbonate sedimentology, sedimentary processes, paleontology, geochemistry and seismic stratigraphy, with a balanced participation between academia and industry.

The current committee members are: Vitor Abreu (ExxonMobil, Chair), Joe Curiale (Unocal), Andre Droxler (Rice University), Carlos Pirmez (Shell), Gene Rankey (University of Miami), Morgan Sullivan (University of California at Chico), and Laura Crossey (University of New Mexico, SEPM Special Publications Editor).

SEPM has a full agenda planned for next year. At the 2005 AAPG/SEPM Annual Meeting (June 19-22), SEPM will present the Research Symposium: Transportation, Accumulation, Colonization, and Stratigraphic Organization of Muddy Sediments. There is also a selection of excellent Short Courses and Field Trips, so be sure to check them out.

There are three research conferences in the schedule for 2005. You can read about them in the notices in this issue and details about them are online at the SEPM Website. Two are currently open for registration, so please take a close look and consider attending one of these excellent conferences.

And there are more to come in 2006. If you would like to propose a research topic for a conference, symposium or special publication, please contact SEPM through our Executive Director, Howard Harper (hharper@sepm.org) for more information.

Vitor Abreu
SEPM Councilor for Research Activities

Fluvio-Deltaic? Make Up Your Mind!

INTRODUCTION

The term fluvio-deltaic is common in geologic publications and in oil company reports. It is often used to describe channelized sand bodies deposited by some combination of the processes operating in rivers and deltas. While it may be reasonable to describe a sedimentary section as being fluvio-deltaic, we need to be more specific when we try to explain the origin of individual oil and gas reservoirs – especially when constructing reservoir models. I use examples from Southeast Asia to highlight the importance of taking a stand, and offer a few suggestions to help geologists get off the fence.

WHY WE USE THE TERM

Use of the term fluvio-deltaic reflects the gradual change in sedimentary processes from a fully fluvial system, operating in alluvial plains and the upper delta plain, to the truly deltaic processes that operate at the delta front. Interfingered fluvial, deltaic, and marine strata are deposited over time due to changes in eustatic sea level, coastal progradation, and switching of major distributaries. Thus the term can be used in a general sense to describe a section of alternating fluvial and deltaic strata.

The expression begins to suffer abuse when we apply it to individual reservoir sands. This may simply be a reflection of uncertainty whether a sinuous, channelized sand body was deposited within a river or a distributary channel, but it may also reflect the interpreter's desire for the reservoir to be something better than it really is. Our models get nudged in a basinward direction due to a general perception that deltaic sand bodies are larger than those of fluvial origin. While it is true that some delta front sands are deposited over large areas, Reynolds (1999) showed that the average width of distributary channel sands is smaller than that of fluvial channels (500 meters and 750 meters, respectively).

ANOTHER SOURCE OF CONFUSION

Surprisingly, geoscientists continue to be confused about just what is a delta. A commonly cited model for deposition of Miocene sandstone in the Gulf of Thailand depicts a precursor of the Chao Praya River system extending across the gulf during low stands of sea level. The model places a delta where the river terminates at the ocean, south of Vietnam, and predicts deposition of fluvial and deltaic sandstone as the shoreline advanced and retreated. Curiously, illustrations of this model often depict an estuary at the river mouth (the ocean protrudes into the coastline) instead of a delta. Now we have to wonder if some fluvio-deltaic sandstones should bear that name at all.

WHY IT MATTERS

Once we get into the business of reservoir modeling, we need to make up our minds about where the sand was really deposited. Differences in the orientation and extent of permeability barriers and differences in sand texture between fluvial, deltaic, or estuarine reservoirs have implications for reservoir simulation, well targeting, and development plans.

Thailand provides a good example of modern-day reservoirs in the making (Figure 1). The Central Plain of Thailand can be divided into two distinct physiographic zones (Figure 1). The Lower Central Plain is an area of very low relief with an average elevation of only 2 meters above sea level. It formed following the Holocene transgression by coastal progradation (Sinsakul, 1997; Sinsakul, 1992; Dheeradilok, 1992). Tidal processes strongly influence the rivers (Sinsakul, 1997), and the classic straight – meandering – straight fluvial pattern described by Dalrymple et al. (1992) can be seen. In contrast, the Upper Central Plain is made up of a series of great dissected terraces formed from flood plains of the Ping, Wang, Yom, and Nan river systems. Sandy point bars can be observed in satellite images of the Upper Central Plain. They cannot be observed in the Lower Central Plain; this reflects a decrease in relief and stream gradient and an increase in tidal influence to the south. The boundary between the upper and lower Central Plain marks the point of maximum marine transgression and coincides with a break in slope. Therefore, it marks the bayline (Shanley and McCabe, 1994; Allen and Posamentier, 1993; Van Wagoner et al., 1990). Net energy available for bedload transport is reduced in fluvial channels downstream of the bayline due to reduction in gradient and interaction with marine processes (Dalrymple et al., 1992); thus the average grain size of sand deposits would be reduced. A similar low gradient surface is seen in delta plains of the region, which were also built following the Holocene transgression.

Sand deposits of the meandering fluvial systems in the Northern Central Plain are found in elongate belts containing numerous point bars. The meander belts contain abandoned channels, such as oxbow lakes and clay drapes across lateral accretion surfaces that will act as permeability barriers. Carter (2003) showed how lateral accretion surfaces influenced the response of oil wells when water was injected into the Widuri Field of Indonesia.

