Applications of Ichnology to Petroleum Exploration

A Core Workshop

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S. George Pemberton

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PREFACE

The field of ichnology (the study of animal-sediment relationships) is undergoing rapid expansion. Increased significance is being attached to trace fossils in environmental and diagenetic interpretations of rock units and in establishing basic stratigraphic frameworks. The subject, therefore, is of importance not only for ichnologists but also for invertebrate and vertebrate paleontologists, paleoecologists, sedimentologists, stratigraphers, and resource geologists.

Unlike most other branches of paleontology, trace fossils are also amenable for study in subsurface core and as such, have proven to be powerful tools in subsurface facies analysis and sequence stratigraphy. The main purpose of this workshop is: a) to introduce the basic concepts of ichnology; b) to learn how to recognise basic types of trace fossils in core; c) to place these structures in their appropriate paleontologic, sedimentologic, and stratigraphic content; and d) to integrate this data with other lines of evidence to aid in petroleum exploration.

The papers presented in this volume pertain to Cretaceous deposits in the Western Interior, especially the Western Canadian Sedimentary Basin. I have been fortunate enough to put together a series of papers that concentrate on marginal marine to shallow marine environments in siliciclastic systems. Where possible the authors have tried to place the rocks in a sequence stratigraphic framework and have highlighted how the ichnological data has strengthened their interpretation. I hope that this group of papers will serve to illustrate how an integrated approach using combined ichnologic, sedimentologic, and stratigraphic lines of evidence can constitute a powerful approach to subsurface facies analysis and interpretation.

On a more personal note, this volume is very special to me for two reasons. First it is dedicated to my dear friend and colleague Bob Frey who passed away January 1, 1992. Secondly because most of the authors are either past or present students who have gone through my program at the University of Alberta. One of the true pleasures of the teaching profession is being able to instruct graduate students. Since starting at the University of Alberta in 1984 I have been fortunate enough to be associated with a wonderful group of students who have been a source of great personal pride to me. Over these past eight years this group has included 5 PhD and 22 MSc students. Their collective contributions have made this volume possible.

S. George Pemberton
Edmonton, Alberta
1992
ACKNOWLEDGMENTS

This core workshop and volume were made possible only with the invaluable assistance of many people. I would like to thank Ray Garber of Chevron Canada for initiating the project, Ben Robertson of Chevron Canada for logistic support, and Trish Auberle, Robin Dixon and the SEPM staff for handling everything in a most professional manner. I would like to express my gratitude to Ray Shepard and the staff of the Energy Resources Conservation Board Core Research Facility for providing the venue. The graphics, photography, and typesetting were done by the skilled staff of Exxon Production Research and I thank photographer John Blankinship, typesetter Daryll Ritter, and illustrators Donna Bartels, Judy Becker, Larry Besong, Charles Burwell, Becky Everitt, Mack Johnson, Kevin Linke, Becky Miller, and Diane Reina for their efforts. Additional typing was done by Joanne Wells of Exxon and Catherine Yuill and John Bourak of the University of Alberta.

I would also like to thank two of my PhD students, Mike Ranger, who for the past five years has served as virtually a co-supervisor for my students and James MacEachern, who more recently has become a valuable addition to our program. Both of these people have gone way beyond what is expected and are always willing to share their experience and knowledge.

This volume was completed during my tenure as a visiting scientist at Exxon Production Research in Houston, Texas. A special thank you to John Van Wagoner for initiating my visit; his views on sequence stratigraphy gained from years of experience in the field and in industry has given me the opportunity to apply a new stratigraphic perspective to ichnology. I would also like to thank Bob Todd and Kirt Campion for their generous support of my work and the rest of the geologists at Exxon who have made my stay so memorable.

In conclusion, I must thank my wonderful wife Teresa, my daughters Sarah and Erin, and my son Joshua for all their love and support. I couldn’t do what I do without them!
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DEDICATION TO ROBERT W. FREY

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Robert Wayne Frey’s death, January 1, 1992 after a long and courageous fight with cancer, deprives Ichnology of one of its most influential figures. Bob will long be remembered for his monumental contributions to our understanding of the basic principles of organism-substrate relationships in both modern and ancient settings. In appreciation of his fundamental work, this volume is dedicated to Bob Frey’s memory.

