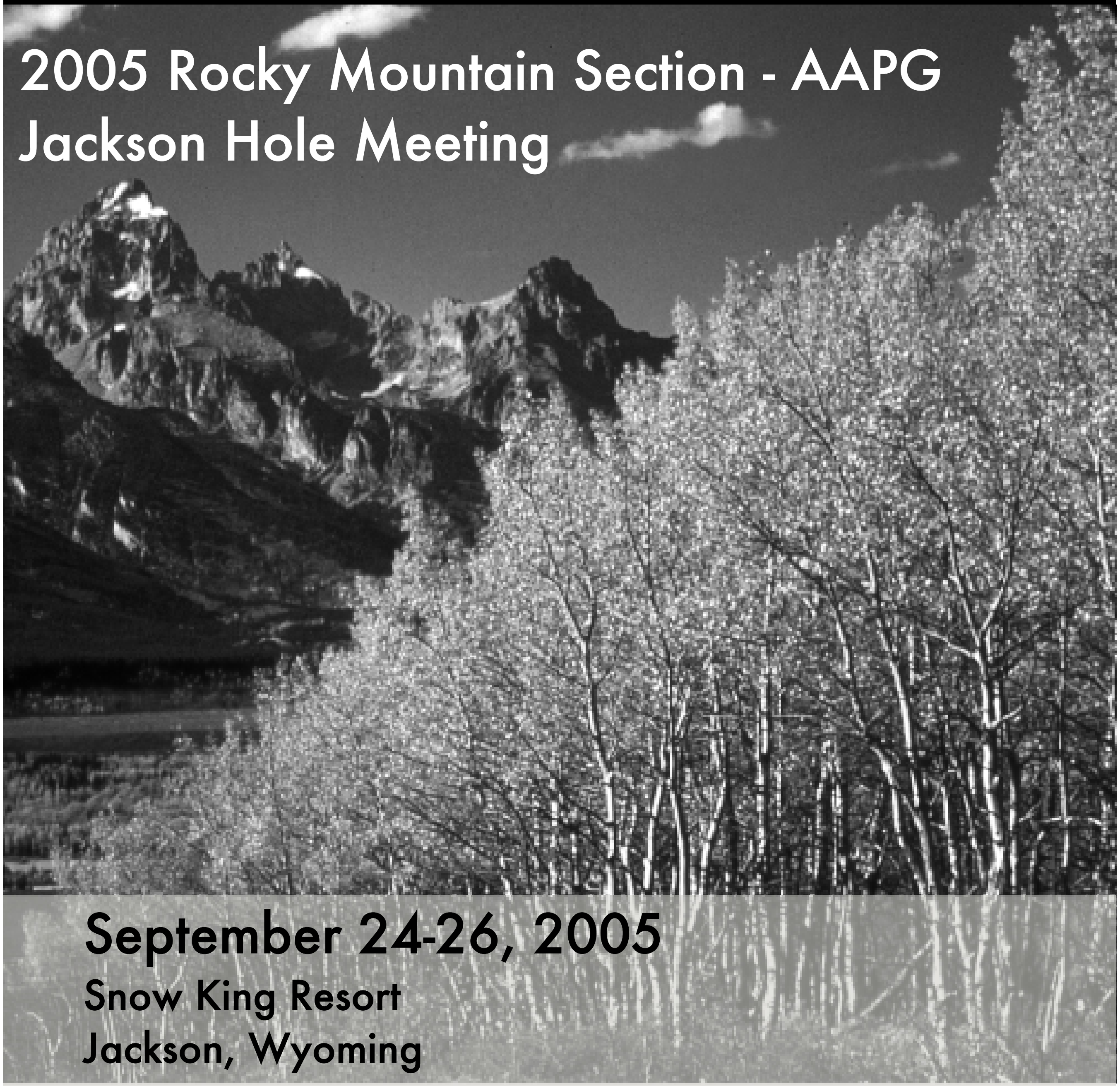
MEETING PROGRAM

2005 Rocky Mountain Section - AAPG
Jackson Hole Meeting



September 24-26, 2005

Snow King Resort
Jackson, Wyoming

Hosts: Wyoming Geological Association
Nevada Petroleum Society
Idaho Association of Professional Geologists

Program sponsored by

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Convention Committee Chairs

General	Jerry Walker and Sandra Mark
Technical Program	Lyn George
Awards/Judging	Paul Baclawski
Exhibits	John Kerns
Field Trip	Chuck Kluth
Finance	Charlie Gillespie
Publicity	Diane Phillips
Registration	Sandi Pellissier and Mary England
Short Course	Sandra Mark
Special Projects	Sam Limerick
Sponsorship	Margi Oldani Boissevain and Bill Houston
Volunteers	Robb Clayton and Ed Coalson

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President-Elect	Rob Diedrich
Secretary/Treasurer	Steve Schamel
Secretary/Treasurer-Elect	John Robinson

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Wyoming Geological Association (2005)

President	Tim McCutcheon
President-Elect	Tom Anderson
1st Vice President	Ralph Specht
2nd Vice President	Mark Milliken
Secretary/Treasurer	Brian Black

Nevada Petroleum Society (2005 - 2006)

President	Jerry Walker
Vice President/President-Elect	Jon Price
Secretary	Carl Welch
Treasurer	Steve Foster

Idaho Association of Professional Geologists (2005 - 2006)

Acting President	Starr Marea Johnson
Acting Secretary/Treasurer	Karl Languirand

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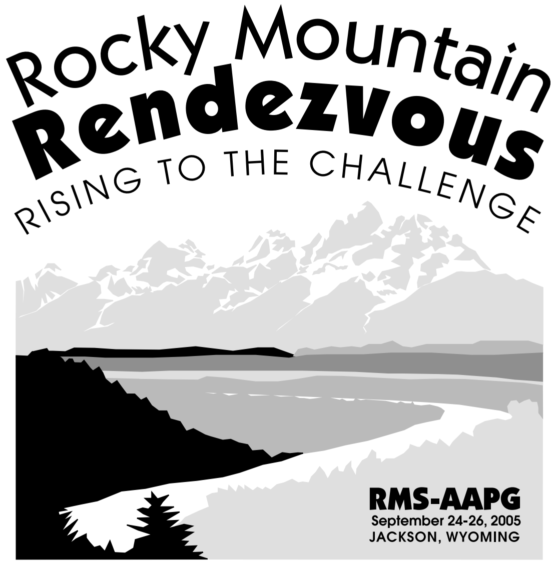
Sketches by Larry Jacox

Welcome to Jackson Hole and the 2005 Rocky Mountain Section Meeting



Thanks to you all for taking part in our exciting, jam-packed 2½-day program that is as wide ranging as the geologic provinces of its host societies: the Wyoming Geological Association, Nevada Petroleum Society, and Idaho Association of Professional Geologists. Like the fur trappers of the early 1800's, we believe you will experience the economic and social interactions of an old fashioned Rocky Mountain Rendezvous – honing your skills, trading ideas, and acquiring the necessities to rise to the challenge of securing our country's energy needs.

You're certain to enjoy the technical program, as Lyn George has put together a gem. Start off by attending Saturday afternoon's forum on Federal land use, and learn about the impact of the planning process and regulatory programs on oil-and-gas exploration and development of public lands. Then, make the hard decisions about which talks to attend on Sunday and Monday, for you'll have plenty from which to choose. Our Mega-Session, *Increasing the Supply of Rocky Mountain Natural Gas*, offers four sessions – *The Role of CBM 1 (Powder River Basin)* and *2*, *Economic and Technologic Aspects*, and *Geologic Aspects*, with attractive advice towards accomplishing this goal. Seven other sessions explore contemporary topics in the Rocky Mountain region: *Geologic Developments in the Rockies 1* and *2*, *Resource Plays*, *Advanced Technologies for Exploration and Production 1* and *2 (Seismic)*, *Reservoir Models and Case Studies*, and *Exploration Challenges of the Great Basin and Utah Hingeline*. Rounding it off, three general poster sessions provide an informal format to review the presenters' latest work.

Here's hoping that you'll be able to squeeze in one of the two well-timed short courses which Sandra Mark has organized. *Intro to Mining the Internet: Free GIS Data / Low Cost Software for the Oil & Gas Professional* provides hands-on instructions for a powerful computer application, while the short course on *Bakken Play Essentials* gives you an exciting look at the newest Williston Basin action. If you've got a hankering to get out into the field and see remarkable geology, we're sure you've checked out Chuck Kluth's offerings. A pre-meeting trip out of Rock Springs – led by Randi Martinsen, Ron Steel, Adam Van Holland, and Carolina Gomez – takes you to outcrops of tight gas sands and coalbed-methane resources in the Upper Cretaceous Mesaverde Group. As an adjunct to this trip, Jim Steidtmann and Randi Martinsen will cover the geology on Saturday's drive from Rock Springs to the meeting in Jackson Hole, with a visit to Jonah Field courtesy of EnCana Oil & Gas (USA) Inc. Or, you can take the Jonah tour by itself. After the meeting, soak up the breath-taking geology of the Jackson Hole region with Dave Lageson and David Adams.

John Kerns has gathered together a virtual melange of pertinent exhibitors who will display a wide range of services and items. Our *All Convention Luncheon* on Sunday features Bob Smith, from the University of Utah's Seismology and Active Tectonics Research Group, as our keynote speaker, who will captivate you with the story behind the evolution of the Yellowstone hot spot. At Monday's *AAPG Divisions Luncheon* you'll hear about the dynamic activities of each AAPG Division, with emphasis on the Rocky Mountains.

Don't miss Saturday evening's *Welcoming Reception*, where friends can congregate around the Snow King's heated pool and inviting lobby fireplace. The *Icebreaker* will be held in the Exhibit Hall Sunday afternoon. Partake of western cuisine and learn to swing dance at Sunday night's *BBQ Dinner*. Guest activities include a luncheon visit to the acclaimed National Museum of Wildlife Art, and a van tour or 10-mile float trip in Grand Teton National Park.

Jackson Hole, and Grand Teton and Yellowstone national parks offer a wonderful variety of outdoor activities. Indeed, September can be one of the best times of the year to visit these scenic treasures, when vistas are no longer packed by the hurried crowds of summer, replaced instead by the brilliance of autumn colors. Whitewater float trips, scenic lake cruises, hiking, and horseback riding are just some of the ways to take in the spectacular beauty. Chuck wagon dinners and fine dining provide tastes of both the old and new West, while the National Museum of Wildlife Art offers an unforgettable feast for the eyes of all to see.

We hope you experience a great meeting and get to enjoy all the wonders of Fall in Jackson Hole!

Jerry Walker and Sandra Mark
General Co-Chairs

Schedule of Events

All events will be held in the Snow King Resort unless otherwise noted.

Wednesday, September 21

5:00 p.m.	Field Trip 1 – Regressive vs. Transgressive Systems: Processes & Geometries	Meets in Rock Springs, WY

Thursday, September 22

8:00 a.m.	Field Trip 1 – Regressive vs. Transgressive Systems: Processes & Geometries	Rock Springs, WY

Friday, September 23

6:00 p.m.	Field Trip 1 – Regressive vs. Transgressive Systems: Processes & Geometries	Ends in Rock Springs, WY

Saturday, September 24

7:30 a.m.-4:00 p.m.	Field Trip 2A – Geology of Rock Springs to Jackson Hole *(with Jonah Field tour)*	Departs Rock Springs, WY
8:30 a.m.-1:00 p.m.	Field Trip 2B – Jonah Field Tour	Departs from and returns to intersection of U.S. Highway 191 and road to Jonah Field (milepost 67).
10:00 a.m.-7:00 p.m.	Registration	Jackson Room
10:00 a.m.-7:00 p.m.	Speaker Rehearsal/Judges Room	Timberline Two
12:00 p.m.-5:00 p.m.	Short Course 1 – Bakken Play Essentials	Timberline Three
12:00 p.m.-5:30 p.m.	Guest Hospitality Room	Paintbrush 153
1:00 p.m.-3:50 p.m.	Environmental Forum – Federal Land Use Planning	Timberline One
1:00 p.m.-4:00 p.m.	Short Course 2 – Intro to Mining the Internet: Free GIS Data / Low Cost Software	Computer Lab, Jackson H.S.
4:15 p.m.-5:30 p.m.	Opening and Awards Session	Timberline One
5:30 p.m.-7:00 p.m.	Welcoming Reception	Lobby/Poolside

Sunday, September 25

6:45 a.m.-8:00 a.m.	AAPG House of Delegates Breakfast	Summit Two
6:45 a.m.-8:00 a.m.	RMS-AAPG Foundation Breakfast Meeting	Summit One
6:45 a.m.-8:00 a.m.	Speakers/Poster Presenters/Judges Breakfast	Timberline Three
7:30 a.m.-5:00 p.m.	Speaker Rehearsal/Judges Room	Timberline Two
7:30 a.m.-6:00 p.m.	Registration	Jackson Room
8:00 a.m.-11:30 a.m.	Technical Session - Advanced Technologies for Exploration and Production 1	Teton Room
8:00 a.m.-4:00 p.m.	Guest Hospitality Room	Paintbrush 153
8:20 a.m.-11:30 a.m.	Mega-Session – Gas Supply: Economic and Technologic Aspects	Timberline One
9:00 a.m.-5:30 p.m.	Exhibit Hall	Grand Room
11:30 a.m.-3:30 p.m.	Guest Activity – Luncheon and Tour of the National Museum of Wildlife Art	Departs Snow King Resort
11:45 a.m.-1:15 p.m.	All Convention Luncheon	Lodge Room, Snow King Center
1:30 p.m.-4:20 p.m.	Mega-Session – Gas Supply: Role of CBM 1 (Powder River Basin)	Timberline One
1:30 p.m.-4:00 p.m.	Technical Session – Resource Plays	Teton Room
1:30 p.m.-4:00 p.m.	Technical Session – Geologic Developments in the Rockies 1	Timberline Three
1:30 p.m.-4:00 p.m.	General Poster Session 1	Rafferty's
4:00 p.m.-5:30 p.m.	Icebreaker	Grand Room
6:30 p.m.-9:30 p.m.	BBQ Dinner and Western Dancing	Lodge Room, Snow King Center

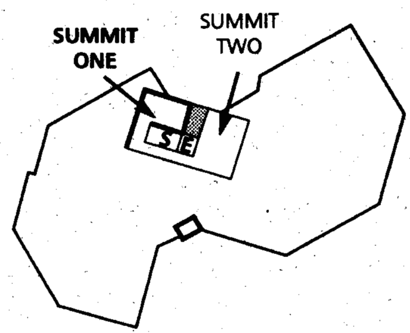
Monday, September 26

6:30 a.m.-9:00 a.m.	RMS-AAPG Executive Committee Breakfast Meeting	Jackson Room
6:45 a.m.-8:00 a.m.	Speakers/Poster Presenters Breakfast	Summit Two
7:30 a.m.-5:00 p.m.	Speaker Rehearsal/Judges Room	Timberline Two
8:00 a.m.-1:00 p.m.	Registration	Lobby
8:00 a.m.-5:00 p.m.	Exhibit Hall	Grand Room
8:00 a.m.-5:00 p.m.	Guest Hospitality Room	Paintbrush 153
8:00 a.m.-11:30 a.m.	Mega-Session – Gas Supply: Role of CBM 2	Timberline One
8:00 a.m.-11:30 a.m.	Technical Session – Advanced Technologies for Exploration and Prod. 2 (Seismic)	Teton Room
8:00 a.m.-11:30 a.m.	Technical Session – Geologic Developments in the Rockies 2	Timberline Three
9:00 a.m.-11:30 a.m.	General Poster Session 2	Rafferty's
9:00 a.m.-3:00 p.m.	Guest Activity – Tour of Grand Teton National Park	Departs Snow King Resort
9:15 a.m.-2:30 p.m.	Guest Activity – Snake River Float Trip through Grand Teton National Park	Departs Snow King Resort
11:45 a.m.-1:15 p.m.	AAPG Divisions Luncheon	Summit Two
1:30 p.m.-4:40 p.m.	Mega-Session – Gas Supply: Geologic Aspects	Timberline One
1:30 p.m.-4:40 p.m.	Technical Session – Exploration Challenges of the Great Basin and Utah Hingeline	Teton Room
1:30 p.m.-4:40 p.m.	Technical Session – Reservoir Models and Studies	Timberline Three
1:30 p.m.-4:00 p.m.	General Poster Session 3	Rafferty's

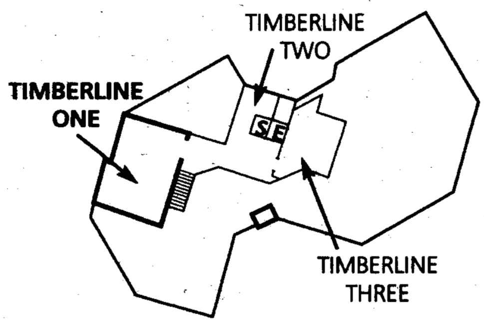
Tuesday, September 27

8:00 a.m. -5:00 p.m.	Field Trip 3 – Overview of the Geology of Jackson Hole and the Teton Range	Departs Snow King Resort

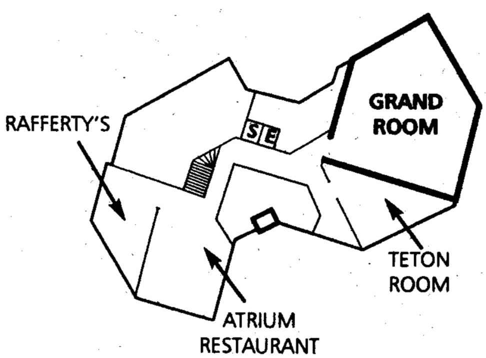
Floor Plans - *Snow King Resort*



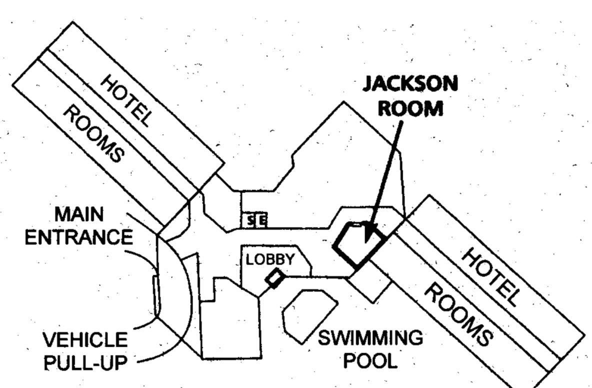
SUMMIT LEVEL (4th floor)



TIMBERLINE LEVEL (3rd floor)



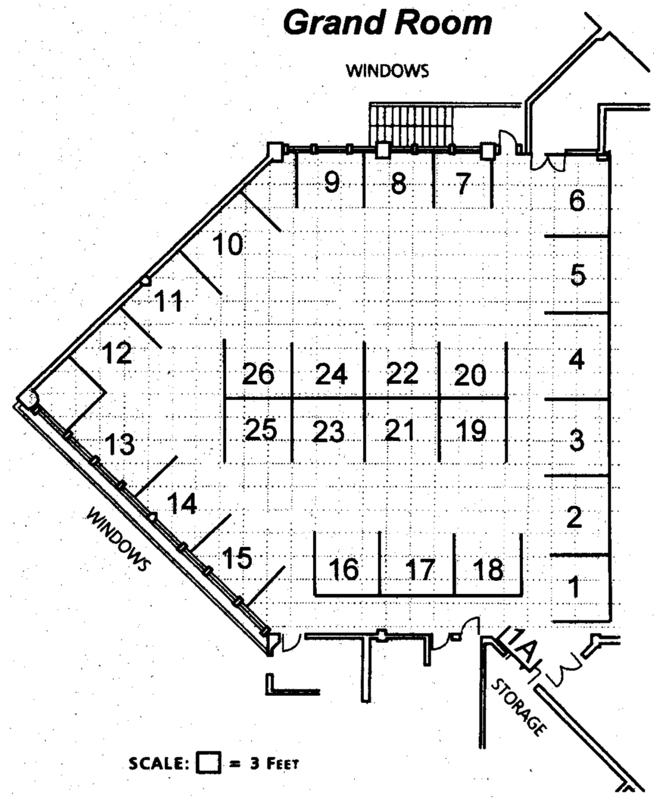
GRAND TETON LEVEL (2nd floor)



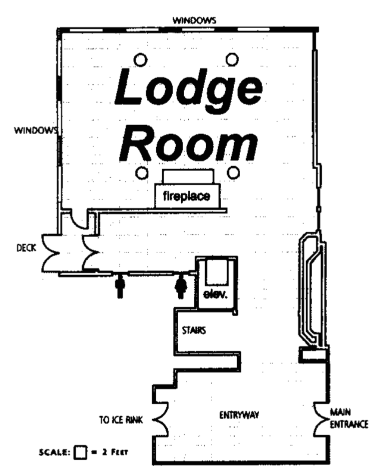
MAIN LEVEL (1st floor)

EXHIBIT HALL

Grand Room



Snow King Center



Located 200 yards west of Hotel lobby.

