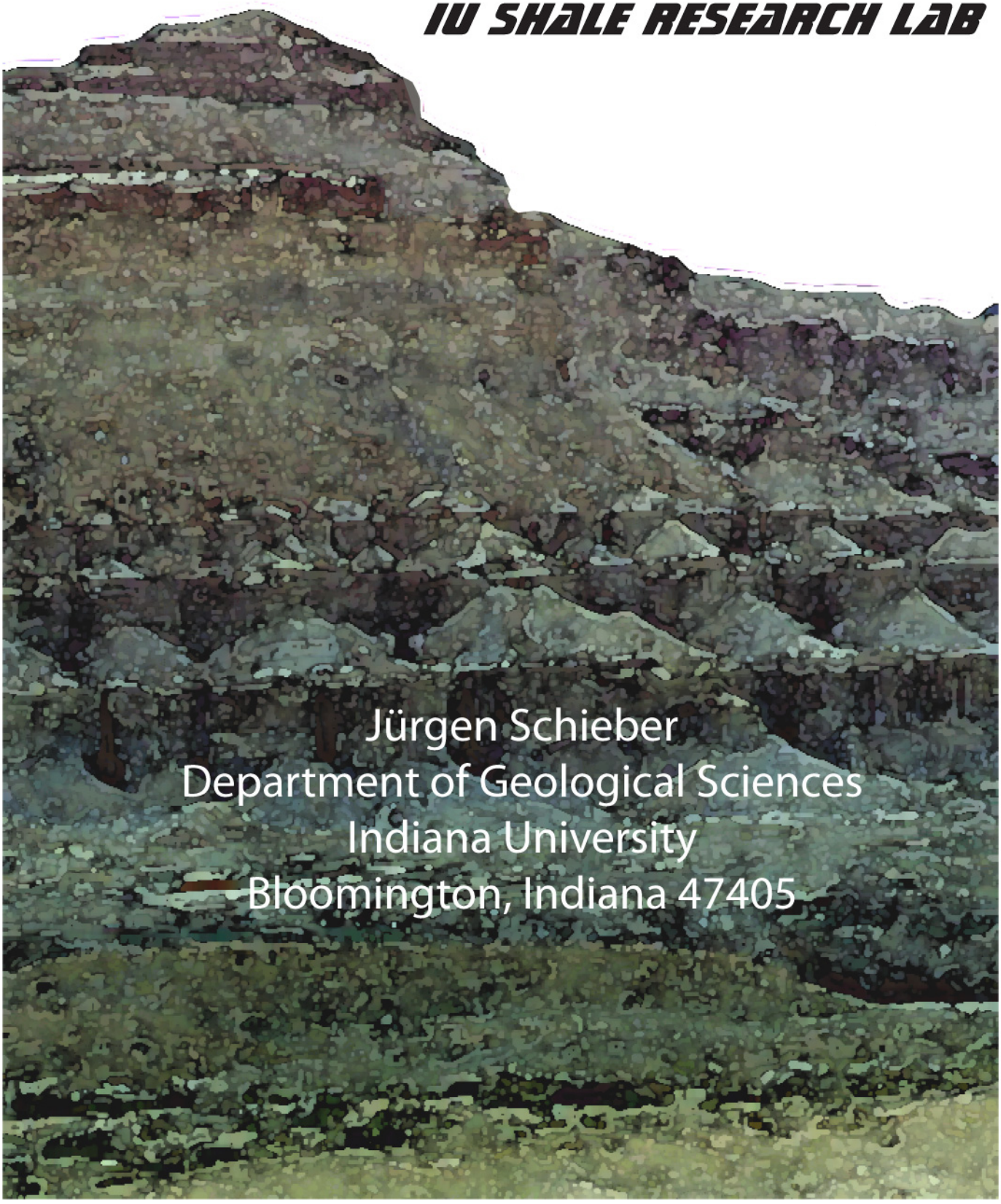
Research Prospectus



Jürgen Schieber
Department of Geological Sciences
Indiana University
Bloomington, Indiana 47405

Research Prospectus

Indiana University Shale Research Consortium

Dr. Juergen Schieber
Professor of Sedimentary Geology

Indiana University Department of Geological Sciences
1001 E 10th Street
Bloomington, Indiana 47405
e-mail: jschiebe@indiana.edu
Phone: 812-855-5322
Fax: 812-855-7899

Introduction

The Indiana University Shale Research Lab conducts cutting edge research into fundamental processes that determine distribution and petrophysical properties of shales and mudstones. Our inventory of research methodologies includes sedimentological and stratigraphic field studies, experimental studies in race-track flumes, geochemical investigations (organic carbon, major and trace elements, stable isotopes), petrographic studies under optical/petrographic microscopes, and electron microscopy with a high performance analytical FEG SEM.

Our research philosophy is multi-scale data integration for accurate assessment of critical qualities of shale successions. We take a holistic approach to the geologic understanding of fine grained sediments and strive to study shales from a wide range of depositional settings in order to arrive at comprehensive depositional models. Our research program spans more than two decades and encompasses strata that range in age from Archean to Tertiary. The general goal is to derive fundamental insights into shale depositional systems from in depth studies of particular stratigraphic units. In recent years, we have been engaged in sequence stratigraphic and sedimentologic research of Devonian age shales, due to a combination of availability of outcrops, drill core, and favorable funding.

