Facilitation of Science and Engineering Collaboration and Technology Transfer

Technology Transfer Report

For

Using Microstructure Observations to Quantify Fracture Properties and Improve Reservoir Simulations

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Bureau of Economic Geology
The University of Texas at Austin
University Station, Box X
Austin, Texas 78713-8924

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SUMMARY

Key to the success of research projects involving collaboration across disciplinary, organizational, and geographic boundaries is the use of appropriate and effective mechanisms to exchange data and analyses among research team members. Where diverse university-based research groups are also sharing data and results with industry and government collaborators and sponsors, timely and appropriate information transfer to these entities is also important to project success. Despite rapid evolution of electronic communication technologies, this data sharing and data analysis sharing function is commonly less successful than many stakeholders desire, and less effective than current technology allows. By taking advantage of a secure, interactive website environment, geoscientists, engineers, and others can communicate and share a variety of information resources effectively and conveniently. This results in closer collaboration, faster progress, lower costs, and more effective technology transfer to the private sector. However, the traditional Internet Web site, Intranet, and Extranet approaches are not solutions to many of the challenges of diverse, collaborative research teams. This report outlines the solution to this challenge developed in our project.

The project "Using Microstructure Observations To Qualify Fracture Properties and Improve Reservoir Simulation" involves multidisciplinary studies of natural fractures in hydrocarbon reservoirs by a research team of geologists and engineers at The University of Texas at Austin that is dispersed among different buildings and two different campuses. In addition, a collaborating group of industry scientists representing seven companies includes individuals located in different cities (or continents). Successful cooperative research and technology transfer for such a widely distributed group is a serious logistical and organizational challenge.

As part of the project, the research team at The University of Texas at Austin developed an aggressive data-sharing plan that involved close collaboration with the group of industry scientists.

This plan also involved cooperating with a developer of Web site technology to improve the flow of information within the university research team and to the industry group (and ultimately, to the public). This Web site is a unique, fully scalable, data base-driven, interactive, secure, and customizable site specifically organized for diverse research teams. The cost of the Web site development effort was partly defrayed by industry cofunding and time and effort donated by the Web site developer; consequently, this element of the technology transfer plan was accomplished without diverting significant research funds from the university budget. The university research team provided guidance on the requirements and organization of the Web site and furnished the technical content.

Although the creation of the Web site software is not a product of this research project, the structure and design of the Web site reflects the technology transfer principles of the project. All research study participants have daily access at their desktops to current study data, archived files and publications, and online forums in which members can privately discuss project-related issues at their convenience. This approach can be used by other projects having diverse scientific teams faced with complex technical issues that cross disciplinary boundaries. This report summarizes the essential elements of this technology transfer effort, with special emphasis on the Web-based technology transfer tool.

INTRODUCTION

"Using Microstructure Observations to Qualify Fracture Properties And Improve Reservoir Simulation" is a multidisciplinary study of natural fractures in hydrocarbon reservoirs conducted by a research team of engineers and geologists at The University of Texas at Austin. The research for this project, funded by the U.S. Department of Energy, will provide new technology to understand and successfully characterize, predict, and simulate reservoir-scale fractures. Such fractures have worldwide importance because of their influence on successful extraction of resources. Natural fractures pose serious technical challenges to producers, and unless these challenges are met successfully, many conventional and unconventional U.S. reservoirs and much of the as-yet untapped hydrocarbon resource may be inefficiently or incompletely developed.

This report describes aspects of the technology transfer effort that is part of this project. The research team at The University of Texas at Austin developed an aggressive technology development and transfer plan that involved close collaboration with a group of industry geologists and engineers. A goal of the research project from the outset was to integrate the diverse disciplines (and viewpoints) represented in the research team and the group of collaborating industry scientists to facilitate progress and rapid technology transfer.

We have found that research progress has been greatly augmented by the participation of the industry in periodic progress reviews and, perhaps more importantly, through an ongoing dialog on technical issues. The collaboration involves several levels of involvement, including regular, formal group meetings, E-mail alerts, informal written reports, site visits by our research group to the industry and vice versa, and a dedicated project Web site. This report focuses on several special aspects of the Web site that was developed in the course of the project.