Exhibitors

A2D Technologies **3**
2345 Atascocita Road
Humble, TX 77396
Phone: (281) 319-4944
Fax: (281) 319-4945
Web Site: www.a2d.com

AAPG Bookstore . . . . **21 & 23**
P.O. Box 979 / 1444 South Boulder
Tulsa, OK 74101-0979 / 74119
Phone: (800) 364-2274 or (918) 584-2555
Fax: (800) 898-2274 or (918) 560-2652
Web Site: www.aapg.org

Baker Atlas **9**
2001 Rankin Road
Houston, TX 77073-5100
Phone: (713) 625-6313
Fax: (713) 625-6510
Web Site: www.bakerhughes.com/bakeratlas

Core Laboratories **19**
538 Olathe Street, Suite F
Aurora, CO 80011
Phone: (720) 532-2666
Fax: (720) 532-2665
Web Site: www.corelab.com

Digital Formation **26**
Denver Place, South Tower / 999 18th St, Suite 2410
Denver, CO 80202
Phone: (888) 747-5372 or (303) 770-4235
Fax: (303) 770-0432
Web Site: www.digitalformation.com

Direct Geochemical **20**
130 Capital Drive, Suite C
Golden, CO 80401
Phone: (303) 277-1694
Fax: (303) 278-0104
Web Site: www.directgeochemical.com

Entrada GeoSciences **7**
11 Inverness Way South
Englewood, CO 80112
Phone: (303) 825-7140
Fax: (303) 799-4190
Web Site: www.entradageo.com

ESRI **11**
One International Court
Broomfield, CO 80021
Phone: (303) 449-7779
Fax: (303) 449-8830
Web Site: www.esri.com

GeoCare Benefits **25**
P.O. Box 9006
Phoenix, AZ 85068-9006
Phone: (800) 337-3140
Fax:
Web Site: www.geocarebenefits.com

GeoGraphix . . . . **22 & 24**
1805 Shea Center Drive, Suite 400
Highlands Ranch, CO 80129
Phone: (303) 779-8080
Fax: (303) 796-0807
Web Site: www.geographix.com

Geologic Data Systems **4**
1821 Blake Street, Suite 1A
Denver, CO 80202
Phone: (303) 837-1699
Fax: (303) 837-1698
Web Site: www.gdata.com

geoPLUS **1**
8801 South Yale, Suite 380
Tulsa, OK 74137
Phone: (918) 971-7071
Fax: (918) 971-7074
Web Site: www.geoplus.com

Minerals Diversified Services 1A
P.O. Box 2256
Bismarck, ND 58502
Phone: (701) 224-1811
Fax: (701) 258-8577
Web Site: www.willistonbasin.com

Omni Laboratories 12
8845 Fallbrook Drive
Houston, TX 77064
Phone: (832) 237-4000
Fax: (832) 237-4700
Web Site: www.omnilabs.com

Pason Systems USA 14
16100 Table Mountain Parkway, Suite100
Golden, CO 80403
Phone: (720) 880-2000
Fax: (720) 880-0016
Web Site: www.pason.com

Premier Data Services 2
8310 South Valley Highway, Suite 220
Englewood, CO 80112
Phone: (800) 210-9100 or (303) 377-0033
Fax: (303) 377-3663
Web Site: www.premierdata.com

Rocky Mountain Assoc. of Geologists 18
820 16th Street, Suite 505
Denver, CO 80202
Phone: (303) 573-8621
Fax: (303) 628-0546
Web Site: www.rmag.org

Rocky Mountain Oilfield Testing Center 6
907 North Poplar, Suite 150
Casper, WY 82601
Phone: (888) 599-2200 or (307) 261-5000
Fax: (307) 261-5997
Web Site: www.rmotc.com

Schlumberger 5
5599 San Felipe, Suite 1700
Houston, TX 77056
Phone: (713) 513-2000
Fax: (713) 513-2006
Web Site: www.sis.slb.com

Ulrich's Fossil Gallery 8
Fossil Station #308
Kemmerer, WY 83101
Phone: (307) 877-6466
Fax: (307) 877-3289
Web Site: www.ulrichsfossilgallery.com

Utah Geological Survey 10
Box 146100 / 1594 West North Temple, Suite 3110
Salt Lake City, UT 84114-6100
Phone: (801) 537-3300
Fax: (801) 537-3400
Web Site: geology.utah.gov

Veritas DGC .... 16 & 17

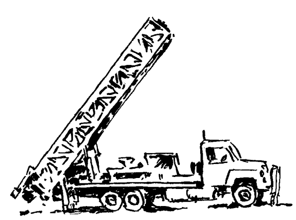
10300 Town Park Drive	410 17th Street, Suite 1140
Houston, TX 77072	Denver, CO 80202
Phone: (832) 351-8300	(303) 825-7400
Fax: (832) 351-8701	(303) 825-2233

Web Site: www.veritasdgc.com

WellDog 13
1482 Commerce Drive, Suite T
Laramie, WY 82070
Phone: (307) 721-8875
Fax: (307) 742-0943
Web Site: www.welldog.com

Wyoming Geological Assoc. ..... by Registration
P.O. Box 545
Casper, WY 82602
Phone: (307) 237-0027
Fax: (307) 234-4048
Web Site: www.wyogeo.org

Wyoming State Geological Survey 15
P.O. Box 1347
Laramie, WY 82073
Phone: (307) 766-2286
Fax: (307) 766-2605
Web Site: www.wsgs.uwyo.edu



General Information

Registration

Jackson Room
Saturday, 10:00 a.m.-7:00 p.m.
Sunday, 7:30 a.m.-6:00 p.m.

Lobby
Monday, 8:00 a.m.-1:00 p.m.

Exhibit Hall

Grand Room
Sunday, 9:00 a.m.-5:30 p.m.
Monday, 8:00 a.m.-5:00 p.m.

Exhibit setup: Sunday, 6:00 a.m.-9:00 a.m.
breakdown: Monday, 5:00 p.m.-8:00 p.m.

Speaker Rehearsal/Judges Room

Timberline Two Room
Saturday, 10:00 a.m.-7:00 p.m.
Sunday, 7:30 a.m.-5:00 p.m.
Monday, 7:30 a.m.-5:00 p.m.

Speaker/Poster Presenter Information

All speakers should check-in at the Speaker Rehearsal Room in Timberline Two, to preview their PowerPoint presentation and receive technical assistance. All poster sessions will be held in Rafferty's. Set-up time for Sunday and Monday afternoon poster sessions is 12:30-1:30 p.m.; breakdown is 4:00-5:00 p.m. Set-up time for the Monday morning poster session is 8:00-9:00 a.m.; breakdown is 11:30 a.m.-12:30 p.m. Presenters should be at their display during the initial two hours of their session. Speakers and poster presenters should attend the complimentary breakfast each morning of their session. The breakfasts are at 6:45 a.m. in the Timberline Three Room on Sunday and the Summit Two Room on Monday.

Judges Information

All poster and oral session judges should attend the complimentary Speakers/Poster Presenters/Judges Breakfast on Sunday at 6:45 a.m. in the Timberline Three Room to receive judging forms and final instructions. If you are unable to attend the breakfast, you can pick up your packet in the Speaker Rehearsal/Judges Room in Timberline Two.

Environmental Forum

(Saturday, September 24th, 1:00 p.m. – 3:50 p.m., Timberline One Room)

How the Federal Land Use Planning Process and other Regulatory Programs Impact Oil and Gas Exploration and Development on Public Lands

This forum will review issues related to environmental protection and their consequences on the oil-and-gas industry's access to and use of public lands. It will focus on how the federal land-use planning process works and how it affects oil-and-gas exploration and development – from leasing to final reclamation. Federal land-use planning is conducted through the Resource Management Plan. A land-use lawyer will discuss how industry can be more involved in this planning process. Increasing demand for access to public land by industry has placed additional burdens on the US Bureau of Land Management. Representatives from the Utah and Wyoming BLM state offices will discuss how their offices are meeting the challenges presented by these demands, and will provide updates for their states. For an industry perspective on these issues, a Wyoming operator will talk about his experiences on Federal lands and how his company is striving to deal with the regulatory environment.

Speakers include Claire Mosely (Executive Director, Public Lands Advocacy, Denver), Kent Hoffman (Deputy State Director, Lands and Minerals, BLM, Utah), Alan Rabinoff (Deputy State Director, Minerals and Lands, BLM, Wyoming), and John Kennedy (Kennedy Oil).

Opening/Awards Session

(Saturday, September 24th, 4:15 p.m. – 5:30 p.m., Timberline One Room)

The session will include opening remarks from Steve Veal, AAPG Vice President, and by leaders of the Rocky Mountain Section and the Wyoming Geological Association. Candidates for national AAPG offices will have an opportunity to briefly address the attendees.

Paul Baclawski, Chair of the Awards/Judging Committee, will present the A.I. Levorsen Award, Steve Champlin Memorial Award, and the Runge Award to the awardees from the 2004 RMS-AAPG Denver annual meeting.

A.I. Levorsen Award for Best Oral Presentation

R.A. Lamarre and S.K. Ruhl: *Atlantic Rim Coalbed Methane Play: The Newest Successful CBM Play in the Rockies*

Steve Champlin Memorial Award for Best Poster Presentation

N. Waechter, J. Shipps, G. Hampton III, and J. Seidle: *Comparison of Lost Gas Projections in Coalbed Methane*

Runge Award for Best Student Presentation

A. Ellison, M.J. Pranter, R.D. Cole, and P.E. Patterson: *Quantification of Stratigraphic Heterogeneity within a Fluvial Point-Bar Sequence, Williams Fork Formation, Piceance Basin, Colorado: Application to Reservoir Modeling*

Levorsen Award

The A.I. Levorsen Memorial Award was established as a result of contributions from many individuals and societies who wished to contribute a lasting memorial to Dr. A.I. Levorsen. A plaque is given at the section meetings of the American Association of Petroleum Geologists for the best paper, with particular emphasis on creative thinking toward new ideas in exploration.

Steve Champlin Memorial Award

The Wyoming Geological Association sponsors the Steve Champlin Memorial Best Poster Award, which is presented to the poster author receiving the highest score at the annual Rocky Mountain Section of the American Association of Petroleum Geologists annual meeting. This award was created to encourage poster authors to strive for excellence in their presentations and to foster the one-on-one discussions of geology for which Steve Champlin was well know. First created in 1986, it is hoped that this award will carry on Steve's spirit of friendly cooperation for the exploration of our natural resources.

All divisions of the RMS-AAPG, EMD, DEG, and SEPM are eligible for this award, and a plaque will be presented to the winner or to the senior author in case of multiple authors. The only restriction is that the display and the oral presentation must not be part of a professional presentation that is for sale or is part of a sales presentation. The award is for scientific endeavor, and for the courage to display a new concept before your peers and to defend that concept under their scrutiny.

Runge Award

The Runge Award recognizes professional and scientific excellence in the student papers presented before the RMS-AAPG annual meeting, with particular emphasis on creative thinking toward new ideas in exploration. Established in 1975, the award is made to the student presenting the best paper as judged by a committee established for evaluation of papers at each meeting. The qualifications of the author or authors is defined as follows:

1. The paper was prepared during the author's enrollment in a college or university.
2. The abstract was submitted to the Section during enrollment or no later than one year following the end of the last semester of enrollment of the author.
3. If more than one author participated on the paper, all authors must meet the above qualifications.

The award is an engraved plaque which is presented to the recipient at the next meeting of the RMS-AAPG. The award is provided by John S. Runge, petroleum geologist, Casper, Wyoming.

Luncheons

All Convention Luncheon

Sunday, 11:45 a.m. – 1:15 p.m., Lodge Room (in the Snow King Center, 200 yards west of the Hotel Lobby), $25

The All Convention Luncheon will feature Dr. Robert B. Smith, from the University of Utah's Seismology and Active Tectonics Research Group. Bob will speak on *The Yellowstone Hotspot: Its Plume Origin and Effect on Western U.S. Tectonics*. His current research projects include the study of the geodynamics and evolution of the Yellowstone hot spot and caldera, seismicity and volcanic hazards of Yellowstone, operation of the Yellowstone seismograph network, and crustal deformation and earthquake hazards of the Wasatch and Teton faults using GPS and fault modeling. Dr. Smith has been featured in the BBC Science television show *Supervolcano*, about the volcanic history of Yellowstone.

AAPG Divisions Luncheon

Monday, 11:45 a.m. – 1:15 p.m., Summit Two, $25

Representatives from all three AAPG Divisions will speak at the AAPG Divisions Luncheon. President Steven P. Tischer will represent the Division of Environmental Geosciences and President-Elect Rich Green the Division of Professional Affairs. Laura L. Wray, Rocky Mountain Section Councilor, will speak on behalf of the Energy Minerals Division. Their presentations will highlight the activities and initiatives of their respective Divisions, emphasizing developments in the Rocky Mountains.

Social Events

Welcoming Reception

Saturday, 5:30 p.m. – 7:00 p.m., Lobby/Poolside, By badge only

After a day of travel, stop by the Snow King Resort for a warm welcome. Congregate around the heated pool and inviting lobby fireplace with your old friends and make new ones. Enjoy your favorite cocktails and hors d'ouevres while trading stories about the latest Rocky Mountain plays and technologies.

Icebreaker

Sunday, 4:00 p.m. – 5:30 p.m., Exhibit Hall (Grand Room), By badge only

Join us at the Icebreaker Sunday afternoon in the Exhibit Hall. Browse through the exhibits while you enjoy your favorite cocktails and hors d'ouevres. If you missed past colleagues and associates last night, you'll have a second chance this afternoon to catch up with your old acquaintances.

Your badge will gain you admittance to this event. Please note that children under the age of 13 will not be allowed into the exhibits area.

BBQ Dinner and Western Dance

Sunday, 6:30 p.m. – 9:30 p.m., Lodge Room (in the Snow King Center, 200 yards west of the Hotel Lobby), $40 (includes dinner and dance lessons)

Join us in the Lodge Room, just across the Resort parking lot in the Snow King Center, for a BBQ dinner and western dance. Savor the western cuisine, including salads and Cole slaw, hearty BBQ'd pork ribs and tender chicken, corn on the cob, spicy ranch-style baked beans, cornbread and hot apple walnut cobbler. Then, grab your partner, kick up your heals, and be ready to work off those extra ribs you couldn't pass by. Instructors from the Jackson Dance Group will teach us the Western Swing (a.k.a. the 4-Count Swing) and the 2-Step. Afterwards, head to the Square and put your newly learnt talents to work on the Million Dollar Cowboy Bar's dance floor.

Guest Activities

Guest Hospitality Room

Paintbrush 153, Snow King Resort

Saturday, 12:00 noon – 5:30 p.m.
Sunday, 8:00 a.m. – 4:00 p.m.
Monday, 8:00 a.m. – 5:00 p.m.

Please stop by the hospitality room for refreshments and information on exciting things-to-do in Jackson Hole. It's a great place to relax, catch up with old friends and make new ones.

Luncheon and Docent Tour of the National Museum of Wildlife Art

Sunday, 11:30 a.m. – 3:30 p.m., $35

Come join us for a delightful luncheon at the National Museum of Wildlife Art's Rising Sage Café, overlooking the National Elk Refuge and Gros Ventre Mountains. After lunch, we will be given a guided tour of the Museum – home to the nation's premier public collection of fine art devoted to wildlife.

The NMWA was founded in 1987 with a prestigious collection of wildlife art donated by Joffa and Bill Kerr. The current 51,000 square-foot facility, opened in 1994, blends into the rugged hillside with its irregular architectural lines and natural building materials. The NMWA houses 12 galleries, featuring artists such as John J. Audubon, Albert Bierstadt, Pablo Picasso, Carl Rungius, and Charlie Russell. Enjoy the Summer 2005 Exhibitions: "Wildlife Art for a New Century" and "GEORGIA O'KEEFFE: The Unexplainable Thing in Nature."