In this prospectus we also summarize the research objectives that we would like to pursue with consortium funds. Consortium members are encouraged to suggest additional research topics, in particular if such cooperation involves application of our research methodology to shale successions and depositional scenarios that have not previously been investigated, or which were not examined in detail.

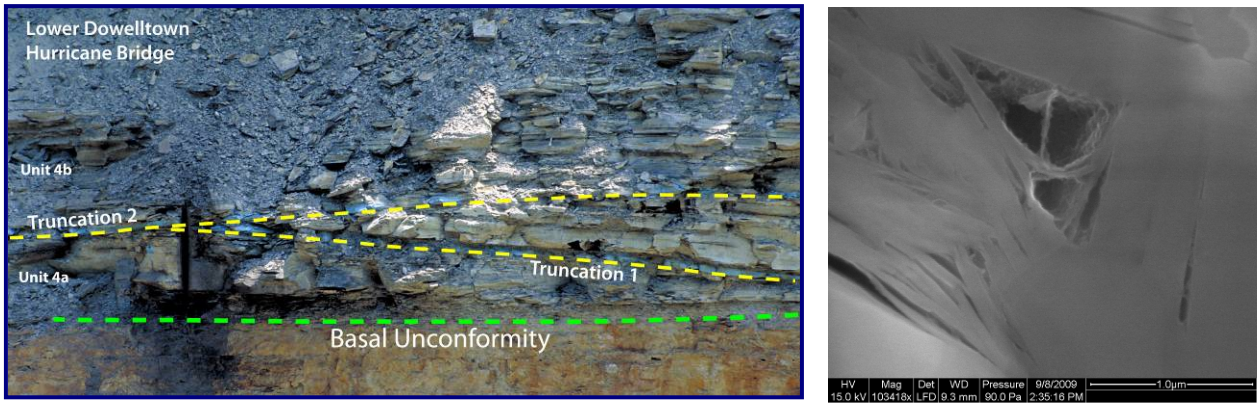
Sponsorship of our research program will help to advance the understanding of fine-grained sediments and of parameters that are critical for their economic development. In addition, consortium funds will benefit the training of a new generation of petroleum geoscientists that will have a solid grounding in the particulars of fine-grained sediments. Their integrated training, involving basin scale evaluation of entire formations, detailed petrographic and pore studies, as well as flume experiment analogs, will be a powerful combination to address future challenges in the shale gas industry. Our research program is the only one available that

provides comprehensive exposure to these multiple investigative methodologies, and builds on more than two decades of experience in shale research.

General Research Interests

The research areas our lab is engaged in include:

(1) Shale facies studies and assessment of depositional settings
(2) Flume studies of mud deposition and "reverse engineering" of specific sedimentary features and textures found in the rock record. The objective is to calibrate depositional models with actual physical data.
(3) Sequence stratigraphic studies of shale successions.
(4) Diagenetic processes and their relationship to depositional conditions and sequence stratigraphic stages.
(5) Pore development in shales and its relationship to depositional process, depositional fabric, and burial history.



Studies of the IU Shale Research Lab range from the basin-scale to the nano-scale. At left erosional truncations (sequence boundaries) in Devonian black shales, at right SEM image of an ion-milled sample that shows phyllosilicate framework pores in shale of same age.

Relatively speaking, shale research is still a young field of inquiry, but the results from above studies have the potential to have a significant impact on:

(1) Understanding the boundary conditions of source rock formation.
(2) Origin and development of petrophysical properties that impact mechanical modification/fracturing of shale gas reservoirs.
(3) Production characteristics of shale gas reservoirs.

Our integrated approach to the study of shale facies and mud deposition has value for predicting reservoir distribution as a consequence of underlying sedimentary processes and diagenetic modification in shale dominated depositional systems. Thus, consortium studies will have direct applicability to shale gas reservoir characterization and efforts to model shale gas reservoir facies.

Proposed Projects

1) Sequence stratigraphic study of Devonian black shales in the eastern US
2) Shale facies studies of selected Phanerozoic shale successions (Eau Claire, Maquoketa, New Albany, Ohio, Chattanooga, Green River, Mancos)
3) Early diagenetic silica precipitation in shales
4) Pore development in the New Albany Shale along a maturity gradient
5) Study of ion milling artifacts in gas shale reservoir rocks
6) Flume simulation of sedimentary features and fabrics in shales across a range of depositional conditions (unidirectional flow, combined flow, wave, tidal flow)

Additional information about our past work can be found at the following web site:
http://www.shale-mudstone-research-schieber.indiana.edu/
Information about ongoing projects will be accessible to consortium subscribers on a dedicated web site.