EFFECTIVE RESEARCH TEAM COOPERATION

The aim of effective day-to-day participation in research activities requires that all research study participants have daily access at their desktops to current study data, archived files and publications, and online forums in which members can privately discuss project-related issues at their convenience. A factor in planning project research and technology transfer was the diverse, multidisciplinary nature of the university research team. Achieving effective communication and cooperation on research within the group that comprises scientists in several disciplines was a concern during project planning. Moreover, the university research team is dispersed among different buildings and two different campuses, presenting a potential impediment to cooperation. For the industry group, limited resources, conflicting travel schedules, and outside time constraints often mean that not all stake-holders are able to receive the full benefits of participation.

Cross-organizational workgroups are not new in geoscientific research, but they are becoming increasingly important to the advancement of science and technology transfer. Progress on geoscientific research projects involving collaboration across disciplinary, organizational, and geographical boundaries is greatly facilitated through the use of appropriate Internet technologies. However, the traditional Internet Web site, Intranet, and Extranet approaches are not solutions to many of the challenges created by the distributed collaboratory environment.

Research Team-Specific Web Site

The solution for this project was to cooperate with a developer of Web site technology to improve the flow of information within the university research team and to the industry group (and ultimately, to the public). The university research team provided guidance on the requirements and organization of the Web site and furnished the technical content, and the Web site developer designed the software and built the Web site. This Web site is a unique, fully scalable, data base-driven, interactive, secure, and customizable site specifically organized for diverse research teams (Burns and Laubach, 1998).

Although the Web site has been developed over the course of the project, and has only recently become fully utilized, it has accomplished an important role in cross-disciplinary research among team members and has improved communication between the team and the industry group. Through collaboration with industry partners, the Web site was created without diverting funds from the essential research goals of the project. The Web site was also designed to survive the official end of the DOE-funded project in order to further the goal of technology transfer. The template for this type of Web site, called a Virtual Collaboratory™, is now being made available to industry by the developer, Geolectica, LLP. The term Virtual Collaboratory™ and its graphical representations are a trademark of Geolectica, LLP.

Although the creation of the Web site software is not a product of this research project, many of the elements incorporated in the design are a manifestation of the technology transfer principles of the project, and the deployment of this innovative Web site research and technology transfer tool is an accomplishment of this project. This approach can be used by other projects having diverse scientific teams faced with complex technical issues that cross disciplinary boundaries. Limited resources, conflicting travel schedules, and outside time constraints often mean that not all stake-holders are able to receive the full benefits of participation in such projects. With this Web site, all research study participants have daily access at their desktops to current study data, archived files and publications, and online forums in which members can privately discuss project-related issues at their convenience.

Requirements of Fracture Research Project

The fracture research project involves cooperation with a consortium of energy and technology companies that support multidisciplinary studies of natural fractures in hydrocarbon reservoirs. The research is conducted by a team at The University of Texas at Austin in collaboration with scientists from the sponsor companies. Challenges to integrated research for such a group are formidable. Not only are the company representatives located in different cities

(or continents), but the team in Austin is also separated. The leadership of the project is in the departments of Petroleum and Geosystems Engineering and Geological Sciences, which are across campus from each other, and in the Bureau of Economic Geology, which is on a satellite campus about 15 miles from the main UT campus. Thus, the project is faced with serious logistical hurdles to effective cooperation in addition to the challenge of communication across disciplinary boundaries between geology, mechanical modeling, geostatistics, and reservoir testing and simulation. A variety of new scientific approaches, tools, and techniques are employed in the studies. The project makes use of many large images that must be made available to all, and large data bases to which all participants must have access. Characteristics of the research team are outlined in Table 1.

In addition to enjoying the significant benefits derived from collaboration, the research team also inherited a set of problems due to the cross-organizational, geographically distributed nature of the consortium membership. Table 2 outlines some of the major problems associated with distributed collaboration.

Many of the problems created by distributed collaboration can be resolved by employing suitable Internet technologies. In recognition of this, the project Web site is being developed to allow the project's participants to take full advantage of evolving Internet technologies to enhance collaboration. A Web site solution was selected because all of the participants already had the capability to connect to the Internet and use a Web browser. Special care was taken in designing the Web site so that participants would not be required to purchase any new hardware or software or learn any special skills.