Tour of Grand Teton National Park

Monday, 9:00 a.m. – 3:00 p.m., $80

Experience the spectacular scenery of Grand Teton National Park and learn about the natural and human history, geology and wildlife of Jackson Hole. An experienced guide will take you to the wonders of the park. Possible destinations include Antelope Flats, Gros Ventre landslide, Menor's Ferry, Jenny Lake, Signal Mountain, and the collection of fine Native American art at Colter Bay. The private trip can be personalized to the interests of the participants. Price includes park entrance fee, box lunch, bottled water and snacks.

Snake River Float Trip through Grand Teton National Park

Monday, 9:15 a.m. – 2:30 p.m., $80

Beneath the towering peaks of the Teton Range, the Snake River threads its many channels through a landscape hardly touched by human hand. Sometimes swift, sometimes meandering, it sustains an environment rich with spruce and willows, beaver and moose, ospreys and eagles. Barker-Ewing's 10-mile scenic float trip in Grand Teton National Park, which began in 1963, allows you to experience the outstanding Teton scenery and glimpse the abundant wildlife from the Snake River. The trip runs from historic Dead Man's Bar, located just below the Snake River Overlook, to Moose Village, and takes 2 1/2 to 3 hours. The comfortable and stable rafts are guided by professional boatmen, who will share their thorough knowledge of the natural history of Jackson Hole.

Barn in Teton Range.

Short Courses

Short Course #1: Bakken Play Essentials

Date: Saturday, 12 noon – 5 p.m.
Instructors: *(see list of instructors below)*
Location: Timberline Three, Snow King Resort
Fee: $35 (includes lunch sponsored by Sunburst Consulting)
Limit: 48 persons
Sponsors: Rocky Mountain PTTC and Montana Geological Society

Instructors

Dick Findley (Prospector Oil, Inc., Billings, MT)
Julie LeFever (North Dakota Geological Survey, Grand Forks, ND)
John Kieschnick and Robert Suarez-Rivera, (TerraTek, Salt Lake City, UT)
Michael Holmes (Digital Formation, Denver, CO)
Gary Gill (Schlumberger, Calgary, AB)
Tom Lantz (Halliburton, Denver, CO)

Short Course #2: Introduction to Mining the Internet: Free GIS Data / Low Cost Software for the Oil & Gas Professional

Date: Saturday, 1 p.m. – 4 p.m.
Instructor: David Bickerstaff (Bickerstaff Associates, Denver, CO)
Location: Jackson Hole High School, Computer Lab 1507
Fee: $125, includes transportation from Snow King Resort, notes, and afternoon snacks
Limit: 25 persons
Sponsors: Rocky Mountain PTTC and Nevada Petroleum Society

Field Trips

Field Trip #1: Regressive versus Transgressive Systems: Processes and Geometries in the Upper Cretaceous Mesaverde Group

Date: Wednesday, 5:00 p.m. through Friday, 6:00 p.m.
Leaders: Randi Martinsen (University of Wyoming, Laramie, WY)
Ron Steel (University of Texas, Austin, TX)
Adam Van Holland (EnCana Oil & Gas (USA) Inc.)
Carolina Gomez (University of Texas, Austin, TX)
Fee: $475 (includes transportation during field trip, three nights lodging based on double occupancy, refreshments, lunches and guidebook)
Limit: 25 persons
Sponsor: RMS-AAPG

Note: Field trip begins and ends in Rock Springs, Wyoming. Transportation from Rock Springs to Jackson is available at extra cost via Field Trip #2A.

Field Trip #2A: Geology of Rock Springs to Jackson Hole, Wyoming *(with Jonah Field tour)*

Date: Saturday, 7:30 a.m. – 4:00 p.m.
Leaders: Jim Steidtmann (University of Wyoming, Laramie, WY)
Randi Martinsen (University of Wyoming, Laramie, WY)
Fee: $125 (includes transportation from Rock Springs to Jackson, Wyoming, lunch and drinks)
Limit: 25 persons (If you require transportation from Rock Springs to Jackson, this is the way to go. Sign up early to assure a place.)
Sponsor: RMS-AAPG

Note: Field trip provides optional transportation from Rock Springs to the Snow King Resort in Jackson, Wyoming following completion of Field Trip #1.

Field Trip #2B: Jonah Field Tour

Date: Saturday, 8:30 a.m. – 1:00 p.m.
Organizers: Debra Nishida and Brandy Butler (EnCana Oil & Gas (USA) Inc.)
Randi Martinsen (University of Wyoming, Laramie, WY)
Fee: $75 (includes transportation during tour and lunch)
Limit: 35 persons (including participants of Field Trip #2A)
Sponsor: EnCana Oil & Gas (USA) Inc. (This trip is fully subsidized by EnCana. All proceeds from the trip go to RMS-AAPG.)

Field Trip #3: Overview of the Geology of Jackson Hole and the Teton Range

Date: Tuesday, 8:00 a.m. – 5:00 p.m.
Leaders: Dave Lageson (Montana State University, Bozeman, MT)
David Adams (University of Oregon, Eugene, OR)
Fee: $35 (includes lunch and printed materials)
Limit: 25 persons
Sponsor: RMS-AAPG

Exhibits

(Sunday, 9:00 a.m. – 5:30 p.m., and Monday, 8:00 a.m. – 5:00 p.m., Grand Room)

Vendors in service to the petroleum exploration and development industry are demonstrating the latest in a wide range of products and services that are available to the industry.

Exhibits will be housed in the Grand Room of the Snow King Resort. The exhibition also serves as the high-tech setting for the late afternoon Icebreaker on Sunday.

The AAPG Bookstore is brimming with new and interesting publications, so count on using it as your rendezvous point with colleagues during the meeting.

NOTE: A trade exhibition is not a safe place for children, so please be advised that no one under the age of 13 will be allowed in the hall at any time.

DISCLAIMER

The Rocky Mountain Section of the American Association of Petroleum Geologist ("RMS-AAPG"), Wyoming Geological Association ("WGA"), Nevada Petroleum Society ("NPS"), and Idaho Association of Professional Geologists ("IAPG") specifically disclaim any liability for any act or omission of any exhibitor, except the WGA booth, at the RMS-AAPG Section Meeting September 24-26, 2005. With the exception of the WGA booth, the RMS-AAPG, WGA, NPS, and IAPG hold no interest in any exhibitor, and no commission or renumeration is paid to the RMS-AAPG, WGA, NPS, or IAPG based upon sales or income of any exhibitor. Exhibitors are independent business persons who rent exhibit space, and the RMS-AAPG, WGA, NPS, and the IAPG are not responsible for any exhibitor's acts and omissions.

Bull Elk in Autumn.

Technical Program

All Technical Program events will be held in the Snow King Resort.

September 24 — Saturday Afternoon Oral

Environmental Forum: How the Federal Land Use Planning Process and Other Regulatory Programs Impact Oil and Gas Exploration and Development on Public Lands

Timberline 1
Chair: B. Berg

1:00 **Introductory Remarks**
1:05 **C. Moseley:** Review of the Federal Land Use Planning Process
1:35 **K. Hoffman:** Utah—Permitting Challenges in a Rocky Mountain Petroleum Frontier
2:05 **A. Rabinoff:** Overview of Oil and Gas Permitting—Issues Faced by the Bureau of Land Management in Wyoming
2:35 **J. Kennedy:** Management of Produced Water from Coalbed Natural Gas Wells, Powder River Basin, Wyoming
3:05 **Audience Q & A**
3:25 **Concluding Comments by Speakers**
3:45 **Concluding Remarks**

September 25 — Sunday Morning Oral

Increasing the Supply of Rocky Mountain Natural Gas: Economic and Technologic Aspects

Timberline 1
Co-Chairs: D. Hawk and M. Doelger

8:20 **Introductory Remarks**
8:30 **D. Nummedal:** A New Energy System for the Intermountain West—Built on Domestic Primary Resources and Negative Carbon Emissions
8:50 **R. H. De Bruin, N. R. Jones*, R. M. Lyman, A. J. Ver Ploeg:** Overview of an Interactive Online Internet-Based Map Server (IMS) for Wyoming's Northern Powder River Basin
9:10 **C. Hansen:** Supplying the Next Generation of Petroleum Professionals
9:30 **Break**
9:50 **B. G. Hassler:** The Rocky Mountain Transportation Conundrum
10:10 **J. B. Curtis:** Utility of Rocky Mountain Tight Gas Sand Resource Assessments: Data Sources, Methodologies and End Users
10:30 **R. C. Surdam, Z. Sheng:** A Strategy to Reduce Risk in Searching for Gas Accumulations in Tight-Gas Sand
10:50 **C. A. Wood, C. E. Graham:** Regulatory Framework for 80-Acre Development Created in the Greater Wamsutter Development Area
11:10 **S. Kneller, R. W. McDermott, S. G. Zinke:** What's UP on the Pinedale Anticline

Advanced Technologies for Exploration and Production 1

Teton
Co-Chairs: J. Steidtmann and K. Grubbs

8:00 **Introductory Remarks**
8:10 **H. Tie, N. R. Morrow*:** Low Flood Rate Residual Saturations in Carbonate Rocks
8:30 **D. Schumacher, D. Hitzman, B. Rountree:** Geochemical Exploration Surveys in the Rockies: Strategies for Success
8:50 **K. van't Veld, J. M. Boyles, B. Towler, A. Ergenc, C. Mason:** Using the EORI Scoping Tool to Assess the Potential Suitability of a Wyoming Oil Field for Enhanced Oil Recovery

*Denotes speaker other than senior author.

Technical Program *continued*

9:10 **J. S. Arbogast, S. M. Goolsby:** Inversion Modeling of the SP Log—Resurrecting and Quantifying a Critical Measurement for Predicting Permeability and Formation Water Resistivity
9:30 **Break**
9:50 **D. D. Cramer:** Analyzing Hydraulically Fractured Gas Well Performance in the Greater Green River Basin of Wyoming
10:10 **E. E. Wadleigh:** Application of Fractured Reservoir Simulation Concepts—Teapot Dome
10:30 **R. W. Klusman:** Is It Possible to Detect Gas Seepage from CO_2-EOR Projects? Experience at Rangely, Colorado, with CO_2-EOR, and Teapot Dome, Wyoming, at Baseline Condition
10:50 **S. Wo:** Reservoir Modeling and Simulation for CO_2 Flooding: The Effect of Reservoir Heterogeneity on Simulation Forecasts
11:10 **P. Yin:** Characterization of Tensleep Sandstone Reservoirs

September 25 — Sunday Afternoon Oral

Increasing the Supply of Rocky Mountain Natural Gas: The Role of CBM 1, Powder River Basin

Timberline 1
Co-Chairs: J. Goolsby and F. Mark

1:30 **Introductory Remarks**
1:40 **M. Ashley:** Wyodak Coal, Tongue River Member of the Fort Union Formation, Powder River Basin, Wyoming: "No-Coal Zones" and Their Effects on Coalbed Methane Production
2:00 **M. J. Blackstone:** The Fort Union Formation of the Powder River Basin, Campbell County, Wyoming: The Methane Gas Potential of the Upper Fort Union Formation Sandstones
2:20 **R. E. Zilinski, D. M. Goldstein:** Paleotectonic Control and Its Relationship to Wyodak Coal Deposition and Production in the Powder River Basin, Wyoming
2:40 **G. Ulrich, R. DeBruyn, M. Finkelstein, J. Weber*:** Active Biogenesis of Methane in Ft. Union Coals of Wyoming's Powder River Basin
3:00 **D. A. Klein, R. M. Flores, S. McKinney, L. P. Pereyra, A. Pruden-Bagchi:** Cultural and Molecular Studies of Methanogens in Paleocene Fort Union Formation Coal from the Powder River Basin of Wyoming and Montana
3:20 **M. S. Ellis, G. D. Stricker, R. M. Flores:** Gas Desorption Tests: Application for Powder River Basin Gas Production Prediction
3:40 **C. R. Nelson:** Coalbed Natural Gas Resource Potential of the Wyodak-Anderson Coal Zone in the Powder River Basin
4:00 **J. S. Chamness:** Coalbed Methane Produced Water Management—Beneficial Use Alternatives in the Rocky Mountain States

Resource Plays

Teton
Co-Chairs: J. LeFever and B. Bereskin

1:30 **Introductory Remarks**
1:40 **J. Kieschnick, R. Suarez-Rivera, D. Handwerger:** Evaluating Thermogenic Tight Gas Shales: The Unconventional Frontier with Proven Success
2:00 **S. Schamel:** Shale Gas Reservoirs of Utah
2:20 **J. Morel:** The Goshen Multi-Zone Project: A Resource Area Where Multi-Stage Frac Technology May Commercialize Stacked Low Permeability, Hydrocarbon Saturated Targets
2:40 **S. Schamel, S. R. Bereskin:** Detached Silt-Rich Lowstand Shoreface Deposits of the Western Interior Seaway: Known and Prospective 'Shale' Gas Reservoirs
3:00 **R. C. Johnson, T. M. Finn, S. B. Roberts, L. N. R. Roberts, P. G. Lillis, P. H. Nelson:** Upper Cretaceous and Tertiary Petroleum Systems and Assessment Units, Wind River Basin, Wyoming
3:20 **J. A. LeFever:** Horizontal Drilling Potential of the Middle Member Bakken Formation, North Dakota

*Denotes speaker other than senior author.

3:40 **J. T. Sperr, R. B. Burke:** The Upper Birdbear Formation (Nisku) of Western North Dakota: Another Emerging Williston Basin Horizontal Play

Geologic Developments in the Rockies 1

Timberline 3
Co-Chairs: R. Martinsen and P. Isaacson

1:30 **Introductory Remarks**
1:40 **D. Nummedal, H. Luo, S. Liu:** Late Cretaceous Subsidence in Wyoming
2:00 **H. Luo, D. Nummedal:** Documentation of Late Cretaceous Forebulge Migration in Southwestern Wyoming
2:20 **A. S. Otteman, A. W. Snoke:** Structural Analysis of a Larmide-Age, Basement-Involved, Foreland Fault Zone, Rawlins Uplift, South-Central Wyoming
2:40 **T. G. Neely:** 3-D Strain at Transitions in Foreland Arch Geometry: Structural Modeling of The Beartooth Arch—Rattlesnake Mountain Transition, Northwest Wyoming
3:00 **E. Erslev:** What are the Mechanisms and Timing of Joints in the Rockies?
3:20 **M. Millard, R. W. Clayton, C. S. Painter:** Sediment Diapirism and Gravity Sliding of the 2 Ma Huckleberry Tuff Near the Teton Dam, Idaho: Small-Scale Structural Constraints
3:40 **W. D. Hausel:** Gemstones in Wyoming: Geology and Exploration

September 25 — Sunday Afternoon Poster

General Poster Session 1

Rafferty's
Chair: L. George

1:30 to 4:00 p.m.

P1 **P. B. Anderson:** Mesaverde Gas Play—Eastern Uinta Basin, Utah
P2 **Y. Bartov, D. Nummedal:** Exploring the Basin Fill History of the Green River Formation in the Piceance Creek and the Uinta Basins
P3 **T. C. Chidsey, Jr., D. A. Sprinkel:** Petroleum Geology of Ashley Valley Field and Hydrocarbon Potential of the Surrounding Area, Uintah County, Utah
P4 **H. Pekarek:** Structure, Stratigraphy, and Hydrocarbon Potential of Butte Valley, White Pine County, Nevada
P5 **C. S. Painter, W. W. Little, G. F. Embree, M. Millard:** Geomorphic Response of the Henrys Fork River to Pleistocene Volcanism, Mesa Falls Recreation Area, Caribou-Targhee National Forest, Idaho
P6 **T. L. De Keyser:** Petrographic Reservoir Characterization—Direct Measurement and Analysis of Pore and Grain Size Data from Thin Sections

September 26 — Monday Morning Oral

Increasing the Supply of Rocky Mountain Natural Gas: The Role of CBM 2

Timberline 1
Co-Chairs: J. Goolsby and F. Mark

8:00 **Introductory Remarks**
8:10 **M. Mavor, W. D. Gunter:** Evaluation of Coal Seam Permeability in Marginal Reservoirs
8:30 **R. A. Larson, G. J. Holm, J. Lorenz:** Coalbed Methane Resource Development in Ecologically Sensitive Environments, Vermejo Park Ranch, New Mexico—a Case Study
8:50 **R. A. Lamarre:** Undersaturation in Coals: How Does It Happen and Why Is It Important
9:10 **P. R. Oldaker, U. Fehn:** Dating of Coalbed Methane Reservoir and Surface Waters in the Raton Basin, Colorado and the Susitna Basin, Alaska
9:30 **Break**
9:50 **J. Pope:** Same Day Downhole Critical Gas Content Without the Core
10:10 **A. R. Scott:** Coalbed Methane in the San Juan and Powder River Basins: Differences and Similarities

*Denotes speaker other than senior author.