In the Lower Central Plain point bars become muddy due to the influence of tides. Sand deposition appears to be restricted to the

Figure 1. Map of Indochina showing the locations of the Thai Central Plain, Tertiary basins in the Gulf of Thailand, and deltas. Dimensions of the Tertiary basins are an indicator of the accommodation space available for delta development during the Miocene.

channels and possibly tidal mouth bars. Coleman (1970) showed that sand deposition in small high tidal deltas of Southeast Asia was also restricted to the channels. The daily slack-water period at high tide reduces vertical permeability through the deposition of numerous clay drapes. Bedding surfaces in mouth bars are inclined basinward due to progradation, and clay drapes along these surfaces also impact permeability. Ainsworth et al. (1999) demonstrated how incorporation of such surfaces into reservoir models of mouth bar sands resulted in lower recovery factors for oil in the Sirikit Field of Thailand.

SOME SUGGESTIONS

Perhaps you didn't need me to convince you of the importance of deciding between rivers and deltas, but the choice can still be still difficult. Here are a few thoughts that might help you make a stand:

• First consider whether the geologic setting was appropriate for the formation of deltas. A comparison of the areas of the Tertiary basins in the Gulf of Thailand to major deltas in the region (Figure 1) shows that there was insufficient accommodation space for the development of large deltas. Only small bay head deltas were possible. The size of the watershed is an important factor as well. The relatively small watershed of the Thai Central Plain compared to that of the Irrawady and Mekong River systems must be a contributing factor for the lack of a delta south of Bangkok (Figure 1).

• Deltaic sequences should have clear upward-coarsening and upward-thickening sand units. Fluvial sands usually have sharp bases, but interbedded shales can provide other important clues. Foraminifera-bearing claystones have been useful for identifying estuarine units in the Gulf of Thailand (Teerman et al., 2000).

• In my Southeast Asian examples, there are significant textural differences in fluvial sands as compared to deltaic and estuarine sands. Sand-body geometry is also a useful discriminator since sand deposits downstream of the bay-line are more likely to be within channels rather than on point bars. Seismic data can sometimes be used to illustrate the development of point bars, as was shown by Carter (2003).

• Don't be tempted to choose a deltaic model just because it is a more optimistic view. Distributary channel sands have a smaller average width than fluvial channels (Reynolds, 1999).

Good luck getting off the fence!

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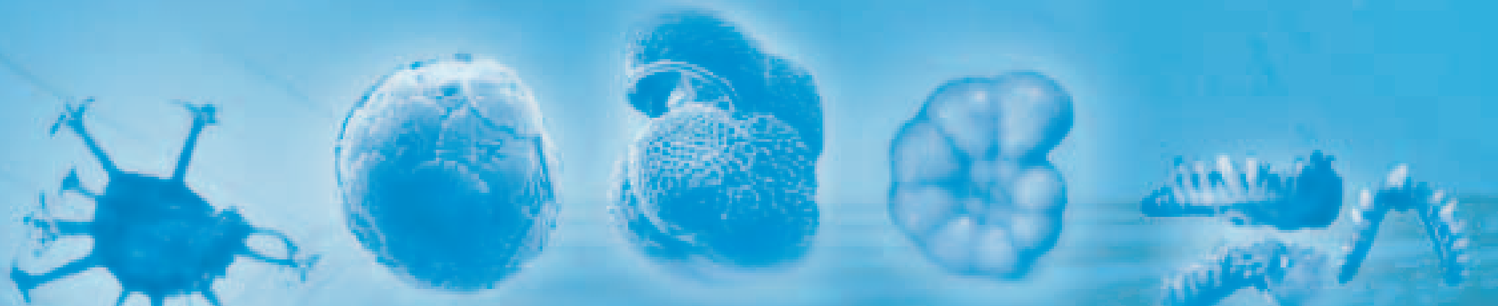
FINAL CIRCULAR



An International Conference
In Memory of Garry D. Jones
Geological Problem Solving with Microfossils
March 6-11, 2005
Rice University, Houston, Texas USA

SPONSORS

- North American Micropaleontology Section of SEPM (host organization)
- Gulf Coast Section SEPM
- SEPM (Society for Sedimentary Geology)
- The Micropaleontological Society
- American Association of Stratigraphic Palynologists
- International Nannofossil Association
- Cushman Foundation
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- Pander Society
- International Commission on Stratigraphy
- The Micropaleontology Project (Micropress)
- Geology Department, Rice University

PURPOSE

- Bringing together a diverse array of geoscientists to showcase the problem solving power of microfossils in a variety of geological settings

WHO SHOULD ATTEND

- Geoscientists wanting to learn more about the geological application of microfossils
- Professionals in microfossils from industry, academia, museums, and government agencies
- Students

ICEBREAKER (March 6)

- Warwick Hotel, Terrace Lounge

FORUM (March 7-9)

- 2.5-day conference
- Over 60 Oral and Poster presentations
- Invited papers
- 2004 Time Scale Roundtable Discussion

PLENARY DINNER (March 8)

- Houston Museum of Natural Science
- Tribute to Garry Jones
- Guest Speaker, IMAX Theater

SEPM FIELDTRIP (March 10-11)

- Upper Cretaceous of Central Texas
- Cost US$295, includes meals and accomodations

PUBLICATIONS

- Conference program with abstracts
- Post-conference SEPM Special Publication

- Visit the official Conference Website **www.sepm.org/microfossils2005.htm** for detailed information
- Registration ends **Feburary 15th, 2005** via the website
  - Registration fee US$250 Professional, US$125 Students; Late registration US$300, One-day registration US$125
  - Registration includes admittance to all technical sessions and social events, plus abstracts volume
- Hotel reservations required by **February 4th, 2005** via the hotel website **www.warwickhotelhouston.com**
  - Enter Group Code "Micro" to receive the special conference room rate

Direct all inquiries by e-mail to Thomas Demchuk (Thomas.D.Demchuk@conocophillips.com)

Microfossil images courtesy of The Natural History Museum (London), Mitch Covington, and Gulf Coast Section SEPM