INTERNET TECHNOLOGIES AND VIRTUAL COLLABORATORIES

Many organizations that participate in distributed collaborative activities already employ Internet technologies in a variety of ways. It has become common in the last several years for geoscientific organizations to publish and maintain Internet Web sites. Such Web sites, however,

Table 1. Characteristics of research project.

- Collaborators cross disciplinary, industry, organizational, and geographic boundaries
- New technology development and testing demands high levels of interaction
- Proprietary, time-sensitive information demands prudence
- Data sharing among subgroups requires coordination and access

Table 2. Problems inherent in distributed collaboration.

- Time zone differences limit availability of collaborators
- Scheduling conflicts reduce participation
- Infrequent interaction inhibits synergy
- Traditional publication lead times too long
- Print-based materials limit usability
- Unfamiliar research technologies require time and guidance to master
- Participants use wide range of incompatible computers and software

typically provide a static, one-way flow of information to outsiders and rarely enable secure information transfer. A growing number of organizations are developing Intranets to facilitate internal communications. An Intranet can be characterized as an internal Web site accessible only to employees within an organization. Recognizing the importance of developing a more effective means of interactive communication with those on the outside, some organizations are deploying Extranets. These hybrids allow selected outsiders to access some parts of an organization's Intranet, but present serious security, resource, and computer incompatibility concerns.

Although Internet Web sites, Intranets, and Extranets are useful in addressing many communications and publication issues, they do not present optimal solutions for distributed collaborative workgroups made up of individuals from a variety of both private and public sector organizations. Typically, such workgroups have no dedicated computing resources, nor do they necessarily use the same types of computers or software. The short-term, continually changing nature of these project-based collaborations requires similarly flexible, quickly deployed, and easily retired approaches. The optimum solution for such workgroups is to utilize the facilities of a team-specific Web site, such as a Virtual Collaboratory, to facilitate internal discussion and publication of project-related items.

A Virtual Collaboratory is the data base-driven, scalable, secure, interactive Web site template developed by Geolectica, LLP especially for distributed workgroups. Virtual Collaboratories can be easily used with any common computer operating system and Web browser. They are designed to support the entire range of interactive Internet technologies and digital transmission formats as they evolve. Virtual Collaboratories are hosted on a third-party Web server computer to free up the limited computing and human resources of the participating organizations. This third-party hosting arrangement also greatly reduces any security risks to organizations that otherwise would expose their own networks to outsiders.

FRAC CITY

Frac City™ is the Virtual Collaboratory developed for this project. It can be found on the World Wide Web at http://www.frac-city.org. It is designed to achieve three purposes: (1) to facilitate collaboration and publication of proprietary information among the project's consortium members, (2) to provide a forum for greater professional interaction among all fracture researchers, and (3) to promote the research to the interested public.

Design Considerations

For a Web site solution to be effective in achieving its goals, good design principles must be followed. There are many factors to be considered in determining the structure, features, and technologies employed in the Web site. Table 3 lists the factors that were considered in the design and implementation of Frac City.

To address these issues and achieve the various goals, an interactive, data base-driven Web site is being deployed. The use of interactive data bases allows the restriction of access to proprietary information and also allows the control of where and when content is displayed on the Web site. Based on the design factors stated above, a Web site with the characteristics outlined on Table 4 was developed and implemented.

To site visitors, Frac City appears to be one Web site, with access to the "Members Only" section restricted to project participants only. For the purpose of discussion, however, Frac City can be considered two separate Web sites: a public and a private. Each site, or side, of Frac City has its own subsections, content, and distinct navigational scheme. Both sides are controlled by the backend data bases running on Geolectica's Web servers from which the viewer downloads the pages on his or her browser.

Table 3. Considerations, issues, and constraints.

Security

- Proprietary data must be secured from access by nonmembers for specified periods of time
- Intellectual property rights must be protected
- Project-related discussions must remain private

Management

- Large volumes of a variety of digital data formats impose high storage and retrieval requirements
- Continual input from researchers requires consistent, skilled site management
- Member-driven nature of project demands flexibility and scalability
- Must allow for near real-time updating

User-friendliness

- Must accommodate a variety of computer platforms, monitor sizes, modem speeds, and preferred browsers
- Must not impose additional hardware, software, skill set or time burdens on members
- Must be accessible at consortium members' convenience

External communication

- Inform nonmembers about the research and new techniques
- Encourage widespread use of technology
- Promote lively scientific discussions on day-to-day basis

Financial

- Must not divert funds from research budget
- Must not demand major continued input of funds
- Self-supporting site preferable

Table 4. The Frac City solution.