Technical Program *continued*

10:30 **T. Hayes, D. Arthur:** Treatment Technologies for Coalbed Methane Produced Water Management
10:50 **B. Miller, S. Ruhl:** A Historical Perspective of Anadarko's CBNG Exploration and Development Success in the Rocky Mountain Region
11:10 **S. H. Hollis:** A New Look at Cow Creek Field, Carbon County, Wyoming

Advanced Technologies for Exploration and Production 2 (Seismic)

Teton
Co-Chairs: K. Grubbs and J. Steidtmann

8:00 **Introductory Remarks**
8:10 **S. Ronen, M. Wagaman, C. Ansorger:** Improved Imaging of the Darby Thrust Fault Using Multi-Component Seismic Receivers
8:30 **T. L. Inks, T. Collett, D. J. Taylor, W. F. Agena, M. W. Lee, R. B. Hunter:** Prospecting for Gas Hydrate Accumulations Using 2-D and 3-D Seismic Data, Milne Point, North Slope Alaska
8:50 **B. Mattocks, D. Todorovic-Marinic, S. L. Roche, S. Ronen:** Characterizing a Fractured Carbonate with an Embedded Multicomponent Seismic Test
9:10 **P. M. Duncan, J. Lakings, C. Neale:** The Use of Passive Seismic Monitoring for the Exploration and Production of Hydrocarbon Reservoirs
9:30 **Break**
9:50 **S. G. Zinke, S. E. Shearer:** Pinedale Field: Geophysical Applications in a Major Tight Gas Field, Green River Basin, Wyoming, U.S.A.
10:10 **S. L. Roche, M. Wagaman, H. J. Watt:** Acquisition and Analysis of Multicomponent Seismic Data, Anadarko Basin, Oklahoma, U.S.A.
10:30 **R. W. Keach, II, P. Harrison, D. Harrison:** Detailed Stratigraphic Delineation Using 3-D Volume Interpretation: A Case Study from the Uinta Basin, Utah
10:50 **J. J. Reeves:** A New Technology for 3-D Seismic Exploration and Development of Fractured Tight Gas Reservoirs
11:10 **J. H. McBride, R. W. Keach, II, T. H. Morris, W. Monn, T. Anderson:** Investigating the Interaction of Sevier and Laramide Structural Development in the Rocky Mountains with 3-D Seismic Mapping

Geologic Developments in the Rockies 2

Timberline 3
Co-Chairs: R. Martinsen and P. Isaacson

8:00 **Introductory Remarks**
8:10 **L. Batt, P. E. Isaacson, M. C. Pope, I. P. Montañez:** High Resolution Sequence Stratigraphy of Latest Mississippian (Chesterian) Carbonate and Siliciclastic Facies in East Central Idaho and Southwest Montana
8:30 **J. M. Abplanalp, P. E. Isaacson, A. S. Gilmore:** Late Mississippian (Chesterian)-Early Pennsylvanian (Morrowan) Conodont Biostratigraphy of East-Central Idaho and Southwest Montana
8:50 **A. J. Ulishney, R. D. LeFever:** Sandstone Lithofacies within the Icebox Formation (Ordovician), Williston Basin, North Dakota and Montana
9:10 **M. Dechesne, R. G. Raynolds:** Reservoir Geometry of the Regressive Fox Hills Sandstone: Control on Aquifer Quality
9:30 **Break**
9:50 **C. R. Carvajal, R. Steel, D. Reitz:** Lewis Deltaic Shelf Sequences Predict Deepwater Sand Presence/Absence
10:10 **M. Hendricks:** Goodbye to the Upper Cretaceous Seaway—Models for Lewis, Fox Hills, and Lance Strata in the Greater Green River and Wind River Basins
10:30 **A. R. VanHolland, R. S. Martinsen:** Facies and Architecture of the Chimney Rock Member, Rock Springs Formation (Mesaverde Group), Southwest Wyoming
10:50 **A. L. Petter:** Cretaceous Lowstand Shorelines of the Middle Park Basin, Colorado
11:10 **P. E. Isaacson, M. C. Pope, I. P. Montañez, L. Batt:** Middle and Upper Paleozoic Carbonate Sequences in Idaho: Foreland Subsidence, Eustacy and Reefs

*Denotes speaker other than senior author.

September 26 — Monday Morning Poster

General Poster Session 2

Rafferty's
Chair: L. George

9:00 to 11:30 a.m.

P1 **S. B. Roberts, R. C. Johnson, P. G. Lillis:** The Waltman Shale Total Petroleum System: Does It Have a Favorable Future?
P2 **P. G. Lillis, R. C. Johnson:** Characterization of the Natural Gas Systems of the Wind River Basin, Wyoming
P3 **R. C. Johnson, S. B. Roberts, D. J. Nichols:** New Stratigraphic and Palynologic Studies of the Paleocene Waltman Shale Member, Wind River Basin, Wyoming: Implications for Basin Depositional Environments
P4 **T. J. McCutcheon, J. M. Skeim:** Discovered Crude Oil Resources of Wyoming, U.S.A.
P5 **G. L. Ford:** Application of a High-Frequency Sequence Stratigraphic Framework in the Second Frontier, Green River Basin, Wyoming
P6 **B. Blakeney DeJarnett, A. J. Scott:** Tidally Influenced Sedimentation in the Upper Cretaceous Almond Formation, Patrick Draw Field, Sweetwater County, Wyoming: Come Look at the Cores

September 26 — Monday Afternoon Oral

Increasing the Supply of Rocky Mountain Natural Gas: Geologic Aspects

Timberline 1
Co-Chairs: D. Bowen and M. Dempsey

1:30 **Introductory Remarks**
1:40 **R. C. Surdam, Z. Sheng:** Deep Gas Potential in Wyoming
2:00 **J. E. Fassett, B. C. Boyce:** The San Juan Basin Is NOT a Model for "Basin-Centered Gas"
2:20 **S. P. Cumella , J. Scheevel:** Geology and Mechanics of the Basin-Centered Gas Accumulation, Piceance Basin, Colorado
2:40 **N. B. Harris:** Shallow Thermogenic Shale Gas in the Rocky Mountains
3:00 **Break**
3:20 **A. V. Rigoris, I. Pasternack, J. B. Curtis, N. F. Hurley:** Source-Rock Analysis of the Lower Member of the Lewis Shale, Washakie Basin, Wyoming
3:40 **G. E. Norris, T. McClain*:** Case Study: Greater Wamsutter Field, Wyoming—Tight Gas Reservoir
4:00 **V. L. Riggert, J. A. Hornbeck, D. S. Muller, B. W. Horn, G. E. Norris, D. H. Phillips, E. Glørstad-Clark, J. L. Coleman, Jr.:** Almond Reservoir Stratigraphy and Its Impact on Well Density Rule Changes in the Greater Wamsutter Development Area
4:20 **M. Niemann, P. R. Clarke, C. T. Cornelius, B. Ryan, M. J. Whiticar:** Gas Origin in Coals of the Blackhawk Formation, Castlegate Coalbed Methane Field, Utah

Exploration Challenges of the Great Basin and Utah Hingeline

Teton
Co-Chairs: B. Ehni and D. French

1:30 **Introductory Remarks**
1:40 **D. A. Sprinkel, T. C. Chidsey, Jr.:** Exploration History and Petroleum Geology of the Central Utah Thrust Belt
2:00 **F. C. Moulton, M. L. Pinnell*:** Central Utah, a New Oil and Gas Province
2:20 **D. Strickland, J. P. Vrona, K. R. Johnson, D. D. Schelling, D. A. Wavrek:** Structural Geology and Petroleum Systems of the Newly Discovered Covenant Field Area, Central Utah Thrust Belt
2:40 **J. Trexler, Jr., P. Cashman:** Late Paleozoic Tectonism in the Central Great Basin Requires Revision of Stratigraphic and Structural Interpretations
3:00 **Break**

*Denotes speaker other than senior author.

Technical Program *continued*

3:20 **G. L. Lisle:** Integrated Gravity and Magnetic Interpretations Yield New Insights to Basin and Range Structures
3:40 **D. M. Seneshen, J. H. Viellenave, J. V. Fontana:** Surface Geochemical Tools for Hydrocarbon Exploration and Structural Mapping in the Great Basin of Nevada and Utah
4:00 **L. C. Bortz:** Eagle Springs Oil Field East Extension—a 1965 Soil Gas Survey Success
4:20 **J. B. Hansen, C. Schaftenaar:** The Megabreccia Reservoir at Ghost Ranch Oilfield, Railroad Valley, Nevada

Reservoir Models and Case Studies

Timberline 3
Co-Chairs: T. Anderson and R. Gries

1:30 **Introductory Remarks**
1:40 **C. D. Morgan, K. McClure, T. C. Chidsey, Jr., R. Allis:** Structure and Reservoir Characterization of Farnham Dome Field, Carbon County, Utah
2:00 **T. H. Morris, W. Monn, J. H. McBride, R. W. Keach, II:** Integrated Reservoir Characterization of the Entrada Erg-Margin Gas Play, Utah: An Outcrop and Seismic Analog for the North Hill Creek/Flat Rock Field, Southern Uinta Basin, Utah
2:20 **J. M. Boyles, K. van't Veld, B. F. Towler, C. F. Mason:** Using Production History and Field Characteristics to Quantify the Influence of Geologic and Engineering Attributes on Reservoir Performance in Wyoming Oil Fields
2:40 **F. E. Bakun, C. N. Cecil, H. C. Gee, K. A. Haley, E. R. Ellis, S. L. McConkey:** Techniques to Evaluate Reservoir Performance in a Tight Gas Field: The Wamsutter Experience
3:00 **Break**
3:20 **T. C. Stiteler, T. J. Young, K. E. Meisling, W. B. Hanson:** A Structural Model of Jonah and South Pinedale Fields, Wyoming
3:40 **R. W. McDermott, T. G. Graham:** Pinedale Field: A Giant New Gas Resource, Green River Basin, Wyoming, U.S.A.
4:00 **C. E. Mullen:** Big Sand Draw Field—The Proof Is In the Details
4:20 **Q. Zhang, D. Nummedal, P. Yin:** Stratigraphy, Sedimentology and Petrophysics of the Tensleep Sandstone at Teapot Dome and in Outcrop

September 26 — Monday Afternoon Poster

General Poster Session 3

Rafferty's
Chair: L. George

1:30 to 4:00 p.m.

P1 **M. E. Ward, S. E. Laubach:** Fractured Sandstone Outcrops in Northeast Mexico: Guides to the Attributes of Fractures in Tight Gas Sandstones
P2 **K. Tushman, S. E. Laubach:** Regional Subthrust Fracture Arrays in Outcrop: Guide to Attributes of Tight Gas Sandstones
P3 **M. D. Milliken, T. J. McCutcheon:** Surface Mapping Validates 3D Seismic Faulting Interpretations at Teapot Dome Field, Natrona Co., Wyoming
P4 **N. J. Gilbertson, N. F. Hurley:** 3D Geologic Modeling and Fracture Interpretation of the Tensleep Sandstone, Alcova Anticline, Wyoming
P5 **J. M. Pope:** Same Day Downhole Gas Content Analysis with Raman Spectroscopy
P6 **K. A. Duncan, R. P. Langford:** Lacustrine Deposits Examined as a Sratigraphic Control on Migration and Compartmentalization in Eolian Reservoirs

*Denotes speaker other than senior author.

2005 RMS-AAPG Jackson Hole Annual Meeting

September 24-26, 2005

ABSTRACTS

Late Mississippian (Chesterian)-Early Pennsylvanian (Morrowan) Conodont Biostratigraphy of East-Central Idaho and Southwest Montana

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Biostratigraphic investigation and biofacies analysis of Late Mississippian (Chesterian) to Early Pennsylvanian (Morrowan) conodonts in east-central Idaho and adjacent Montana were required to delineate sequences on a platform to foreland basin transect. Three conodont biozones were encountered and time lines through thin and thick successions are evident. Formations containing these zones are interpreted to represent westward thickening shelf margin, cratonic trough or embayment, shallow shelf, and near-shore deposition on the basis of associated conodont biofacies, faunal correlatives, and lithology. Conodont faunas present within the boundary interval are dominated by species of *Cavusgnathus*, *Adetognathus*, *Gnathodus*, and *Rhachistognathus*, which compose nearly 95% of conodonts recovered. Late Mississippian (Chesterian) conodonts recovered include *Cavusgnathus naviculus, C. altus, C. regularis, C. windsorensis, C. convexus Adetognathus unicornis, Gnathodus bilineatus,* and *G. commutatus commutatus*. Several broadly occurring and correlatable biostratigraphic zones are delineated for the Chesterian and include: 1) the mid-Chesterian *Cavusgnathus sp*. zone; 2) the upper Chesterian *Adetognathus unicornis/Cavusgnathus naviculus* zone; 3) the uppermost Chesterian *Rhachistognathus muricatus/Gnathodus bilineatus-commutatus commutatus* zone. Early Pennsylvanian (Morrowan) conodonts recovered include *Adetognathus lautus, A. spathus, A. gigantus, Rachistognathus muricatus*, and *R. primus*. The Mississippian-Pennsylvanian boundary is marked by the overlapping occurrence of *Rachistognathus primus*, *Adetognathus lautus*, and *A. spathus* with the concurrent decimation of *Cavusgnathus sp*. and *Gnathodus bilineatus–commutatus commutatus*. These defined biostratigraphic zones allow for the accurate correlation of shallow marine strata across the study area.

Mesaverde Gas Play - Eastern Uinta Basin, Utah

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The Mesaverde Group is quickly becoming a major producer of gas in the Uinta basin, Utah. Gas from the Mesaverde in the interior of the Uinta basin appears to fit a basin-centered gas model although the transition into conventional traps is poorly understood. Current production from Mesaverde only completions is concentrated on the east to northeast, and west edges of the Greater Natural Buttes field. Early production from the Mesaverde has generally been commingled with basal Wasatch sands. These commingled wells are examined to approximate the production contribution from the Mesaverde. Few Mesaverde only wells have been completed in the heart of the Greater Natural Buttes field, but the play is rapidly expanding out and into all of the eastern Uinta basin. Good reservoir and source rocks in the Mesaverde are present throughout the Uinta basin.

Three subsurface cross sections, with formational contacts within the group, depositional facies, tested intervals with results, Ro values, are developed for this play. Cumulative production, IP, isopach of the Mesaverde Group, and structure on the Castlegate maps help evaluate this play. Because many Mesaverde completions are commingled with Wasatch zones, these wells have a percent net Mesaverde perforations indicator to help estimate the influence of the Mesaverde completion zones. Mesaverde completions by decade are mapped to visually tract where the play is headed and how it has developed historically. Funding by the Utah Geological Survey has supported this study.

Inversion Modeling of the SP Log… Resurrecting and Quantifying a Critical Measurement for Predicting Permeability and Formation Water Resistivity

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The Spontaneous Potential (SP) curve is an important geophysical log measurement, however it is difficult to use quantitatively due to poor vertical resolution and the effects of borehole and formation fluid resistivity. Tedious and cumbersome chart book corrections are only valid for "ideal" beds (permeable beds encased in conductive shale) that are greater than 4 or 5 ft. thick. Service companies do not charge for the SP curve and, as a result, have been less concerned with quality control on the SP measurement in recent years. As a result, the SP log is often ignored quantitatively in favor of the Gamma Ray measurement (which may be unrelated to reservoir quality).

Inversion modeling can make the SP measurement quantitatively useful from zone to zone and from well to well. Inversion modeling yields a pseudo-static SP (PSP) curve with a vertical resolution of 1-2 ft. and removes the effects of thin beds, formation resistivity, and borehole size. The PSP can be normalized to accommodate changes in formation water resistivity (Rw) and mud filtrate resistivity (Rmf). The normalized PSP is a clay volume (Vshale) curve which can be used quantitatively in multiple well projects to accurately determine connate water resistivity (Rw) and rock quality (permeability).

Because the SP curve has been acquired universally for more than 70 years, the modeled results provide a standard measurement for comparing rock properties in areas with mixed vintage log suites. Examples include data from the Pinedale area of Wyoming and the National Petroleum Reserve located in California.

Wyodak Coal, Tongue River Member of the Fort Union Formation, Powder River Basin, Wyoming: "No-Coal Zones" and Their Effects on Coalbed Methane Production

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The Powder River Basin contains more than 80 percent of the state's coal resources within the Tongue River Member of the Fort Union Formation (upper Paleocene). The Fort Union Formation is divided from older to younger into the Tullock, Lebo Shale, and Tongue River Members. The coals of the Tongue River Member consist of approximately 32 coal seams with a combined thickness in excess of 300 ft. One of the major coal seams within the Tongue River Member is the Wyodak coal.

The Tongue River Member of the Fort Union Formation was deposited by a fluvial-deltaic system filling Lake Lebo. Extensive peat deposits accumulated within poorly drained interdeltaic and deltaic swamps. There are “no-coal zones” within the Wyodak coal seam where the coal has been replaced by sandstones and shales. The “no-coal zones” are distributary fluvial channels that meandered throughout the swamps. Several methods have been developed to predict the locations of the fluvial channels and avoid drilling “no-coal zones.” Additionally, the relationship between adjacent coal seams may imply a pattern of production.

Techniques to Evaluate Resevoir Performance in a Tight Gas Field: The Wamsutter Experience

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The Greater Wamsutter Development Area (Wamsutter) is a giant tight gas accumulation in south central Wyoming, half way between the Rawlins and Rock Springs Uplifts. The field produces primarily from the Almond Formation, a Late Cretaceous collection of stratigraphic traps with ultra-low permeability. Wells are massively hydraulically fractured in 2-3 stages placing 150-250 thousand pounds of proppant per stage. Initial flow rates range from 700 – 1200 mscfd and quickly decline in a generally hyperbolic fashion.

Performance evaluation in Wamsutter focuses on three key issues: rate forecasting, ultimate recovery prediction, and hydraulic fracture evaluation. While these issues are not unique to Wamsutter, the fact that reservoir permeabilities are a few micro-darcies significantly complicates traditional analysis techniques. Further, wells can be in transient flow for years or even decades.

Several techniques are currently used to evaluate the Wamsutter field including, decline curve analysis, Agarwal-Gardner Type Curve matching, single and multi-well simulation and analog benchmarking. Examples of each technique will be shared along with observed limitations and how integrating all of the above listed techniques can avoid potential pitfalls.

Exploring the basin fill history of the Green River Formation in the Piceance Creek and the Uinta Basins

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The Green River lakes occupied the Uinta, Piceance and Great Green River Basins during the Early to Middle Eocene time. These foreland basins were initiated during the late Cretaceous and early Cenozoic Laramide Orogeny. The Green River Formation in the Piceance Creek Basin contains over 2000 ft of lacustrine deposits composed of alternating, kerogen-rich mudstones, carbonates and sandstones and forms the world’s larges oil shale reserve of about 1 trillion BOE. In this study we used outcrops, cores and over 100 well-logs to identify the major sequences across the Piceance Creek Basin and into the Uinta Basin, in order to quantify the various controlling factors of the basins’ fill. The sections that we analyzed are composed of numerous high frequency sequences manifested by distinctive flooding surfaces. These prominent surfaces have a relatively conformable flat-lying stacking thus indicate small incision between sequence boundaries that are probably tied to high frequency low amplitude lake level changes. The sections also indicate an important sedimentary source from the Douglas Arch that divides the two basins, and a sedimentary fill that keeps pace with the spatially variable basin subsidence. The chronostratigraphic correlation also points to an in-phase relationship between the two lakes not only during the Mahogany Ledge time but throughout the entire Parachute Creek Member. The correlated signals in the gamma-ray logs between the two basins indicate either a physical connection between the two lakes with an over-filled condition or a similar response to climate changes in closed under-filled conditions. At the time this abstract is written we cannot differentiate between the two possibilities.