Bob Frey’s career spanned a period of dynamic change in ichnology, from a time when ichnologists were few in number to the present day when paleontologists, sedimentologists and stratigraphers are concerned with trace fossil analysis to aid in their interpretations. To this rapid scientific evolution, the contributions of Bob Frey have been numerous, varied and almost always fundamental. He can be considered without doubt the “Father of American Ichnology”. He had a direct hand in shaping the modern principles of ichnology and we all owe him a great debt. A more detailed version of this memorial along with a complete list of Bob Frey’s publications will be published soon (Pemberton, 1992).

Bob Frey was born on a farm in Cleveland County, Arkansas on December 13, 1938. He graduated from the New Edinburgh High School in June 1956 and immediately joined the United States Air Force. He served from 1956-1960 and was honorably discharged with a top-security clearance. Bob then attended Lower Columbia College in Longview, Washington from 1960-1962. It was at Longview that Bob met and married Sharon Cowles who was a tower of strength for Bob during his long illness. In 1962, Bob transferred to the University of Montana in Missoula where he graduated with a B.A. in December, 1964.

At Montana Bob acquired a keen interest in paleontology and decided to do graduate work at Indiana University, where he came under the tutelage of Don Hattin. From Indiana Bob received the M.A. degree in 1967 and the Ph.D degree in 1969. His dissertation, entitled “Stratigraphy, ichnology, and paleoecology of the Fort Hays Limestone Member of the Niobrara Chalk (Upper Cretaceous) in Trego County, Kansas” stands, along with Richard Osgood’s “Trace fossils of the Cincinnati area”, as a benchmark in the development of ichnology in North America. Bob successfully applied traditional paleoecological concepts to trace fossils and used them as essential elements in the interpretations of the depositional history of the Niobrara.

He soon realized that in order to comprehend fossil traces, one must first observe and understand how recent organisms behave. His first introduction to modern organism-sediment relationships occurred while he was still at Indiana. He attended a field seminar at Beaufort, North Carolina and in typical Frey-style was able to translate his work into a series of four papers in the *Journal of Paleontology*. This has always been a trademark of Bob Frey, knowing instinctively how to optimize his research opportunities and then disseminate that information.

After graduation, Bob started his long and productive association with the University of Georgia, first as a Post-Doctoral Research Associate (1968 - 1969), then Research Associate, Marine Institute, Sapelo Island (1969 - 1970), Assistant Professor (1970 - 1974), Associate Professor (1974 - 1978), finally rising to the rank of Professor in 1978. It was at Sapelo Island
that Bob teamed up with Jim Howard, the resident sedimentologist at the Skidaway Institute of Oceanography in Savannah, Georgia. The main thrust of their joint work was an evaluation of the ichnology and geologic significance of present-day benthic organisms found in all major marine environments of Georgia: the continental shelf, inlet shoals, beaches, dunes, washover fans, relict mud deposits, estuaries, tidal flats, point bars, channel margins, and salt marshes. Their evaluations embraced:

1. characteristic environmental distributions of animals and plants and their associated ecologic and sedimentologic parameters (e.g., wave or current energy, salinity, feeding adaptations, substrate coherence, and sediment textures and fabrics),
2. the role of organisms as geologic agents, including not only their behavior and habitat adaptations but also their inter-relationships with physical processes of erosion, reworking, transportation, and deposition of sediments:
3. potential preservability of the organisms as fossils, together with their associated physical and biogenic sedimentary structures, facies relationships, and stratigraphic sequences; and
4. fidelity of these preserved or preservable features as potential geologic indicators of ancient organisms and their adaptations, environments, and ecologic-sedimentologic parameters represented in the fossil record.

Although Bob and Jim were mainly responsible for the conception, coordination, execution, and completion of the research; numerous graduate students also were involved. In addition, during certain phases of the research they were joined by the staff of the renowned Senckenberg Institute for Marine Geology and Biology, Wilhelmshaven, Germany including Hans Reineck, and Gunther Hertweck, and Jurgen Dörjes (recently deceased).

The results of this research program are impressive, rarely has a single coastal zone received such comprehensive geologic coverage. Consequently, the work attracted international attention and is widely cited in the literature. Characteristics of the Georgia coast became a model for comparison with numerous other modern and ancient systems. After perfecting their methodology in Georgia, Bob and Jim took their show on the road - literally, with the help of a bus turned into a mobile laboratory. This led to extended soirees to the Holocene of Florida, North Carolina, California, Massachusetts and Korea.

Bob Frey's publication record is most impressive with one hundred and thirty-one entries included are: eighty-five journal articles, thirty-four contributions to symposium compendia, guidebooks, short course manuals, and chapters of books; five edited volumes; five versions of an Historical Geology laboratory manual; and two monographs. His papers were scientifically innovative, lucid, and profusely illustrated, they were also virtually error-free.