Entire Site

- Data base-driven backend allows fast publishing and retrieval of all digital files
- Hyperlinkages allow quick, logical navigation
- Template-based architecture allows fully flexible site growth and management
- Developmental platform allows highly interactive functionality
- Digital watermarking of downloadable material protects authors
- Third-party site hosting protects intellectual property rights
- Third-party site hosting allows commercial involvement
- Third-party site hosting eliminates demand on collaborators' computer resources
- Third-party site maintenance and updates leave researchers free to concentrate on science
- Secure server environment protects data transmission

Private Side

- Three levels of security protect collaborators and content
- "Members Only" access controlled by independent data base of pre-approved individuals
- Easy to use—register once, browse at will
- Discussion forums facilitate convenient, private interaction on a variety of project-related issues

Public Side

- Informs interested individuals about research
- Promotes and facilitates public discussion on a variety of scientific topics
- Online technical assistance for new technology users reduces down time
- Different look and feel than private side eliminates possibility for confusion

Sections of Frac City

Public Section

The public side of Frac City is open to anyone with a professional interest in natural fractures. Its purpose is to inform nonmembers about the research and new techniques, encourage prospective members to join the consortium, and to promote lively, meaningful scientific discussions relating to fractures on a day-to-day basis. The current site architecture of the public side is described in more detail by Burns and Laubach (1998). All content is submitted by members of the consortium. Content that does not arise from within the research consortium may be added to the site with the prior approval of the project's Principal Investigator.

The main features of the public side are "About this Project," "What's New," "Discussion Forums," and the "Site Map." Information about the project and the consortium members is featured in the "About this Project" section. "What's New" acquaints visitors with recent additions or changes to the site, as well as other news relevant to the project. The "Site Map" allows visitors a quick and easy method of gauging the depth and breadth of the site at a glance, and allows single-click access to any page.

The "Discussion Forums" allow interested individuals to participate in moderated, lively scientific discussions pertaining to a variety of aspects of fracture research. The main idea behind the threaded forums is to pick up where the discussions at professional meetings leave off. Specific topics of discussions are scheduled and guided by carefully selected moderators who are themselves active participants in a variety of disciplines within fracture research. Since the discussions occur within a private environment, any possible incidences of misuse can be controlled or prevented.

Private Section

The private, "Members Only" side is accessible only to preapproved members. One of the most important aspects of Frac City is that it allows members to publish and discuss research-related information that is then made available only to other members of the consortium. Burns and Laubach (1998) show the current site architecture of the private side. All content is submitted by members of the consortium.

The private side contains proprietary research data, with summaries and reports in a variety of digital formats. Consortium members also agree that this information is to be made available only to members of the consortium for a specific period of time. After that, the information may be made available to the public. Frac City uses an interactive data base that controls when such proprietary content may be viewed on the public side of the site.

The main sections of the private side are the "Calendar of Events," "What's New," "Discussion Forums," "Studies," "Publications," "References," and a "Site Map." The "Calendar" displays dates and details of relevant conferences, seminars, and deadlines for project-related activities that are submitted by project members. The "What's New" section informs members of recent additions or changes to the private side, as well as other news relevant to the project. The "Publications" section features reports and articles relating to the research that are still considered proprietary. "References" contains articles and links considered relevant to the research. A "Site Map" allows members to quickly and easily gauge the depth and breadth of the entire site at a glance, and allows single-click access to any page. Once access is granted to the private side, members may freely navigate between the public and private sides at will.

The "Discussion Forums" facilitate threaded discussions about research-related and logistical issues by allowing members to view contributions posted by all members and to reply at will. Unlike the public discussion forums, these forums are not moderated.

The "Studies" section is the most important section of the private side. "Studies" contains the proprietary research data, images, reports, presentations, and other files directly related to all of the

research areas. Very large photographic images must be made available to all, and several large data bases must be accessible to many of the participants.