High Resolution Sequence Stratigraphy of Latest Mississippian (Chesterian) Carbonate and Siliciclastic Facies in East Central Idaho and Southwest Montana

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Latest Mississippian (Chesterian) successions of mixed carbonates and siliciclastics, spanning 300 kilometers across east-central Idaho and southwest Montana, show 2nd and 3rd order sequences across depositional strike into the Idaho foreland basin. Sequences can be distinguished from subsidence events. Meter scale lithofacies analysis, conodont biostratigraphy, and carbon isotope chemistry provide the basis for interpretations. Deposition occurred on a westward facing ramp positioned between the Laurentian craton and the Antler foreland basin. Considerable lateral variability in depositional facies across the regional transect affords an excellent setting for deciphering the sedimentary response to changes in relative sea level. Third order cycles (1-5my) in Idaho are stratigraphically distinct from their updip counterparts, but exhibit similar overall trends. Lower Chesterian cycles in Idaho shallow gradually upward from massive mudstones into skeletal shoals. Updip equivalent cycles shallow into intertidal peloid and oncoid packstones. Cycle amplitude and frequency increases in the Upper Chesterian. In Idaho, thin bedded skeletal packstones are capped by prograding calcite-cemented siliciclastics. Correlative cycles in Montana are siliciclastic-dominated and commonly unconformity-bound. Well developed soils, plant fossils and lag conglomerates attest to the role of terrestrial processes in constructing these sequences. Vertical changes in cycle frequency and amplitude in these successions are mimicked in the carbon isotope curve derived from these rocks. Together the chemical and stratigraphic trends suggest superposition of a 2nd order (>10my) sea level regression that persists across the mid-Carboniferous boundary. This regression may be related to global cooling associated with the onset of a Late Carboniferous icehouse climate.

The Fort Union Formation of the Powder River Basin, Campbell County, Wyoming: The Methane Gas Potential of the Upper Fort Union Formation Sandstones

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A portion of the Powder River Basin (PRB) 96 miles long and 18 miles wide was researched in order to establish the relationships between the major upper Fort Union coal beds and stratigraphically equivalent sand bodies. The area included a south to north divide between thick coal zones as delineated by thickest coal maps of the PRB. Previous authors have written about east to west "deltas" within the coal zone that appeared to coalesce along this south-north thin coal trend. Oldham points out the commercial value in studying the sands associated with these coals in The Mountain Geologist January 1997 in his report on the Oedekoven and Chan shallow gas fields which produced approximately 2 BCF water-free methane.

Several cross sections were created across the project area. Due to the shallow depth to the sands, mainly gamma ray logs were available to construct the cross sections. Sandstone isopach maps were then created using these cross sections. These maps strongly suggest the presence of a six mile wide, sand-rich paleofluvial system that drained the basin north across the study area, parallel to the strike of the PRB. The "deltas" from the east may be tributary fluvial channels.

Differential compaction and up dip meanders in this south to north trending system set up potential traps for gas generated by the coal beds. Discovery will depend upon running the correct logs to detect gas within the sand bodies, or rig fires, which was the first indication of gas at the Oedekoven Field.

Tidally Influenced Sedimentation in the Upper Cretaceous Almond Formation, Patrick Draw Field, Sweetwater Co, Wyoming: Come Look at the Cores

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The Almond Formation has been a prolific hydrocarbon producer in the Green River Basin for over 50 years. In Patrick Draw Field, Sweetwater County, Wyoming, the Almond has produced approximately 60 MMBO and 130 BCFG since its discovery in 1959. Patrick Draw, made up of Monell and Arch Units, has undergone primary and secondary (waterflood) recovery efforts. Initial stratigraphic interpretations were based on cores taken in the 1960's and 70's. Most cores from Monell Unit were subsequently lost or destroyed, and most cores from Arch Unit reside at the USGS in Denver. The Almond reservoir sandstones in Patrick Draw were originally interpreted as two north-south trending barrier bars with fine-grained lagoonal sediments forming an updip trap to the west and the transition into marine mudstones defining the eastern extent of the reservoir.

Anadarko Petroleum Corporation has recently begun tertiary recovery of the oil in place through CO_2 flooding of the Almond in Monell Unit. Improving efficiency of CO_2 flooding in this significant oil reservoir is critical in light of the alternative costs of drilling all new wells and building new facilities. Over 10 recent cores have been taken in Monell, and new stratigraphic interpretations can be made by integrating these cores with earlier cores. The Almond deposits are now interpreted as flood tidal deltas, tidal inlets, tidal channels, tidal creeks, spit platforms, bay muds and oyster patch reefs. Understanding the complex stratal architecture of these lithofacies is critical to designing and operating a more successful CO_2 flood for Monell Unit.

Eagle Springs Oil Field East Extension – a 1965 Soil Gas Survey Success

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Eagle Springs, Nevada's first oil field, discovered in 1954 by Shell Oil Company, has produced 5,103,703 BO through October 2004. The discovery well was completed pumping 343 BOPD, and Shell drilled three additional oil wells and three dry holes by 1961 and then farmed out the non-producing portion of the field to Texota Oil Company in July 1963. Texota completed 2 successful extension wells, and afterwards a Horvitz-type soil gas survey was completed in August of 1964 which resulted in a distinct "Ethane Plus" anomaly 1/2 mile east of the Texota wells. Subsequently, 6 more successful extension wells were drilled by Texota and Western Oil Lands within the anomaly.

The soil gas anomaly can be directly related to the boundary fault zone being a leaky trap and the faults have provided a direct migration path from the reservoir to the surface. Soil gas anomalies have been mapped over other Nevada oil fields (Trap Springs, Blackburn and Grant Canyon), however, these anomalies were either not recognized prior to drilling the discovery or the soil gas surveys were done after the discovery. Also, in Nevada, many dry holes have been drilled on "strong" soil gas anomalies. The message remains: soil gas surveys must be combined with geology and geophysics to identify drillable prospects.

Using Production History and Field Characteristics to Quantify the Influence of Geologic and Engineering Attributes on Reservoir Performance in Wyoming Oil Fields

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The University of Wyoming's Enhanced Oil Recovery Institute is studying Wyoming oil fields to better understand past performance in order to assist operators with (1) predicting future production and (2) improving the efficiency of their oil production practices. The primary goal of this research is to quantify the impact that various geologic and engineering attributes have on field production. Through an advanced statistical approach to the classic decline-curve analysis of oil field production, the impact of factors such as reservoir type, porosity, permeability, fracture intensity, drive mechanism and oil viscosity is being investigated. Initial work is being done on fields in the Powder River Basin to test and refine the technique. Expected benefits include the ability to estimate how a reservoir should have performed, based upon the production performance of its peers. This should allow operators to identify which of their fields are underperforming and hence are candidates for additional study to discover the nature of deleterious factors. Additionally, the statistical analysis should allow the grouping of fields based upon production characteristics. EOR scoping models based upon these groups should allow operators to determine if their reservoirs are potential EOR candidates and worthy of additional study.

Lewis Deltaic Shelf Sequences Predict Deepwater Sand Presence/Absence

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The likely presence or absence of deepwater sand on the slope or basin-floor of large-scale clinoforms can be predicted from the regime/facies of the shoreline at the shelf-edge. We postulate that it is possible to differentiate between scenarios (1) where there has been little or no sand delivery into deepwater areas because most of the sediment budget during any fall-to-rise base-level cycle has been stored on the shelf and coastal plain, and (2) where there has been much sand delivered and by-passed across the shelf, with a significant portion of the sediment budget partitioned into the deepwater slope and basin-floor.

The model is being tested in the Lance-Fox Hills-Lewis system in southern Wyoming, where we are tracking at a basin scale Late Cretaceous clinoforms. Sediment partitioning and shoreline types exhibit a sharp contrast in the basin. In the east, sandy basin-floor deposits are abundant and the shelf-edge shows feeder deltas that are river dominated (albeit tidally reworked) and toplap truncated by by-pass erosion surfaces. These incision surfaces are filled by sandstones that become progressively slumped towards the shelf-edge rollover, and were apparently connected to deepwater slope channels. In contrast, in the west, shale-prone basin-floors are linked to an un-incised shelf-edge dominated by a storm-wave regime. These strandplains are either the result of low sediment input from small rivers (more time for wave reworking) or are entirely strike fed from the easterly deltas. Thus, the outer-shelf regime at each location predicts the probability of having a sand/shale-prone slope and basin-floor.

Coalbed Methane Produced Water Management—Beneficial Use Alternatives in the Rocky Mountain States

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Coalbed natural gas, more commonly referred to as coal bed methane (CBM), is an increasingly important source of natural gas in the United States. The sedimentary basins of the Rocky Mountain States contain the largest CBM reserves discovered in recent years. In the Powder River Basin of Wyoming and Montana alone the BLM estimates that 60,000 to 75,000 new wells will be installed over the next 20 years to fully develop the CBM resource.

CBM development in the Rocky Mountain region involves the production of high volumes produced water. In the arid west, impacts to water supplies, as well as the environmental effects associated with management and disposal of produced water are of critical concern to citizens and regulators. Management costs for treatment and disposal of produced water play a significant role in the economics of CBM development. Although deep well injection is still the most common means of disposal in some basins, beneficial use alternatives can provide an economically attractive win-win scenario between operators and local stake holders. The economics and viability of beneficial use alternatives varies from state to state and basin to basin. Evaluation of alternatives demands a thorough understanding of pertinent federal, state, and sometime local regulatory considerations; assessment of local hydrogeology, water chemistry and soils; and up-to-date knowledge of treatment technologies.

Petroleum Geology of Ashley Valley Field and Hydrocarbon Potential of the Surrounding Area, Uintah County, Utah

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Ashley Valley field was discovered in 1948 and represents the first commercial oil production in Utah. The field is located southeast of Vernal, Utah, north of the Uinta Basin boundary fault. The primary reservoir is the eolian Pennsylvanian/Permian Weber Sandstone in a northwest-southeast-trending faulted anticline. Pay thickness of the Weber is about 60 ft with an average porosity of 13% and permeability ranging from 27-161 mD. Nearby production-scale outcrops provide analogs of the subsurface reservoir-facies characteristics and boundaries that determine the overall Weber heterogeneity. The productive field area is 780 acres and there are currently 17 producing wells. Cumulative production is over 20 million bbls of oil. The oil represents a mixture of hydrocarbons from source rocks in both the Permian Phosphoria Formation and Cretaceous Mancos Shale.

Over 50 unsuccessful exploratory wells have been drilled to search the 300-square-mile area of the eastern Uinta uplift for another field like Ashley Valley. Targets include subtle anticlines on trend with Ashley Valley field, other major surface structures, and areas hidden beneath basement-involved faults such as the Cliff Ridge fault.

The Weber Sandstone also serves as a ground-water aquifer for the region. Recharge occurs where the Weber outcrops in high-elevation areas such as the nearby Blue and Split Mountains and the Uinta Mountains. Hydrodynamic conditions suggest that oil in the Weber may have been flushed southward by the flow of fresh ground water moving from outcrops to the north of Ashley Valley, thus creating the best oil potential closest to the Uinta Basin boundary fault.

Analyzing Hydraulically Fractured Gas Well Performance in the Greater Green River Basin of Wyoming

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Hydraulic fracture stimulation often dictates the economic outcome of wells completed in low permeability gas reservoirs. Evaluating well performance - the rate and pressure behavior of a well over its productive life - provides the opportunity to discover the key elements driving stimulation and completion effectiveness in any particular environment. This presentation demonstrates the integrated use of reservoir engineering, petrophysical and geologic analysis to evaluate well performance, identify flow regimes and distinguish between reservoir and completion induced behavior. Tools used include well log analysis (for pay identification and petrophysical calculations), the reciprocal productivity semi-log method (to normalize the inevitable variations in flow rate when evaluating the post-linear, infinite acting radial flow period), fractured well type-curve analysis, pressure buildup analysis and numerical simulation. The main emphasis is an expanded discussion outlining the fundamentals of production data analysis. Case studies from the Greater Green River Basin of Wyoming of single wells and entire fields draining low permeability gas reservoirs are used to demonstrate this methodology, and significant reservoir, completion and production factors affecting well performance are identified as an outcome. The impact of critical completion and production factors will be revealed and discussed. These problems and factors include wellbore liquid loading (in reducing or eliminating the effective hydraulic fracture length), treatment sizing, treatment isolation strategies and sequencing of multi-pay completions, treatment flowback strategy, use of velocity/ tubing strings and selection of landing depths, and shutting in a producing well. Remedies are suggested for stimulation and completion induced problems.

Geology and Mechanics of the Basin-Centered Gas Accumulation, Piceance Basin, Colorado

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The Williams Fork Formation in the Piceance Basin contains multi-TCF reserves in a very large basin-centered gas accumulation. Most gas is produced from a continuously gas-saturated 1,500-2,400 ft gross interval in the lower part of the Williams Fork. During maximum burial, gas was generated and expelled from the Cameo coal interval in the lower most part of the Williams Fork. The Cameo is the primary source of Williams Fork gas. Both the lateral and vertical distribution of gas and the distribution of overpressure are directly linked to the migration of the gas as it moves upward and outward from the Cameo deep-basin coals. The overall distribution and pressure of the gas in the Williams Fork is probably the direct result of pore-pressure assisted fracturing and subsequent migration through the induced fracture systems. The first place one might expect fracture assisted migration to occur is within the gas-generative Cameo interval. When gas generation causes critical pore pressure to be exceeded, the rock fractures, and the rate of gas escape from the overpressured rock rapidly increases, stabilizing or reducing its pressure and allowing gas to flow into a lower-pressured adjacent sand body. One might expect this process to be repeated in a daisy-chain fashion, moving outward and upward from the gas generative parts of the Cameo. Ultimately, the ability of a given sand to sustain overpressured conditions will depend on the balance of the rate of gas entry with the rate of gas escape from the sand.

Utility of Rocky Mountain Tight Gas Sand Resource Assessments: Data Sources, Methodologies and End Users

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Projections by United States government and gas industry research organizations indicate that U.S. gas consumption could increase up to 40% from the current 23 trillion cubic feet by the year 2025. The Rocky Mountain region contains the largest remaining Lower-48 potential gas resource, outside of the U.S. Gulf Coast. The bulk of this assessed resource is thought to be present in tight gas sands or coal seams. With a projected decline in more conventional U.S. gas production, and a stabilization or decline in Canadian imports, these resources are assumed to be the next gas supply increment available (and required) to meet the Nation’s needs, prior to the possible delivery of Alaskan gas, expansion of LNG imports and any future exploitation of natural gas hydrates.

Recent work by the geologic community has questioned both the existence and producibility of significant tight gas sand resources. In turn, this controversy directly impacts the validity and utility of published resource assessments.

This paper examines Rocky Mountain tight gas sand resource assessments completed by the U.S. Geological Survey, Energy Information Administration of the U.S. Department of Energy, National Petroleum Council and the U.S. Potential Gas Committee. The practical utility of these assessments is considered in light of:

- Data sources employed by each organization
- Scale of assessment unit – formation, play or province-level
- Assessment methodologies
- The requirements of end users – E&P companies, the financial community and public policy decision makers.

Overview of An Interactive Online Internet-based Map Server (IMS) for Wyoming’s Northern Powder River Basin

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The IMS is an interactive model that allows the user to view geologic columns with depth to and thickness of geologic units at any point on the map, simple geologic cross sections, and plan view maps that show the extent of 32 different coal deposits within the Eocene Wasatch and Paleocene Fort Union formations. Formation tops for the Upper Cretaceous Lance Formation, Fox Hills Sandstone, and Bear Paw/Pierre Shale were added to the project.

Water quality data from available wells were also a component of the project that is accessible with the IMS. The intended purpose of the IMS is as a predictive tool for developers, water users, coalbed natural gas producers, and regulators to more accurately estimate the quality of ground water prior to production. Interpolated water quality values are available at any point in the project area and both a bubble plot and a color-contour map show the location and the range of values for various constituents.

In addition to the geologic and water quality components, the IMS allows the user to add or subtract roads, county boundaries, well locations, water quality sample sites, and public land surveys. The scale of the map is changeable and users may enlarge or shrink particular areas of interest within the predefined project area.

The northern Powder River Basin IMS was developed by the Wyoming State Geological Survey in cooperation with a private consultant and several state and federal agencies with funding provided by the Wyoming Water Development Commission.

Petrographic Reservoir Characterization—Direct Measurement and Analysis of Pore and Grain Size Data from Thin Sections

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Thin section petrography has traditionally offered only limited insights into the details of sedimentology and even less into reservoir characterization. Petrographic reservoir characterization, making comparisons to engineering and petrophysical data, has not been feasible. Utilization of CCD camera control software provides the means to gather grain and porosity data that can be directly compared to conventional core analysis and mercury injection capillary pressure (MICP) data. Samples of Dakota "J," Nugget, and Mesaverde sandstones were analyzed and compared. Control samples were used to estimate the effects on grain size measurements in thin section. Data gathered consist of length and width measurements of large numbers of sand grains. Frequency distributions of these data provide a sensitive means of discriminating between samples. Interactive selection of pores impregnated by blue-stained epoxy allows gathering measurements of pore area, perimeter, and equivalent circular diameter (ECD). Frequency distributions of pore area and total pore area show the relative contributions to porosity of pores of different sizes. Plotting frequency distributions of pore ECD with grain size shows the relative contribution of intergranular and moldic porosity. Plotting ECD with the pore area and total pore area frequency distributions reveals the contribution of each pore size class to total porosity. Image analysis shows that the interactive pore selection process captures over 90% of the blue-impregnated porosity, down to a few microns. Using this calculation, the pore area data can be plotted by size class, simulating an MICP curve.

Reservoir Geometry of the Regressive Fox Hills Sandstone: Control on Aquifer Quality

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In the Denver Basin the littoral to near-shore Fox Hills Sandstone was deposited during the early phase of the Laramide orogeny as the Cretaceous Interior Seaway retreated to the northeast. This approximately 68 MY regressive sandstone is composed of a series of shingles reflecting episodic seaway retreat. We illustrate the detailed geometry of the sandstone elements that make up the Fox Hills Sandstone. This unit is an important aquifer in the Denver Basin and the distribution of porosity, permeability, and facies tracts is important in predicting the performance of water wells.