Facilities at the IU Shale Research Lab

Two large flumes designed specifically for mudstone research.
A dedicated sample processing lab
An optical petrography lab with 3 Zeiss research microscopes
An electron microscope lab with a fully equipped FEI Quanta 400 FEG analytical electron microscope (EDS, ESEM, EBSD, Chroma-CL)
An ion milling lab with two GATAN 600 Duomills equipped with liquid nitrogen cooled sample stages
All the equipment needed for field studies of shales (including portable gamma ray spectrometer)

The IU flume lab is the only flume facility for mudstone research worldwide. Through contributions to lab funding, sponsors will benefit from access to new results and concepts coming out of our experimental work on mudstone sedimentology. We currently operate two flumes (see below); and by the end of 2010 we will have four flumes in service that will allow us to simulate all typical flow conditions (unidirectional flow, waves, tides) and a variety of sea water chemistries (oxic, suboxic, anoxic, etc.).

Costs and Benefits

The consortium fee of $40,000 is structured to contribute to the support of graduate students, to provide summer salary for the PI, and to support infrastructure needs for the IU Shale Research Lab (~$60,000 per year w/o personnel costs). All consortium sponsors will receive a yearly report of research activities. In addition, preprints of research papers, presented posters, and oral presentations, will all be provided via a proprietary web-based format (mainly PDF files). These can be printed and used by subscribers at their own convenience and discretion. Proprietary web sites will be password protected for the sole use of consortium sponsors. We will run an annual short course that combines (1) a field trip to illustrate outcrop examples of concepts we are working on, typically in (2) conjunction with lab visits for flume demonstrations and petrographic exercises. Specifics of a given short courses can be adapted to collectively expressed interests of consortium sponsors.

These short courses are excellent training opportunities for employees of consortium sponsors and also provide a hands on view of the latest research that is conducted in the IU Shale Research Lab. In the past, these field trips have included exposures of classical shale successions, such as the Mancos Shale of the Book Cliffs, the Green River Shale, and the Devonian of the eastern US.

We are also always interested to discuss opportunities for student participation in specific projects of consortium sponsors, as part of a student's MS or Ph.D. project. Such interactions provide our students valuable experience in an industry setting and are encouraged.

The IU Shale Research Lab regularly solicits funding from other agencies (NSF, DOE, NASA, PRF/ACS) to support ongoing research. Thus, funds of consortium sponsors may be leveraged against significant sums from these agencies and further enhance the total research output that sponsors have access to.

Sponsors will have access to new ideas, new concepts, and research breakthroughs as they happen, versus the larger community that only has access to the final published papers. The latter routinely appear several years after work has been completed. They also have access to myself, students, and post-docs via in house visits and the annual short course.

Selected Publications:

1. Schieber, J., Southard, J.B., and Schimmelmann, A., 2010, Lenticular Shale Fabrics Resulting from Intermittent Erosion of Muddy Sediments – Comparing Observations from Flume Experiments to the Rock Record. *Journal of Sedimentary Research*, v. 80, p. 119-128.
2. Schieber, J., and Southard, J.B., 2009, Bedload Transport of Mud by Floccule Ripples – Direct Observation of Ripple Migration Processes and their Implications. *Geology*, v. 37, p. 483-486.
3. Schieber, J., and Yawar, Z., 2009, A New Twist on Mud Deposition - Mud Ripples in Experiment and Rock Record. *The Sedimentary Record*, v. 7/2, p. 4-8.
4. Schieber, J., 2009, Discovery of Agglutinated Benthic Foraminifera in Devonian Black Shales and Their Relevance for the Redox State of Ancient Seas. *Paleogeograpy, Paleoclimatology, Paleoecology*, v. 271, p. 292-300.
5. Schieber, J., Southard, J.B., and Thaisen, K.G., 2007, Accretion of mudstone beds from migrating floccule ripples. *Science*, v. 318, December 14, 2007, p. 1760-1763.

6. Schieber, J., and Lazar, R.O., 2004, (eds.) Devonian Black Shales of the Eastern U.S.: New Insights into Sedimentology and Stratigraphy from the Subsurface and Outcrops in the Illinois and Appalachian Basins. Field Guide for the 2004 Great Lakes Section SEPM Annual Field Conference. Indiana Geological Survey Open File Study 04-05, 90pp.
7. Schieber, J., and Riciputi, L., 2004, Pyrite ooids in Devonian Black Shales record intermittent Sea level drop and shallow water conditions. *Geology*, v. 32, p. 305-308.
8. Schieber, J., 2003, Simple gifts and hidden treasures – Implications of finding bioturbation and erosion surfaces in black shales. *The Sedimentary Record*, v. 1, p. 4-8.
9. Schieber, J., Krinsley, D., and Riciputi, L., 2000, Diagenetic origin of quartz silt in mudstones and implications for silica cycling. *Nature*, v. 406, p. 981-985.
10. Schieber, J., 1999, Distribution and deposition of mudstone facies in the Upper Devonian Sonyea Group of New York. *Journal of Sedimentary Research*, v. 69, p. 909-925.
11. Lobza, V., and Schieber, J., 1999, Biogenic sedimentary structures produced by worms in soupy, soft muds: Observations from the Chattanooga Shale (Upper Devonian) and experiments. *Journal of Sedimentary Research*, v. 69, p. 1041-1049.