THE FUTURE OF FRAC CITY

One of the main strengths of using the Internet is the ease and speed with which changes may be made to electronically published information and interactive features. Frac City takes advantage of this capability to continually make changes to the site. Members frequently send in new content to be added to the site. The project's Principal Investigator orders changes to the site's overall architecture based on the changing needs of the project. Participants on the forums may read and reply to posted messages more easily than sending E-mail.

Expansion Capabilities

The Virtual Collaboratory template allows Frac City to grow as large as required by the needs of the workgroup. Extremely large numbers and sizes of content files of various types may be stored on the Web servers. Very high levels of simultaneous online traffic on the site may be accommodated. The number of sections and pages that can be included in the Web site is unlimited. The number of members that may be added to the data base is large enough to accommodate growth of participation in the research.

New Features

As the Web site continues to become a workaday part of the consortium members' routine, additional interactive features will be added. In addition to being able to scale into a very large Web site, Frac City's Virtual Collaboratory template also allows it to incorporate any new interactive capabilities the members wish to add.

Financing Frac City

A major concern when planning the development of Frac City was funding. As discussed earlier, all parties felt it was important that funds not be diverted from the research budget for development of the site. Additionally, there was some interest in exploring whether or not the site could be self-supporting, so that technology transfer could continue beyond the end of U.S. Department of Energy funding of research and technology transfer efforts on this project. A funding model, which incorporated a contribution by an analytical instrument manufacturer, Oxford Instruments, and a contribution from The University of Texas to fund the initial development, was established. Geolectica, the developer, underwrote a significant part of the development costs of the site. In order to ensure financial self-sufficiency for the site in the future, it was decided to solicit and eventually display paid advertising banners on the public discussion forums and selected other pages.

Because the research undertaken by the workgroup is not commercial in nature, there are some limitations on appropriate financing for Frac City. The funding model for the future of this site is therefore similar to that of a professional technical journal that covers some of its publication costs through the sale of appropriate advertising. Income from the sale of advertising on the public side of Frac City will go to Geolectica (the "publisher") and is used to promote the goal of ongoing technology transfer (that is, it is used to support the public side of Frac City). Other possible avenues of funding include paid membership to some portions of the public side of Frac City.

Effective use of Frac City by workgroup members will result in many benefits, and this type of Web-based research support vehicle may become standard for geoscientific collaboration in the future.

TECHNOLOGY TRANSFER

The Web site Frac City is one element in the project's ongoing technology transfer effort. The material in the following sections is based on the 1998 Annual Report for this project. What

follows is a brief summary of the more conventional technology transfer efforts that are currently underway that supplement the project's Web site.

The centerpiece of the technology transfer effort is the ongoing dialog we have established with leading scientists from a group of eight companies in the petroleum industry. In the context of technology transfer, this influential group is exposed to our ongoing research and our preliminary results throughout the course of the project. This has resulted in several abstracts and papers on technical results that are coauthored by members of the university research team and the industry group. In addition to the research collaboration and guidance they provide, this industry group is a conduit for technology transfer to their respective companies, and through their professional contacts (as well as our own), a technology transfer link to the industry as a whole. As listed below, this link is maintained through regular, formal group meetings, E-mail alerts, a dedicated project Web site, informal written reports, and site visits by our research group to industry and vice versa.

Technology is also being accomplished through lectures to other companies and to University audiences, presentations at professional meetings, technical publications, and the public project Web site described in this report.

Industry Group

Two formal meetings have been held with the industry sponsors group and another meeting is scheduled for 1998. These formal meetings have been supplemented by numerous informal meetings and by the use of the project Web site and E-mail communications. Details of these meetings were presented in quarterly reports and previous annual reports:

- Initial planning and concept presentation meeting, Austin, July 1996;
- Progress meeting no. 1, Austin, May 1997;
- Progress meeting no. 2, Austin, August 1998;
- Workshop, scheduled for summer 1998.

We are currently considering presenting this technology transfer workshop in Dallas, Houston, and Midland.

In addition, we have issued informal reports on aspects of our research to industry representatives for their review and have made sets of illustrations available to industry research partners to facilitate technology transfer to their companies.