A data base of thousands of oil and gas wells and thousands of water wells is available for study. A subset of these wells has been analyzed to create a three-dimensional model using ArcGIS software. Seven shingles are mapped in detail. Our three dimensional model permits the effective and efficient communication of critical reservoir parameters to resource planners. Comparisons are made to other well-studied regressive systems in the San Juan and Greater Green River basins. We propose that non-uniform subsidence has influenced the stacking pattern of this regressive succession, controlling both the distribution of net sandstone and of coal-bearing strata. These parameters are critical to predicting reservoir performance and quality. The patterns we document are relevant to any effort to extract fluids from rocks of this facies association.

Lacustrine Deposits Examined as a Sratigraphic Control on Migration and Compartmentalization in Eolian Reservoirs

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The Cedar Mesa Sandstone was deposited in an ancient sand dune sea and is an exhumed stratum that has been a host for petroleum migration and accumulation. The Sandstone consists of interbedded and intertonguing eolian, fluvial, pedogenic and lacustrine strata. The focus of the research conducted is the small scale lacustrine, and associated pedogenic, lithologies that formed when the water table was high or when floods filled the interdune areas of the ancient desert. These lacustrine and pedogenic zones are one example of barriers that will affect the compartmentalization and migration of petroleum in a dune deposited reservoir type. The geometric distribution of groups of ponds stacked within sandstones is predictable using outcrop observations and wind direction to reconstruct the dune topography. Lacustrine deposits surveyed run parallel to the long axis of dunes in the interdune areas and are found between beds where petroleum has migrated and where it has not. Two end member types of lacustrine deposits were recognized. Deposits containing dolomite, limestone and dolomitized sandstone are interpreted as deposits of freshwater ponds fed by groundwater. Deposits containing numerous shale beds were repeatedly inundated from stream floodwaters. Many lacustrine deposits contain both shale and limestone and are interpreted to have formed in episodically flooded groundwater fed ponds. The Cedar Mesa's interbedded lacustrine lithologies, their thicknesses, and associated dune interaction zones are compared to better understand how these depositional features may inhibit or enhance production of eolian type reservoirs once they are buried and matured.

The Use of Passive Seismic Monitoring for the Exploration and Production of Hydrocarbon Reservoirs

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The use of passive seismic energy to help understand the static and dynamic nature of the subsurface is rapidly gaining industry interest. These naturally occurring sources can provide a wealth of information regarding larger scale structural features, as well as reservoir scale production or injection induced changes in fluid and rock properties.

Two applications are being progressed that exploit passive seismic on differing scales. Transmission Tomography utilizes local micro-earthquakes as seismic source to create three-dimensional P and S wave velocity volumes, from which structure, faulting and lithology can be inferred. The environmentally benign acquisition methods make Transmission Tomography ideally suited for many exploration applications in the Rocky Mountains due to the negligible permitting requirements and low overall cost.

Monitoring the release of micro-seismic energy associated with reservoir level production activities is becoming a well established technique for understanding several dynamic reservoir processes. Two different methods are being commercially progressed, downhole and surface monitoring. Downhole observation utilizes a linear array of geophones placed in a wellbore to detect and locate the hypo-centers of discrete micro-seismic events. Surface monitoring 'beam-steers' the output from a relatively dense surface array to identify the location of both continuous and transient acoustic sources without requiring the detection of discrete events. Both methods allow the operator to relate micro-seismic events to the progression of dynamic reservoir processes such as hydraulically stimulated fracture growth, injected fluid movement, reservoir compaction, reactivated fault movement and compartmentalization.

Gas Desorption Tests: Application for Powder River Basin Gas Production Prediction

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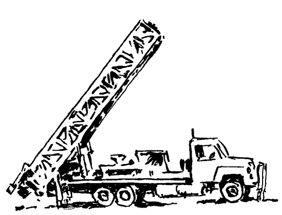
Production of coalbed methane (CBM) from about 20,000 CBM wells from Paleocene-age Fort Union Formation coal in the Powder River Basin (PRB) was about 1.5 trillion cubic feet through 2004. The Bureau of Land Management predicted average lifetime recoveries of 0.20 to 0.50 billion cubic feet per well.

Since 1999, the U.S. Geological Survey and the Bureau of Land Management have collected coal cores with the cooperation of gas operators for use in a CBM desorption study. We applied a variation of Bodden and Ehrlich's (1998) method for projecting gas production from bituminous coal in the Black Warrior Basin in Alabama. They suggested a relationship between a well's first year of CBM production and cumulative measured gas that had been desorbed for 120 days divided by the depth of the coal. Using PRB subbituminous coal, we plotted data for the first 12 months of production against desorbed gas for 5, 40, and 120-day desorption time periods divided by the core depth. The plots showed correlation coefficients of 0.72 for the 5-day interval, and 0.74 for the 40-day and 120-day intervals. Therefore, for PRB subbituminous coal 40 days of desorption data is sufficient to predict a well's first year of production. Using the 40-day graph, we can predict that if the measured gas content of coal from a well was 45 standard cubic feet per ton and the depth was 800 ft, the well would have a 12-month production of about 31 million cubic feet of gas.



What are the Mechanisms and Timing of Joints in the Rockies?

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Joints, also known as extensional or mode 1 fractures, form by opening perpendicular to their surfaces and thus provide important fluid conduits in the Rocky Mountains. The resulting directional permeability can enhance petroleum recovery rates and efficiency as well as hasten water breakthrough and cause the bypassing of large reservoir compartments. A better knowledge of joint mechanisms and timing is essential to effective petroleum production and exploration because early pre- and syn-tectonic joints may be sealed by subsequent processes and uplift-related joints may not extend to production depths in the subsurface.

A recent effort to merge traditional, surface-based fracture studies with new seismic anisotropy studies has resulted in an intriguing mismatch of hypotheses. Many surface studies have attributed jointing to syn-Laramide compression, post-Laramide Rio Grande extension and/or a variant of exfoliation where burial strain is released perpendicular to the topographic surface during uplift and erosion. While joints fitting these mechanisms exist, many joints seen in the field and inferred from seismic data are perpendicular to regional compression directions. This suggests that recent interpretations have neglected an important mechanism of jointing, that of rebound in the direction of prior tectonic compression. This mechanism predicts that many Rocky Mountain joints formed during uplift and erosion in orientations that are perpendicular to prior Laramide shortening trends. A more complete appraisal of joint mechanisms promises to help unlock the tectonic history of the Rocky Mountain basins and allow better predictions of permeability anisotropy in petroleum reservoirs.

The San Juan Basin is NOT a Model for "Basin-Centered Gas"

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In 1979, John Masters of Canadian Hunter Exploration described a radically new trapping mechanism for natural gas in Western Interior basins. He characterized these traps as being: "low porosity-low permeability Cretaceous sandstone, in downdip structural locations, with porous water-filled reservoir rock updip." In his paper, Masters used the San Juan Basin of New Mexico and Colorado as a model for this kind of trap. Over the last 25 years, other authors have also suggested that the San Juan Basin of New Mexico is a good example of a 'basin-centered" gas deposit. Most recently, Masters stated in the December issue of the RMAG Outcrop that the San Juan Basin is "an almost perfect basin-centered accumulation . . . the basin syncline [is] rimmed all the way around by water. The water holds that gas in."

In reality, the three major gas reservoirs in the San Juan Basin; in the Late Cretaceous Dakota Sandstone, Mesaverde Group, and Pictured Cliffs Sandstone are all stratigraphic traps. These rocks units are all tightly cemented, fractured-sandstone reservoirs with a cumulative production of 22 Tcfg. The Dakota Sandstone is the most complex consisting of interbedded and discontinuous marine and continental rocks. The Mesaverde Group consists of a basal regressive shoreface sandstone, a middle continental sandstone and mudstone complex, and an upper transgressive shoreface sandstone. The Pictured Cliffs Sandstone is a regressive shoreface sandstone. Stratigraphic permeability barriers create the traps in all of these rock units.

Application of a High-Frequency Sequence Stratigraphic Framework in the 2nd Frontier, Green River Basin, Wyoming

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A high-frequency sequence stratigraphic model applied over a 700 mi^2 area in the Cretaceous, 2nd Frontier (Kf2) in Green River Basin, Wyoming, resulted in a 41% increase in rate of return from the year 2002 to 2003. The area includes the LaBarge Platform on the north extending up to Chimney Buttes Field, and continuous south across the southern end of the Moxa Arch. To date over 2.8 TCF of gas have been produced from the Kf2 in this region.

Approximately 2,000 wells containing raster and/or digital well-log data were used. Published core descriptions and in-house described cores help constrain the correlations and allow for calibration of facies to log characteristics. The gross stratigraphic framework encompasses two large-scale base-level rise to fall cycles. Smaller scale base-level cycles help explain and predict reservoir distribution across the area. Well-log cross sections based on this stratigraphic framework in conjunction with sand and pay maps illustrate stacking patterns, along-strike facies variations, and stratigraphic changes across the depositional profile, as well as production trends.

3D Geologic Modeling and Fracture Interpretation of the Tensleep Sandstone, Alcova Anticline, Wyoming

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Alcova Anticline is a Laramide-age structure on the southeast margin of the Wind River basin, central Wyoming. The Pennsylvanian Tensleep Sandstone, a prolific oil-producing reservoir in the Rocky Mountains, occurs at the core of the exposed anticline. The North Platte River cuts across the axis of the anticline, resulting in two near-vertical walls of Tensleep Sandstone, approximately 500 m wide, 100 m tall, and separated by 140 m. High-resolution (1-2 cm) Lidar scans of the two walls were acquired to study the frequency and orientation of fractures in the structure. The Lidar survey at Alcova was designed to collect sufficient data points to resolve fracture planes $\geq$1 m^2 in area. Additionally, high-resolution photomosaics were draped over the data set. The Lidar dataset has been processed using various decimation approaches. Fracture planes have been detected using automated and handpicking approaches. One goal of the study is to populate a 3D geologic model with a fracture network, based on outcrop work. The 3D geologic model, which is built from serial cross sections, is constrained by GPS measurements of key formation contacts in the study area. Extracted fracture data from the Lidar dataset determine the parameters used to seed the fracture generating model. A further goal of this study is to provide input into a reservoir model of Teapot Dome anticline, an analogous Tensleep reservoir and a proposed CO_2 sequestration site.

Supplying the Next Generation of Petroleum Professionals

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Instability in the energy industry of the 1970's and 1980's resulted in a major shift in professional personnel. The domestic industry lost more than a half million jobs in the mid-1980's. This volatility poses a special challenge to maintaining a stable workforce.

Following the price collapse of the mid-1980's, dramatic changes in employment demographics emerged. Many of those hired between 1974 and 1983, lost their jobs by the late-1980s. Many of those who retained their jobs comprise the current employment base and are now approaching retirement. Declines in undergraduate and graduate enrollments have weakened many major educational programs. Though technology has allowed the energy industry to reduce technical manpower requirements, these improvements in efficiency will not be sufficient to offset impending manpower losses over the next 7-10 years.

A major factor affecting the quality of any solution is the relationship between the key players in our energy future. The Interstate Oil and Gas Compact Commission (IOGCC) recognizes the lack of a cooperative effort to address the manpower issue. The Petroleum Professionals Blue Ribbon Task Force, an effort of the IOGCC, has recently concluded that the solution to the need for petroleum professionals requires a national effort focused on three areas:

- State Government educating the public;
- Federal Government funding research and outreach; and
- Industry for "on-the-ground focus and involvement.

The Task Force developed individual "templates" outlining the actions recommended for each of these three areas.

The Megabreccia Reservoir at Ghost Ranch Oilfield, Railroad Valley, Nevada

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The reservoir at Ghost Ranch is a large catastrophic Neogene rockfall deposit, known as a sturzstrom. The Ghost Ranch sturzstrom is a limestone and dolomite breccia, which predominantly originated from Paleozoic carbonates. At the 58-35 dry hole east of the field, Tertiary valley fill sediments were encountered below the breccia, which confirmed that the reservoir is a late Tertiary landslide. The brecciated nature of the reservoir is clearly expressed on an imaging log. The intense fracturing imparts huge permeabilities implied by production tests (4320 barrels of water per day at the 58-35). The top of this deposit is a prominent seismic reflection that extends southward to Kate Spring field, interpreted by French, 1991, to be a landslide deposit. Because of the continuity of the seismic reflection, the Kate Spring reservoir is interpreted to be the same lithostratgraphic unit as the megabreccia at Ghost Ranch. The deposit covers approximately 1500 acres and the volume of the deposit is estimated at 0.3 cubic kilometers (380 million cubic yards). According to relationships derived for modern sturzstroms of this size, it is estimated that the Ghost Ranch rockfall had a runout of 8 kilometers (26,250 feet) and a drop height of 1.2 kilometers (4000 feet). This drop height is very similar to the present day relief from the Grant Range to the valley floor. Foliations within the arched core complex of the Grant Range dip into Railroad Valley and may have increased the tendency for such a large landslide to occur.

Shallow Thermogenic Shale Gas in the Rocky Mountains

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The presence of considerable reserves of thermogenic gas associated with shallow, low maturity shales in the Uinta, Piceance and Green River Basins is indicated by four lines of evidence: mudlogs, gas produced from a Uinta Basin well, gas desorption experiments on GRF core, and gas composition. This is noteworthy in that gas generation is generally considered a process that occurs at high temperatures and thermal maturities. However, studies over the last 20 years suggest that a model of gas generation as an exclusively high temperature process is incomplete. Well-constrained field studies (e.g. Western Canada sedimentary basin, Williston basin) and experimental studies (e.g. Green River Formation (GRF) oil shales in the Piceance Basin) indicate that large volumes of gas are generated in some source rocks at low temperatures and low thermal maturity, at temperatures lower than 62°C and thermal maturities from 0.3% to 0.7% Ro.

Initial studies are underway to document the occurrence and distribution of shallow GRF shale gas in the Uinta Basin, and to relate the distribution to burial depth, thermal maturity, organic carbon content and stratigraphy. Preliminary data suggest that gas content is directly related to %TOC and that gas contents approach values for the prolific Barnett Shale in the Forth Worth Basin, Texas. However, a lack of basic data on this resource, including gas storage mechanisms, the role of natural fractures, logging and seismic techniques for mapping gas, and production technologies, is an obstacle to development of this resource.

The Rocky Mountain Transportation Conundrum

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The Rocky Mountain Region has always been on the “bubble” relative to having enough natural gas pipeline export capacity to accommodate growing supplies. Build too much pipeline infrastructure rapidly and perceived value in transportation drops. Build too little infrastructure or delay infrastructure development and commodity prices plummet. The problem is exacerbated by increasing regulatory uncertainty in areas where Federal lands are involved or in areas where water discharge and/or air emissions battles are being fought.

The Wyoming Natural Gas Pipeline Authority is focused on assuring that adequate infrastructure is built in the future to accommodate growth of natural gas supplies from Wyoming and the Rocky Mountain region in the future. By actively monitoring development of supplies within each basin in Wyoming and selective basins outside of the State, a predictive model has been built to determine the level of activity necessary to maintain and grow natural gas production in a systematic and economic fashion in the Rocky Mountain region.

Gemstones in Wyoming: Geology and Exploration

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Prior to 1975, only a few scattered gemstones were known in Wyoming – most notable were the jade deposits of central Wyoming. Over the past several years, the Wyoming State Geological Survey and other research entities have developed exploration models to search for a variety of gemstones. As a result, several gemstones are now recognized in Wyoming including gem-quality diamond, aquamarine, aquamarine-chrysolite, emerald, peridot, iolite, ruby, sapphire, kyanite, pyrope, chromian diopside, chromian enstatite and opal have been identified in the state along with semi-precious hematite and various agates and jaspers.

It is especially notable that evidence supports that the Wyoming craton has been intruded by major swarms of mantle-derived intrusives (kimberlites, lamproites, and lamprophyres), which are potential sources for several gemstones including diamond, chromian diopside, chromian enstatite, pyrope and almandine garnets. To date, 22 diamondiferous pipes have been identified in Wyoming, along with hundreds of kimberlitic indicator mineral anomalies. In addition, the presence of widespread amphibolite-grade metapelites and micaeous gneisses provide excellent source rocks for ruby, sapphire, iolite and gem-quality kyanite. To date, the WSGS has identified two of the largest iolite deposits in the world in these terrains that contain associated ruby, sapphire and gem-quality kyanite.

Treatment Technologies for Coalbed Methane Produced Water Management

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One of the major economic constraints to increasing natural gas production in the Rocky Mountain and Mid-Continent regions of the U.S. is the cost-effective management and disposal of co-produced water. Some of the greatest challenges exist in the coalbed methane (CBM) basins where the existing reinjection well capacities are not sufficient to dispose of growing volumes of produced water. Alternatives to reinjection include treatment of produced water streams to meet criteria for surface discharge, infiltration and beneficial reuse with brine volume reductions sufficient to extend the life of existing Class II reinjection wells. Over the past decade, a number of commercial and advanced technologies have been developed and deployed for the handling of produced waters. In addition, research and development is being conducted on process strategies that are aimed at converting produced water to beneficial-use water supplies. The challenge is to achieve the required levels of treatment while avoiding the equipment-fouling reliability problems commonly observed with conventional membrane-based treatment systems. This presentation will provide an overview of emerging processes that have the potential of improving the economics of treating produced waters to meet objectives of brine volume reduction, surface water discharge, infiltration for groundwater recharge and beneficial use. Some major technical challenges include the control of soluble and free oils, the fouling of membrane-based desalinization processes, the control of elevated levels of precipitates and soluble volatile acids, and the economical control of BTEX.

Promising processing approaches to improve the economics of reaching beneficial-use water management objectives will be discussed.

Good-bye to the Upper Cretaceous Seaway – Models for Lewis, Fox Hills, and Lance Strata in the Greater Green River and Wind River Basins

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Rapid filling of Rocky Mountain basins occurred near the end of the Upper Cretaceous (Maestrichtian). Depositional environments associated with this final regression include shelf, slope, and turbidite-basin deposits of the Lewis Formation, shoreface deposits of the Fox Hills Formation, and coastal plain and fluvial plain deposits of the Lance Formation. This talk will emphasize the Fox Hills and Lance strata and their reservoir potential.

The Fox Hills was deposited in near shore and shoreface environments. Mesotidal deposits occur along the western edge of the Great Divide and Washakie basins and deltaic deposits are common in the central and eastern portions of these basins. Reservoir potential exists in shoreface environments where lobes of sand are encased in shale or pinch out into shale. Slope channels, related to low stand or bypassed distributary channels, are also potential reservoirs.