In every discipline there exists a body of literature that is considered "must reading" in order to fully comprehend its significance. In Ichnology, approximately twelve papers come to mind, of these, Bob authored or co-authored five of them. He edited the first summary book devoted entirely to the study of trace fossils that stood, for many years, as the definitive reference on the subject. He was co-editor and co-founder of *Ichnos* the first journal devoted entirely to organism-substrate relationships. Bob worked hard at not only promoting Ichnology by also at helping young aspiring scientists. Although almost every facet of ichnology was addressed by Bob he was equally adept discussing such diverse topics as salt marsh dynamics, botany, invertebrate zoology, taphonomy, molluscan paleoecology, diagenesis, bryozoan taxonomy, and clastic sedimentology.

The quality of Bob's work has been recognized by a number of awards and distinctions: in 1981 he was awarded a "Medal for Excellence and Creativity in Research" from the
University of Georgia; in 1984 he was co-winner of the "Best Paper Award" for Volume 56, *Journal of Paleontology*, awarded by the Society of Economic Paleontologists and Mineralogists; in 1984 he was given the R. C. Moore "Geehawk" Medal while serving as the Merrill W. Haas Distinguished Visiting Professor at the University of Kansas; in 1990 he was bestowed with the Richard Owen distinguished alumnus award from the Department of Geology, Indiana University; and has recently been nominated for the R. C. Moore Medal awarded by the Society of Economic Paleontologists and Mineralogists.

Bob was a dedicated teacher who genuinely enjoyed his time in the classroom. Bob was voted "Professor of the Year" in 1980 by the graduate students in the Department of Geology, University of Georgia. Reflecting the interest and mutual respect they held for each other. He served as major professor for 20 MSc. students in a diverse array of fields ranging from bivalve systematics to organic geochemistry. He directed 8 PhD students, (Paul Basan, Joe Wadsworth, Jennifer Smith, Steve Henderson, Diane Kamola, M. A. Al-Aawah, Kent Sprague, and Anthony Martin). The quality of their work was a subject Bob took quiet pride in. He took particular pleasure in seeing his students grow not only as scientists but also as individuals.

I believe that the measure of one's value to a discipline, can be measured by the regard in which one is held by his peers in the scientific community at large. Bob's services as a critical reviewer were sought by the editors of 18 international journals and the program directors of five granting agencies. He served as the Field Trip Guidebook Editor for the Geological Society of America 1980 National Meeting in Atlanta and as Associate Editor for the *Journal of Sedimentary Petrology*. He was a major participant in 6 short courses run by the Society of Economic Paleontologists and Mineralogists, the Geological Society of America, and the United States Geological Survey, and assisted in leading 10 major field trips for various professional societies. In 1968 he initiated and co-authored (with Jim Howard) the "Ichnology Newsletter", an informal international newsletter on animal-sediment research, this publication continues to be distributed yearly.

Bob is survived by his wife Sharon, a very special person who was devoted to him, his daughter Valerie and his son Eric. He was a loving husband and father who was very proud of his family. Bob was a modest, unassuming man and the only time you heard him boast was when he spoke of the accomplishments of Sharon, Valerie, or Eric. Those who knew Bob will remember him for his personal qualities - his enthusiasm, generosity, compassion, and high principles. His colleagues will sorely miss the stimulus his ideas brought to their own work.

Ichnology will continue to thrive because it is built on a solid foundation constructed and nurtured by men like Bob Frey. During the last four years, Bob waged a heroic battle against cancer while still maintaining an active research program and fulfilling his teaching obligations. In doing so, he set an example in courage and dignity that will be an inspiration to all of us who knew him. Bob Frey left behind a great legacy of knowledge in Ichnology. His good friend Jim Howard said it best in the citation for Bob's "Best Paper Award" in the *Journal of Paleontology* “In recognition of Robert W. Frey, a nice guy who works too hard. Many of us today and in the future are and will be the fortunate recipients of his unending creative efforts. He is dedicated to his work because he likes what he is doing and he gets excited about it. We and he can’t ask for much more than that”. I was proud to have been his colleague but prouder to have been his friend. I will miss him dearly.
ACKNOWLEDGMENTS

I would like to thank the entire Frey family, especially Sharon for their hospitality during my visits to Athens. They always made me feel at home, even under tragic and trying circumstances. My thanks to Valerie Frey who took the picture of Bob that I used in this memorial, I thought it truly captured Bob’s persona.

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