Publications and Presentations

Published Papers

Although research is ongoing and most of the formal publications to result from this work have yet to be written, several preliminary results from this project have already appeared in the technical literature.

Marrett , R., and Laubach, S. E., 1997, "Diagenetic controls on fracture permeability and sealing": *Int. J. Rock Mech. & Min. Sci.*, v. 34, no. 3–4 (June 1997).

Marrett, R., 1997, "Permeability, porosity, and shear wave anisotropy from scaling of open fracture populations": in *Fractured Reservoirs: Characterization and Modeling*, Rocky Mountain Association of Geologists Guidebook (September 1997), p. 217–226.

Laubach, S. E., Marrett, R., and Lake, L., 1997, Progress report on new methods of natural fracture characterization and simulation: The University of Texas at Austin, Bureau of Economic Geology, research progress report prepared for industry sponsors of the natural fracture project and the Department of Energy, 22 p. + attachments.

Burns, S. L., and Laubach, S. E., 1998, Virtual Collaboratory *Frac City* facilitates geoscientific collaboration and technology transfer: Geoscience Information Society, v. 28, p. 111-116.

Published Abstracts

Marrett, R., Laubach, S. E., Rossen, W., Olson, J., Lake, L., 1998, Integration of new fracture observation, characterization, and fluid-flow modeling technology (abs.): American Association of Petroleum Geologists Annual Convention Official Program, v. 7.

Ortega, O., Marrett, R., Hamlin, S., Clift, S., and Reed, R., 1998, Quantitative macrofracture prediction using microfracture observations: a successful case study in the Ozona Gas Field, West Texas (abs.): American Association of Petroleum Geologists Annual Convention Official Program, v. 7.

Reed, R., and Laubach, S. E., 1998, Density and distribution of microfractures in sandstone: importance to diagenesis (extended abs.): American Association of Petroleum Geologists Annual Convention Official Program, v. 7.

Clift, S. J., Laubach, S. E., Abegg, F. E., Aslesen, K. S., Laroche, T. M., and Stanley, R. G., 1998, New core analysis methods applied to Permian sandstone, Pakenham (Wolfcamp) field, Terrell County, Texas (abs.): Southwest section, American Association of Petroleum Geologists.

Marrett, R., Rossen, W., and Laubach, S. E., 1998, Integration of new technologies for fracture observation, characterization, and fluid-flow modeling (abs.): Fractured Reservoirs: Practical Exploration and Development Strategies, Rocky Mountain Association of Geologists symposium proceedings, p. 319.

Laubach, S. E., 1998, Fractured reservoir predictive case histories: domestic and international examples: Fractured Reservoirs (abs.): Practical Exploration and Development Strategies, Rocky Mountain Association of Geologists symposium proceedings, p. 319.

Laubach, S. E., and Clift, S., 1998, New core analysis methods applied to Permian sandstone, Pakenham field, Terrell County, Texas: Fractured Reservoirs (abs.): Practical Exploration and Development Strategies, Rocky Mountain Association of Geologists symposium proceedings, p. 359.

Laubach, S. E., and Marrett, R., 1997, Inferring fracture permeability from rock microstructure (abs.): American Association of Petroleum Geologists Bulletin, v. 81, no. 8, p. 1393-1394.

Laubach, S. E., 1997, Recent advances in core-based structural analysis (abs.): American Association of Petroleum Geologists Hedberg Research Conference, meeting notes, unpaginated, Bryce, Utah, June.

Marrett, R., and Laubach, S. E., 1997, Diagenetic controls on fracture permeability and sealing (abs.): International Journal of Rock Mechanics and Mining Science, v. 34, nos. 3–4, p. 409.

Clift, S. J., Abegg, F. E., Aslesen, K. S., Laroche, T. M., Stanley, R. G., and Laubach, S. E., 1997, Predicting fracture cementation in Permian sandstone, Pakenham (Wolfcamp) Field, Terrell County, Texas (abs.): W. D. DeMis, ed., Permian Basin Oil and Gas Fields: Turning Ideas into Production, West Texas Geological Society Publication No. 97-102.

Laubach, S. E., 1997, New core analysis methods for fractured siliciclastic reservoirs (abs.): American Association of Petroleum Geologists Annual Convention Official Program, v. 6, A67.