Lance deposits in the Jonah area and throughout the Wind River Basin are fluvial plain sediments that were deposited in single to multi-story, braided channels and low to highly sinuous meandering channels. A west to east depositional change from fluvial plain to coastal plain environments occurs in the Lower Lance across the Rock Springs Uplift. Productive channel sandstones within the coastal plain are locally interbedded with coals. East of the Rock Springs Uplift, intertonguing of Fox Hills shoreface environments occurs within coastal plain deposits. Potential reservoirs exist in these marginal marine and marine sandstones.

In the Wind River Basin, Lower Meeteetse coastal plain strata are time equivalent to the Lower Lance in the Great Divide and Washakie basins, but channels systems are poorly developed and only marginally productive.

Utah - Permitting Challenges in a Rocky Mountain Petroleum Frontier

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Utah has a myriad of opportunities for exploration and development of petroleum. The Bureau of Land Management in Utah has experienced dramatic increases in expressions of interest for leasing, applications for permit to drill, energy related rights-of way, and interest in unconventional energy resources such as oil shale and tar sands. Numerous efforts are underway to provide access to those resources including preparation of new land use plans, environmental impact statements, and proposals for research and development leasing of oil shale. However, significant challenges exist with respect to compliance with the National Environmental Policy Act, National Historic Preservation Act, and Endangered Species Act. This presentation will provide a synopsis and statistics pertaining to the status of leasing, seismic and drilling permits, protests and legal challenges.

A New Look at Cow Creek Field, Carbon County, Wyoming

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The discovery well was drilled at Cow Creek Field by Sohio and completed on January 31, 1960 with an initial potential of 10.965 million cubic feet and 40 barrels of oil per day from the Nugget and Frontier Formations at depths of 9,650 and 8,550 feet respectively. After producing over 14 Bcf from the deeper beds, Double Eagle has rejuvenated the field with coal bed natural gas production from the shallow Mesaverde coals.

Since 1999, Double Eagle Petroleum Co. has concentrated on producing the shallow coals of the Almond Formation of the Cretaceous Mesaverde group. The coals are in the top 400 feet of the Mesaverde at depths of 1,000 to 1,400 feet. Gas contents range from 200 to 300 standard cubic feet per ton. Individual beds range from 1 to 20 feet in thickness and gross coal thicknesses in a borehole range from 10 to 75 feet in the eastern Washakie. Average gross coal thickness is between 20 and 30 feet. Local nomenclature has divided the Almond into the Garden Gulch, Marine, "A" series and Cow Creek sections from top to bottom. The Almond is overlain by the marine shales of the Lewis Formation.

Double Eagle Petroleum Co. has fourteen wells capable of production from the coals. Gas sales have been as high seven million cubic feet per day, but we needed more water management capability to sustain those rates. Pumps have just been installed in most of the wells and, if the field can stay producing consistently through the summer, the economic viability of this play will be properly tested.

Prospecting for Gas Hydrate Accumulations using 2D and 3D Seismic Data, Milne Point, North Slope Alaska

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The Milne Point gas hydrate prospect delineation study was part of the U.S. Geological Survey (USGS) Alaska gas hydrate resource characterization project in association with BP Exploration (Alaska) Inc. and U.S. Department of Energy research that has helped answer questions about gas hydrate distribution and reservoir properties. The interval below the base of ice-bearing permafrost (IBPF) to just below the base of the gas hydrate stability zone (GHSZ) was analyzed. Theoretical seismic modeling of stratigraphic and fluid boundaries, including shale to gas hydrate reservoirs and shale to free gas reservoirs as well as transitional gas hydrate to free gas reservoirs have been used to understand the acoustic properties of these complex systems. Petrophysical analysis of known gas hydrates show saturations of 60-90% and porosities of 30-40%. Reservoir thickness and saturation were the primary variables used in modeling acoustic attributes and calculating potential resource volumes.

Prospective “intra”-gas hydrate-bearing reservoirs below the IBPF and within the GHSZ and free gas-bearing reservoirs trapped below gas the GHSZ were delineated by seismic attributes. Fault-bounded intra-gas hydrate prospects were identified in areas that are structurally high, and that have acoustic properties corresponding to high concentrations of gas hydrate.

The historical log analysis work conducted by the USGS in this area combined with knowledge gained from 3-D seismic attribute analysis has helped us to understand the geologic setting for these unconventional reservoirs. The Milne Point area study has successfully delineated both intra-gas hydrate and sub-gas hydrate free-gas prospects that are appropriate for potential production testing operations.

Middle and Upper Paleozoic Carbonate Sequences in Idaho: Foreland Subsidence, Eustacy and Reefs

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Within Idaho’s mid- and late Paleozoic succession are carbonates and mixed siliciclastic units showing anomalous subsidence combined with several organic buildups in downslope and eustasy-influenced foreland basin settings. Overall, Devonian through Early Permian sediments comprise 7 km thickness. Idaho’s margin was passive in Middle Devonian time, yielding to a significant foreland basin with large accommodation events in the Carboniferous. Starting with the Jefferson Formation (Middle and Late Devonian, over 2 km), downslope rhythmites pass upward into a Nisku-type downslope buildup with stromatoporoids (showing ecophenotypic growth forms) and disphyllid corals. A drowning event occurs, with eustatic lowstand following, subjecting the buildup to subaerial exposure. The abrupt sealevel change is a consequence of coeval glaciation in Gondwana. Coincident with the first Late Devonian/Early Carboniferous tectonic loading event, the resulting foreland basin received western-derived flysch with a 3 km carbonate progradation event following. It is represented by changes from mudstone through packstone, with horizons of pelletal and ooid grainstones. A second tectonic adjustment from sediment loading provided accommodation for a second progradational carbonate package in Bashkirian time. Late Carboniferous carbonates show cyclic development of phylloid algal and hydrozoan(?) buildups, which show an ecologic succession from pelmatozoans (sediment stabilizers), colonial rugosans (colonizers), and diverse shelly faunas and phylloid algae (diversification) and Palaeoaplysina (domination). Buildups show termination by salinity rise (dolomites), siliciclastic suffocation (sands and silts), and brief subaerial exposure.

New Stratigraphic and Palynologic Studies of the Paleocene Waltman Shale Member, Wind River Basin, Wyoming: Implications for Basin Depositional Environments

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New stratigraphic and palynologic studies of lacustrine rocks in the Paleocene Waltman Shale Member of the Fort Union Formation in the Wind River Basin indicate that Lake Waltman was more extensive than previously thought, extending to near the southern and western basin margins. Interpretations of new palynomorph samples along with previously published palynomorph data indicate that the base of the Waltman Shale Member is everywhere in the lower part of the P5 palynomorph zone, confirming previous speculation that the initial transgression of the lake was rapid. At Castle Gardens, a Waltman tongue identified in this study is between coarse fluvial intervals suggesting rapid fluctuations in lake level.

Using the base of the Waltman as a key marker horizon allowed us to better correlate the underlying monotonous Upper Cretaceous and Paleocene fluvial interval in these marginal areas. A single, thick coal bed was identified in the lowermost part of the Paleocene Fort Union Formation throughout an extensive area of the western part of the basin. Several thick, amalgamated sandstone bodies were also identified. The stratigraphically lowest, which is near the top of the Upper Cretaceous Meeteetse Formation, occupies a 3–8 mile wide southeast-trending belt near the basin trough in the western third of the basin. Trends of amalgamated sandstones in the overlying Upper Cretaceous Lance Formation are more complex with one trending northeast off the Wind River Range, near the present course of the Popo Agie River and another trending east just south of the Owl Creek Mountains.

Upper Cretaceous and Tertiary Petroleum Systems and Assessment Units, Wind River Basin, Wyoming

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Total petroleum systems and assessment units were defined for Upper Cretaceous and Tertiary strata of the Wind River Basin. Potential source rocks include the Mowry Shale, lower shaly member of the Cody Shale, Mesaverde Formation, and Meeteetse Formation in Upper Cretaceous strata, and the lower unnamed member and Waltman Shale Member of the Fort Union Formation in the Paleocene strata.

Chemical and isotopic compositions of gases indicate complex origins and highly variable vertical migration distances. These interpretations are supported by drillstem tests indicating the presence of “gas plumes” on highly faulted and fractured anticlines including Madden and Pavillion-Muddy Ridge, where gas saturation extends thousands of feet stratigraphically higher than in surrounding rocks. Because of the likelihood that gases are co-mingled from several different sources in these gas plumes, a composite total petroleum system that includes several source intervals was established.

Coalbed methane assessment units are identified within the Mesaverde and Meeteetse Formations and the lower member of the Fort Union Formation, and are charged largely with migrated thermogenic gas and biogenic gas generated in the coals. Continuous sandstone gas assessment units are identified in the Frontier Formation, Cody Shale, Mesaverde, Meeteetse Formations, and lower member of the Fort Union Formation in the deeper areas of the basin. Conventional gas and oil assessment units cover much of the basin and include the same stratigraphic intervals as the coalbed methane assessment units in the shallower areas of the basin and are present above continuous gas assessment units in the deeper parts.

Detailed Stratigraphic Delineation Using 3D Volume Interpretation: A Case Study from the Uinta Basin, Utah

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[3]Fall-Line Exploration, Inc, Dillion, CO

Gas sand delineation in the absence of “bright spots” poses significant challenges to the interpreter. Lacustrine channels and deltas though typically thin can be productive reservoirs. However, such gas charged sands often have a low amplitude seismic response making them difficult to identify and map using traditional seismic methods. New workflows leverage innovative delineation technology within a 3D volume interpretation environment to reveal reservoir details not seen with traditional methods. Interactive well planning and the calibration of 3D seismic with well and production data reduces risk and increases drilling confidence. In this presentation, an active onshore exploration project from the Uinta Basin is used to highlight the streamlined nature of this workflow and how gas-charged sands are being reliably identified and drilled today. Additional examples from other basins will also be used to highlight other recent advances.

Management of Produced Water from Coalbed Natural Gas Wells, Powder River Basin, Wyoming

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Management of produced water from coal bed natural gas (CBNG) wells in the Powder River Basin has become challenging because of increasing regulatory requirements by the state regulatory authority, the Wyoming Department of Environmental Quality (WDEQ). When CBNG was first being developed in the Powder River Basin, it was recognized that high-quality water produced from coal seams infiltrating into and recharging shallow aquifers would be considered beneficial to the environment and a reasonable disposal option. In response to the very stringent regulatory requirements of the WDEQ for direct discharge into drainages, more CBNG operators are moving toward containing water on-lease in infiltration impoundments. In response to this shift in method of water disposal, various groups that have opposed direct discharge of produced water are attempting to prevent storage in reservoirs and pits. The WDEQ has responded by imposing new requirements and conditions reportedly designed to protect shallow aquifers. However, it is not certain that these new regulations are based on sound scientific reasoning nor are there criteria for defining what is an aquifer.

Evaluating Thermogenic Tight Gas Shales, the Unconventional Frontier with Proven Success

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From an analytical view, tight gas shales can be separated into 3 broad classes; Biogenic (immature clay), Biogenic (mature clay), and Thermogenic. Thermogenic tight gas shales can be subdivided into 4 main types based on similar lithofacies, common clay and kerogen types. One of the most widely recognized and successful types of thermogenic tight gas shales could be identified as Thermogenic Classic (examples include the Barnett, Fayetteville, Caney and many others).

Dominant lithofacies common to this type of shale include; Calcareous Mudstones, Silica rich Mudstones, and “Low Resistivity” Claystones. Other lithofacies are present and can be important “economically” or “mechanically” when present but are not considered common, by the author, across the different basins in which this type of shale is producing. Clays are generally mixed layer smectite-illites with other clays fading in and out. Kerogen types are dominantly mixed percentages of Kerogen Type II and III.

This type of consistency would suggest that these shales could be targeted similarly. However, field experience and laboratory measurements suggest that they require varying completion strategies as dictated by kerogen maturity, changes in diagenic alterations, subtle changes in clay and kerogen type, and even more often by changes in stress regimes and seal arrangements. Unlocking the productivity of these complex reservoirs requires a detailed level of evaluation not common to the industry.

Cultural and Molecular Studies of Methanogens in Paleocene Fort Union Formation Coal from the Powder River Basin of Wyoming and Montana

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The stimulation and replenishment of coalbed methane (CBM) in low-rank coals is of increasing interest in relation to managing this globally abundant and increasingly economically important unconventional energy resource. A critical first step in developing this technology is to document the presence and potential for methanogen development within the coal. Based on nested polymerase chain reaction (PCR) protocols, molecular analyses of coalbed materials have indicated that putative deep-rooted methanogen (PDRM) sequences are present in the Paleocene age Fort Union Formations coal from the Powder River Basin (PRB) in Wyoming and Montana. In this study, coal samples from beds in the Wyodak-Anderson coal zone have been incubated in specially designed polyethylene gas diffusion units, equilibrated in an

anaerobic environment that should provide hydrogen and carbon dioxide at methanogen-permissive concentrations and flux rates. The samples used in the cultural analyses were recovered from freshly-exposed drill core faces using a flame-sterilized minidrill and aseptic sample trapping system. Diffusion sample units were assembled in 2-mil polypropylene using heat-sealed inner and outer packets containing the desired sample and filter-sterilized methanogen basal salts medium under controlled conditions. For analysis of responses after extended incubations (2-3 months), cultural expression of methanogens from these materials is being evaluated, together with quantitative and qualitative molecular signal responses. Understanding how methanogens function in Wyodak-Anderson coal beds, which produced 72 percent of the total CBM production from PRB as of the end of 2004, will be critical in terms of assuring the recyclability leading to longer-term productivity of this important resource.

Is It Possible to Detect Gas Seepage from CO_2-EOR Projects? Experience at Rangely, Colorado, with CO_2-EOR, and Teapot Dome, Wyoming, at Baseline Condition

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Carbon dioxide sequestration in spent oil and gas fields as part of a CO_2-EOR program will likely be an early option that has economic advantages. A concern is the potential for gas microseepage under the overpressured conditions necessary for operation, particularly for CH_4. A comparison was made between the overpressured Rangely, Colorado CO_2-EOR operation and the underpressured Teapot Dome oil field in Wyoming.

Fluxes of CO_2 and CH_4 into the atmosphere under winter conditions of low soil biological activity were determined at both the Rangely and Teapot Dome fields. Shallow soil gas concentrations and stable carbon isotopes on soil gas CO_2 were also determined. Shallow soil gas composition exhibited large differences for CH_4 at Rangely, reflecting high rates of microseepage at a few locations. Stable carbon isotope measurements aided in the recognition of anomalous areas at both Rangely and Teapot Dome.

Ten-meter deep holes were augured for nested soil gas sampling at selected locations of interest for more thorough characterization, including areas of gas microseepage and background. In anomalous locations, a substantial proportion of deep-sourced CH_4 was bacterially oxidized in the unsaturated zone, producing isotopically distinctive, and radiocarbon-depleted CO_2. Carbon isotopic composition of surface materials, such as calcite veins, caliche, vegetation, soil organic and inorganic matter are essential in the characterization of processes operating in the near-surface, that reflect seepage.

What's UP on the Pinedale Anticline

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The combined Pinedale Anticline and Jonah fields are emerging as the new giant for U.S. Natural Gas Production. Ultra Petroleum Corp. through its wholly owned subsidiary, Ultra Resources Inc. is very active in the development of this world class field. Ultra operates the largest portion and is the largest interest owner on Pinedale. Additionally, we are the third largest operator in that Jonah Field. From very modest beginnings, Ultra has utilized a strong Geological and Geophysical basis to develop the model for the play that has been used in what to date has been the highly successful development of this resource. Since the acquisition of the initial 3D on the Mesa area in 1999, Ultra has been using an industry leading 3D data set to guide all location selection decisions on the anticline. Utilizing this data, Ultra has drilled or participated in nearly 200 successful wells on the anticline. During this same period only 4 wells were plugged, all for mechanical reasons. The second component to the success at Pinedale is the evolving completion techniques driven by knowledge and extensive experimentation. These new completions result in shorter times to production at lower costs per Mcf of reserves and improved performance. Assessment of the total resource available is ongoing. Current OGIP estimates for Jonah exceed 13 TCF while the numbers for Pinedale now exceed 40 TCF. The real question is how much is recoverable and at what well density will the fields need to be developed to achieve this.

Undersaturation in Coals: How Does it Happen and Why is it Important

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By combining gas content data with an adsorption isotherm, it is possible to determine the gas saturation condition of a coal sample. Fully saturated coals are ideal from a CBM perspective because they will produce gas immediately as soon as water is produced from the reservoir. As the gas saturation level decreases, more water needs to be produced in order to reduce the reservoir pressure to the critical desorption pressure when gas will start to desorb from the coal.

In highly undersaturated coal reservoirs, many months to years may be required to sufficiently dewater the coals to allow the desorption process to begin. This long dewatering time can ultimately result in an uneconomic prospect due to long period of little or no cash flow accompanied by ongoing operating expenses.

Determination of the gas saturation condition is relatively easy and inexpensive. By collection this data early in the life of a CBM project, much time, effort and money can potentially be saved.

Understurated coal reservoirs may eventually produce large volumes of gas once the reservoir pressure has been reduced to the critical desorption pressure. However, the economics of these reservoirs may be marginal at best. Unfortunately, data collected from many Rocky Mountain CBM prospects indicate that the coals are significantly undersaturated. Examples of some of these prospects, with associated gas and water production data, will be presented.

CBM Resource Development in Ecologically Sensitive Environments—Vermejo Park Ranch, New Mexico — A Case Study

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Vermejo Park Ranch (VPR) is a 588,00 acre privately owned ranch located in Northeastern New Mexicos Raton Basin. VPR is a premier hunting and fishing destination and working bison ranch, with a highly diverse range of ecological environments. Coal Bed Methane resource development is being conducted under a unique partnership between the Surface Estate Owner and Mineral Estate Owner (El Paso Corporation). The parties are in the 4th year of a planned 8 year development program with 511 wells on production through 2004.

The Raton Basin is a Laramide-age strucural basin on the eastern side of the Sangre de Cristo Mountains. Coal Bed Methane is produced from Late Cretaceous (Vermejo) to Early Paleocene (Raton) Formations.