Johns, M. K., Laubach, S. E., and Milliken, K. L., 1997, Syncementation crack-tip and crack-seal microtextures and their implications for fracture connectivity and porosity interpretation (abs.): American Association of Petroleum Geologists Annual Convention Official Program, v. 6, A56.

Marrett, R., Ortega, O., Reed, R., and Laubach, S. E., 1997, Predicting macrofracture permeability from microfractures (abs.): American Association of Petroleum Geologists Annual Convention Official Program, v. 6, A76.

Laubach, S. E., and Marrett, R., 1997, Controls on fracture permeability (abs.): in Kim, K., ed., Proceedings, 36th U.S. Rock Mechanics Symposium, Columbia University, New York, June, 1997.

Laubach, S. E., 1996, Fracturing and diagenesis as coupled processes (abs.): GSA Abstracts with programs, v. 28, no. 7, p. A-136–A-137.

Ortega, O. J., and Marrett, R., 1997, Use of microscopic information for macrofracture characterization in Mesaverde Group Sandstones from the surface and subsurface of the San Juan Basin (abs.), *in* Natural Fracture Systems in the Southern Rockies, Four Corners Geological Society, Durango, Colorado, June 13 and 14, 1997.

Marrett, R., 1996, Scale dependence of fractures and fracture permeability (abs.): GSA Abstracts with programs, v. 28, no. 7.

Ortega, O., and Marrett, R., 1996, Significance of finite layer thickness on scaling of fractures (abs.): GSA Abstracts with programs, v. 28, no. 7.

Reed, R. M., and Laubach, S. E., 1996, The role of microfractures in the development of quartz overgrowth cements in sandstones: new evidence from cathodoluminescence studies (abs.): GSA Abstracts with programs, v. 28, no. 7, p. A-280.

Completed Thesis

Ortega, O. J., 1997, Prediction of macrofracture properties using microfracture information, Mesaverde Group sandstones, San Juan Basin, New Mexico, The University of Texas at Austin, Thesis, 278 p.

Papers in Press

The following papers have been accepted for publication. In addition to these papers, several manuscripts not listed here are in preparation for publication. These reports will shortly be made available on the project Web site.

Milliken, K. L., and Laubach, S. E., 1998, Brittle deformation in sandstone diagenesis as revealed by scanned cathodoluminescence imaging with application to characterization of fractured reservoirs: Springer-Verlag.

Olson, J. E., Hennings, P. H., and Laubach, S. E., 1998, Integrating wellbore data and geomechanical modeling for effective characterization of naturally fractured reservoirs: EUROCK 98.

Lectures

In addition to presentations associated with direct industry contacts and sponsor group meetings, the research group has made several invited presentations to industry and academic audiences. In general, the travel costs for these presentations have been borne by the group or University issuing the invitation rather than by our project budget. The number of presentations of this type will increase as the research moves closer to completion.

"The challenges of reservoir structure in the 21st Century": presented to American Association of Petroleum Geologists Reservoir Deformation Research Group annual meeting, Salt Lake City, May.

"Incorporation of microstructural and statistical fracture data into a reservoir model": Fractured Reservoirs: Practical Exploration and Development Strategies, Rocky Mountain Association of Geologists symposium.

"Origin of reservoir fractures": Invited keynote speaker, The Woodworth Conference of the Geological Society of London, marking 100 years in the evolution of fracture analysis, Coleraine, Northern Ireland, April.

"Fractured reservoir analysis: implications for the petroleum engineer": presented to Departmental Seminar, Petroleum and Geosystems Engineering, The University of Texas at Austin, Austin, Texas, February.

"Current research on reservoir fractures": presented to Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas, February.

"Strategies for reservoir structural analysis": lecture presented to PDVSA (Maraven), Caracas, Venezuela, February.

"Research on structural geology and reservoir engineering": briefing presented to the Chairman, The University of Texas Board of Regents, Austin, Texas, January.

"Practical tools for fractured reservoirs": Fractured Reservoirs: Practical Exploration and Development Strategies, Rocky Mountain Association of Geologists symposium, Denver, Colorado, January.

"The new paradigm in core analysis": presented to Department of Geology, New Mexico Tech University, Socorro, New Mexico, January. Invited.

"Structural geology in support of reservoir engineering in modern reservoir management": presented to graduate class in reservoir engineering (PGSE 360), Department of Petroleum and Geosystems Engineering, The University of Texas at Austin, November.

"Méthodos revolucionarios de análisis de muestras de testigos para yacimientos fracturados (Revolutionary core analysis methods for fractured reservoirs)": keynote address presentado para la celebración del 32dcmo aniversario de la fundación del Instituto Mexicano del Petróleo, Mexico City, Mexico, October. Invited.

"Inferring fracture permeability from rock microstructure", presented to American Association of Petroleum Geologists International Conference, Vienna, Austria, September. Invited.

"Diagenetic controls on fracture permeability": presented to 36th U.S. Rock Mechanics Symposium, Columbia University, New York, July. Invited.

"Fracture properties from rock microstructure": presented to American Association of Petroleum Geologists Hedberg Research Conference, Bryce, Utah, June. Invited.

"Using core analysis to characterize fractures and calibrate seismic data": presented to GRI technical advisory group, Denver, Colorado, June.

"Current progress in fracture evaluation": presented to New Methods of Fracture Characterization and Simulation workshop, Austin, Texas, May.

"Fracture orientation and fracture quality prediction case studies: lessons for practical application": presented to New Methods of Fracture Characterization and Simulation workshop, Austin, Texas, May.

"Diagenesis from a different perspective": presented to SEPM Clastic Diagenesis Group discussion meeting, Dallas, Texas, April. Invited. Best Presentation Award.

"Uncovering fractures": keynote address presented to imaging systems dinner, American Association of Petroleum Geologists convention, Dallas, Texas, April. Invited.

"Diagenetic controls on fracture permeability": presented to 36th U.S. Rock Mechanics Symposium, Columbia University, New York, July.

"Current progress in fracture evaluation": presented to industry sponsors of BEG fracture research, Austin, Texas, May.

"Diagenesis from a different perspective": presented to SEPM Clastic Diagenesis Group discussion meeting, Dallas, Texas, April. Invited.

"Uncovering fractures": keynote address presented to imaging systems dinner, American Association of Petroleum Geologists convention, Dallas, Texas, April.

"New methods of fractured reservoir characterization: examples from the Val Verde basin": presented to SIPES convention, Austin, Texas, March.

"Results of tests on horizontal core": presented to Parker & Parsley, Inc., Austin, Texas, March.

"Recent breakthroughs in analysis of natural fractures": presented to Department of Geology, Tulsa University, Tulsa, Oklahoma, February.

"Fracture analysis methods and applications" and "Application of new structural petrology methods to Chevron's Wolfcamp sandstone core, Pakenham field": presented to Chevron, Midland, Texas, January.

"Quantification and prediction of reservoir fracture attributes": presented to PEMEX, Tampico, Mexico, January.

"Using petrology to unlock gas resources in West Texas": presented to Chevron, Houston, Texas, August.

"Future of outcrop-based studies of natural fractures" and "Advanced subsurface fracture and stress characterization methods": presented to Mobil Corp. strategy meeting for fracture and stress research, Dallas, Texas, August.

"Overview of reservoir simulation project", "Summary of fractured reservoir analyses completed to date", "New fracture characterization methods", and "Inferring fracture conductivity from sidewall core samples": presented to industry/DOE workshop on fractured reservoir simulation, Austin, Texas, July.

"Field and core seminar on fracture systems in carbonate rocks": lectures and field trip presented to Amoco Production geophysics team, Austin, Texas, July.

"New fracture characterization methods for siliciclastic rocks": presented to North American Rock Mechanics Symposium, Montreal, Canada, June.

"Geochemical controls on the evolution of porosity and implications of new microstructural observations for kinetics of crack growth at subcritical tensile stresses": presented to Exxon Production Research, Houston, Texas, June.

"Synthesis of petrologic and structural approaches for solving reservoir characterization challenges": presented to Union Pacific Resources, Fort Worth, Texas, May.

Awards

Best presentation award, structural diagenesis, SEPM Clastic Diagenesis Research Group, Dallas, Texas, April 1997.

Acknowledgments

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