Vermejo and El Paso have voluntarily entered into an agreement that governs how CBM resource development operations proceed on the Ranch, the Mineral Extraction Agreement (MEA). This agreement is unique in the industry and provides the guidelines, checks, balances, and requirements for CBM development. It also provides a framework for VPR's environmental staff to work closely with the operators development staff. MEA specifics will be presented and discussed.

Using GIS and GPS technologies, satellite imagery, and wildlife/forestry management tools, the development phase of the project is being completed in such a manner as to minimize both short and long term adverse effects to VPR resources and values, while allowing for the efficient development and production of coalbed methane gas.

Horizontal Drilling Potential of the Middle Member Bakken Formation, North Dakota

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The Bakken Formation has once again become the focus of activity in the Williston basin. Horizontal drilling of the middle member began in 2001 and has been restricted to Richland County, Montana until recently. As the success rate increased in Montana, activity has increased in North Dakota.

The stratigraphy in the main play area is relatively simple with each successively higher member of the Bakken Formation onlapping the underlying Three Forks Formation. These units pinch out to the south. A bottom seal is formed by the impermeable Three Forks Formation while the overlying Lodgepole Formation forms the top seal. A well developed mappable trend is readily apparent in the middle member on wireline logs over this area.

Technology has finally caught up to the Bakken Formation. The ability to fracture stimulate these horizontal wells is what makes this play work. The zone generally has between 7 to 12% porosity, permeabilities of .01 to .02 mD, and 70 to 80% oil saturation.

The facies that produce in Montana are present basinwide. Additional production potential occurs in North Dakota as the Bakken thickens towards its depositional center. Localized accumulations of the "Sanish Sand" that occur at the base of the Bakken also increases the potential pay section. Already a significant producer at Antelope Field, the "Sanish Sand" interval is untested and occurs throughout the "Bakken Fairway." Detailed mapping of all of the zones will be required to determine the best location to tap into the oil resources of the Bakken Formation.

Characterization of the Natural Gas Systems of the Wind River Basin, Wyoming

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In a re-evaluation of gas systems from the Wind River Basin, new molecular and isotopic composition data combined with data from the literature was used to characterize and identify at least four gas types. Type-A gas is found in Tensleep Sandstone and the Phosphoria, Amsden, Embar, and Sundance Formations in the Beaver Creek, Riverton Dome, Steamboat Butte, Pine Mountain, Big Sand Draw fields, and is most likely derived from the Phosphoria Formation. The gas is typically wet, has high H_2S, He, N_2, and/or CO_2, and is usually found in fields that also contain Phosphoria-sourced oil. Type-B gas has charged Lakota, Dakota, and Muddy Sandstones, and Morrison and Frontier Formations in the Beaver Creek, Riverton Dome, Big Sand Draw, Pilot Butte, Steamboat Butte, Clark Ranch, Muskrat, Sheldon and Wallace Creek fields, and is most likely derived from the Mowry Shale and possibly the Muddy. Type-C gas is found in Upper Cretaceous and Tertiary reservoirs in numerous fields in the northern part of the basin. Type-C gas includes a wide range in gas composition reflecting the variation in organic facies and maturity level of Upper Cretaceous source rocks. Type-D gas is microbial gas found in shallow coal beds of the Mesaverde Formation and is produced from the Wind River Formation at Waltman field. In some fields, gas quality has been adversely impacted by elevated non-hydrocarbon gas content (CO_2 at Madden, N_2 at Pavillion and East Riverton Dome, H_2S at several fields) and by biodegradation (Pavillion and Riverton Dome).

Integrated Gravity and Magnetic Interpretations Yield New Insights to Basin and Range Structures

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New interpretation techniques using detailed gravity and aeromagnetic surveys show faults, lineaments, contacts and regional structural patterns in Eastern Nevada. Oil companies have used gravity surveys as a primary exploration tool in Nevada, partly because seismic data quality is often poor. Within Tertiary basins, the gravity data reflects structures cored with Paleozoic carbonates, and detailed gravity surveys show the fault blocks that form Grant Canyon, Trap Springs and Blackburn fields. The detailed gravity shows complex fault patterns. Gravity surveys are typically acquired only in the valleys, and most exploration efforts have not focused on regional gravity trends. Magnetics can be used to map the subsurface distribution of volcanic rocks over eastern Nevada, but previous magnetic images and interpretations did not correlate well with gravity. The magnetic susceptibly differences are much grater in the volcanics than within the sedimentary section. The aeromagnetic surveys cover both the valleys and ranges, helping to constrain the gravity interpretations in areas of no coverage. The results of these new interpretations show correlation between the gravity and magnetics, revealing new structural information and regional styles. Between the two data sets, faults and contacts may be coincident, or show a longer fault, or show a fault's terminus. Three regional structural styles become apparent: Pine-Huntington-Diamond Valleys; Little Smoky-Butte-Long Valleys; Big Sand-Railroad-White River Valleys.

Documentation of Late Cretaceous Forebulge Migration in Southwestern Wyoming

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The recognition of a forebulge in the subsurface is difficult due to its low amplitude and wide extent. Three regional profiles are established to define the late Cretaceous forebulges in southwestern Wyoming based on detailed well log correlations and good outcrop control. The amplitude of forebulges is 40-80 m according to the stratal erosion and thinning. In response to eastward progressive movement of the Crawford, Early Absaroka, and Late Absaroka thrusts, the forebulges migrated eastward to the Moxa arch, the Rock Springs uplift, and the Washakie basin, respectively. Tectonic analysis show that the late Cretaceous forebulges resulted from the combined elastic response of the lithosphere by the Wyoming thrust belt and Wind River thrust. 3D flexural modeling results further supports this explanation. Following the formation of the forebulge, basement-involved uplifts formed at the Moxa arch and Rock Springs uplift. This probably implies that the forebulges may have weakened these zones of the lithosphere triggering basement-involved uplifting during the Laramide orogeny.

Characterizing a Fractured Carbonate with an Embedded Multicomponent Seismic Test

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While the orientation and distribution of fractures cannot be directly imaged by seismic surveys, characteristics related to fracturing can be inferred from the azimuthal variations of seismic attributes. The same physical phenomena that create azimuthal amplitude variation (AVOA) in primary (P) waves will generate azimuthal velocity variation (shear-wave birefringence) in secondary or shear (S) waves. These two independent techniques – P-wave AVOA and converted-wave birefringence – are complementary methods of evaluating anisotropy caused by the fractured medium. Converted-wave birefringence, which can only be evaluated through full-wavefield recording with multicomponent receivers, also resolves the inherent 90-degree ambiguity in fracture orientations determined by P-wave AVOA analysis alone.

In this US example, the fundamental goal was to determine the essential practicality of acquiring converted-wave data in gas-bearing hydrothermal dolomites at a depth of approximately 9000 ft. This is achieved through an embedded multicomponent test, where 544 three-component digital accelerometers are co-located with production single-component geophone arrays over a subset of the survey area. The embedded test demonstrates the expected characteristics of converted-waves in azimuthally anisotropic media, and provides a clear illustration of the use of shear-wave birefringence in a land dataset. The method of analysis is discussed and the results compared directly to AVOA results from the larger, conventional, P-wave 3-D survey, and verified with well-bore imaging and production data.

Evaluation of Coal Seam Permeability in Marginal Reservoirs

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Recent increases in gas sales prices have made marginal coal gas reservoirs commercially viable. As a result, operators have been completing coal seams that in the past would have been considered to have natural fracture permeability too low to be exploited. These marginal reservoirs are typically stimulated by hydraulically fracturing to increase gas productivity. Due to the high cost of stimulation and the need to minimize costs to exploit marginal reservoirs, it is important to avoid stimulation of coal seams that will not yield commercial gas production rates. Pre-stimulation water injection-falloff testing of multiple seams considered for stimulation in a single well has proven to reduce overall costs. Avoidance of stimulation of one seam generally results in completion cost savings that are greater than the cost of the testing program.

We improved methods analyzing water injection-falloff tests performed in lower permeability coal seams to increase reservoir pressure and natural fracture permeability estimate accuracy. In many cases, water injection-falloff tests, which are the most common permeability evaluation method, increase the permeability several times above the permeability that will control production in marginal seams. It is easy to misinterpret these data to expect substantially greater post-stimulation productivity than possible. Our analysis method is based upon history matching both the injection and falloff data with mathematical models that account for the permeability changes. The analysis also results in in-situ natural fracture porosity estimates. Porosity estimates can be used to predict the volume of water that will be produced.

Investigating the Interaction of Sevier and Laramide Structural Development in the Rocky Mountains with 3D Seismic Mapping

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Three 3-D seismic reflection volumes have been procured by BYU in the western Green River Basin (GRB), the southwestern Powder River Basin (PRB), and the southern Uinta Basin (UB). State-of-the-art 3D visualization and attribute analyses furnish precise and detailed images of the interaction of Sevier (Mesozoic) and Laramide (Late Cretaceous-Cenozoic) deformation episodes and structural styles.

The position of the GRB volume between the Sevier frontal thrust and Wind River thrust, where they begin to approach each other, provides an opportunity to investigate close interactions between Sevier and Laramide deformation. Alternatively, the PRB and UB volumes both represent regions that are proximal to areas of mainly Laramide deformation. We have prepared structure maps of prominent seismic horizons as well as seismic attribute extractions in order to map and characterize varying deformation styles within each of and between the three seismic volumes.

The GRB volume shows the most complex structural variation, including both “thin-skinned” and “thick-skinned” deformation. Small-scale compressional structures in places show dual vergence, suggesting either a component of strike-slip or the interaction of two deformation episodes (Sevier and Laramide). A complex pattern of deeper high-angle faulting appears to penetrate the entire sequence and the top of basement and is accompanied by monoclinal and anticlinal flexure. The PRB and UB volumes show predominantly "thick-skinned" deformation with high-angle faults and/or strike-slip faults cutting through large-scale asymmetric compressional structures. The synoptic view provided from the three volumes allows a more generalized characterization of Laramide vs. Sevier subsurface deformation in the Rocky Mountain region.

Discovered Crude Oil Resources of Wyoming, USA

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The geologic characteristics and distribution of the discovered crude oil resources in nine recognized petroleum systems are summarized for 375 oil fields, accounting for 93% of total crude oil production from Wyoming.

Through 2003 the fields analyzed had produced 6.40 billion barrels of crude oil from a total discovered resource base of 22.28 billion barrels (OOIP). Present remaining reserves are estimated to be 462 MMBO. This suggests that current oil production operations in the state will ultimately recover 7.31 billion barrels of oil, or about 32.8% of the original oil in place.

Approximately 54% of the discovered resource base is attributed to the Phosphoria-Minnelusa systems. The Permo-Pennsylvanian Tensleep and Minnelusa formations and their equivalents contain 35% of the resource. The thick high quality sandstone reservoirs of the Pennsylvanian Tensleep Formation exhibit the highest recovery efficiency, 34% to 62% of the OOIP. Recoveries in the Permian Phosphoria and Mississippian Madison carbonate reservoirs are in the range of 12% to 27%.

The Lower Cretaceous Mowry-Belle Fourche systems account for 26% of the discovered resource base, nearly all of which is contained in sandstone reservoirs of the Lakota (Cloverly), Fall River (Dakota), Muddy, and Frontier formations. A bulk of the remaining resource is contained within the Upper Cretaceous sandstone reservoirs within the Cody-Pierre Shale and their equivalents, the Mesaverde Group, and Lewis Formation. In general, the Cretaceous reservoirs exhibit the lowest average recoveries, ranging from 6% to 25% of the OOIP.

Pinedale Field: a Giant New Gas Resource, Green River Basin, Wyoming, USA

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The Pinedale Field is developing into one of the largest gas fields in the Greater Green River Basin of southwest Wyoming and along with Jonah Field, a significant new natural gas resource in America. Production is from over-pressured, tight-gas sandstones of the Upper Cretaceous Lance Formation and upper part of the undifferentiated Mesaverde ("Lance Pool"), coincident with the Pinedale Anticline. Current development along the Pinedale Anticline spans an area over 3 miles in width and 30 miles in length. The gross hydrocarbon-bearing column, which exceeds 5,000 feet in total thickness, consists mainly of fluvial and flood plain facies rocks deposited in a broad alluvial valley. In order to better understand the Lance Pool reservoir characteristics and to optimize the development of the Pinedale Field, Ultra Petroleum Corp embarked on a coring program in which 10 wells were cored and a total of 853 feet of Lance Pool rock was recovered. Detailed analysis of the core integrated with Ultra's geological, petrophysical and geophysical models has led to a unique understanding of the Lance Pool. The alluvial sandstones of the Lance Pool were deposited in a rapidly subsiding basin by modest-sized rivers reflecting constant channel-belt migration. The resulting reservoirs are laterally- and vertically-discontinuous, multi-story sandstones. Effective reservoir characteristics appear to include lower porosities and permeabilities, a greater range of effective water saturations and a thicker net pay section than previously believed.

Sediment Diapirism and Gravity Sliding of the 2 Ma Huckleberry Tuff Near the Teton Dam, Idaho: Small-Scale Structural Constraints

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A 20 by 20 km sheet of the 2 Ma Huckleberry Tuff and underlying Pliocene alluvial gravel, basalt, and tuffaceous lacustrine sediments were involved in gravity sliding and flow shortly after deposition of the tuff. Large scale structures are similar to those observed in the Gulf of Mexico resulting from soft-sediment and salt flow, and include overturned anticlines >100 m in amplitude, strike slip faults with up to 1 km displacement, sedimentary diapirs, and an arcuate pull-apart valley 12 km long. Because displacement occurred during compaction but before devitrification, the tuff deformed plastically in its lower parts but contains brittle joints in its upper. The brittle joints were opened during shearing by as much as 1 m. We classify and analyze the orientations of plastic shear zones, plastically deformed joints, orientation of zones within the tuff, and joint sets to document the kinematics of deformation. The small-scale structures are consistent with the secondary deformation and gravity sliding originally proposed by Embree and Hoggan in 1999. Sliding was toward the southwest, resulting in NW-SE fold axes, SW-NE trending strike slip faults, and cooling joints that were plastically sheared toward the southwest. The opened joints played a role in the failure of the Teton Dam in 1976.

A Historical Perspective of Anadarko's CBNG Exploration and Development Success in the Rocky Mountain Region

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Anadarko Petroleum has been actively exploring and developing coal bed reservoirs in the Rocky Mountain region for the last 15 years. Their current production is 110 MMCFPD from 700 operated wells. Exploration efforts on Cretaceous marine and Tertiary intermountane deltaic depositional settings have yielded two geologic play types with economic success from coal reservoirs. The Cretaceous play type is represented by the Helper and Clawson areas in the southwestern Uinta basin of central Utah. These areas were identified in the early 1990s and are in a mature stage of development. They are characterized as multiple high gas content bituminous coal seams ranging from thickness of 1 to 20' thick and distributed over a gross interval of 300 feet. These reservoirs are generally at depths of the 2000 from 4500' and require fracture stimulation with initial per well water production ranging 50 to 400 BWPD.

The second play type is represented by the County Line Field, consisting of the Big Mike and Big George Federal Units located in the central Powder River Basin of Wyoming. These areas were identified in the mid- 90's and currently under field development. This play type is characterized by low gas content sub-bituminous coal seam with thicknesses exceeding 100' at average depths of 1100'. Wells are completed open-hole with common water rates of 700 to 1200 BWPD. Critical to these play types are strategies for managing produced water. Various methods such as under ground injection, surface impoundments, irrigation utilization and aquifer recharge are employed in the Anadarko projects.

Anadarko continues its exploration efforts on the Wyoming Land Grant utilizing the experience and knowledge gained in success of previous play types.

Surface Mapping Validates 3D Seismic Faulting Interpretations at Teapot Dome Field, Natrona Co., Wyoming

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The importance of fault control on production at Teapot Dome Field has been known by workers at NPR-3 since the 1920s. Traditional production-based fault maps provided usable reservoir compartment models during the period of "low hanging fruit." In the 21st century, Teapot Dome's low hanging fruit is gone, and decisions regarding further development, must be based on subtle information provided by modern technology. The interpretation of a 3D seismic survey acquired in 2000 has yielded a picture of structural complexity far beyond that imagined in the past. Accurate reservoir compartmentalization models are crucial to future EOR and CO_2 sequestration projects at NPR-3. Basement-cored faults have been extrapolated to the surface, where mapping and trenching have yielded new ideas on the geometry and sealing nature of fault planes. Seismic data suggest basement-cored faults cross the anticlinal structure obliquely, and exhibit changes in apparent throw directions with decreasing depth. This character suggests a degree of wrenching overprint. The faults splay upward into complex horsetail patterns. On the surface, this geometry is manifested by clusters of sub-parallel normal faults with small, outcrop-scale vertical displacements. Faults projected to the surface are difficult to map in the Steele Shale Formation unless distinctive markers are present. The most useful markers include the Sussex Bentonite and Sandstone Members. Faults are invisible on the surface where marine shale is juxtaposed against marine shale. Diagenetic effects in faults include carbonate fracture fillings, subsequently offset by later fault movement. Subsequent fault movement led to fracturing within the vein-filling material, creating a pathway for oil to seep to the surface from the Shannon Sandstone Member. Trench logging has shown that larger, more laterally extensive fault planes exhibit clay smears dragged up from deeper bentonite layers.

The Goshen Multi-Zone Project: a Resource Area Where Multi-Stage Frac Technology May Commercialize Stacked Low Permeability, Hydrocarbon Saturated Targets

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The Goshen Multi-Zone Project is in the northern D-J Basin, southwestern Goshen County, Wyoming. It targets a 1200' thick hydrocarbon-saturated interval from 7800 to 9000 feet deep that includes the Niobrara, Wall Creek, and Muddy formations. The project concept is to achieve commerciality though hydraulic fracture stimulation and commingling of multiple marginal zones.

This project lies to the east of the basin axis on the gently dipping eastern side of the D-J Basin. It is in an active hydrocarbon generation cell that locally reaches the gas window. Lithologies and depositional environments range from coarse clastics in delta fronts and shore faces to open marine organic shales and carbonates. The common feature is that all zones within a 1200' interval are tight and hydrocarbon bearing. Exploration wells between 1955 and 1987 had hydrocarbon shows throughout the interval, small hydrocarbon recoveries from tests, calculated pay on logs, and no water. Overlapping "sweet spots" provide multiple targets for vertical wells.

Contributions to production are anticipated from the Niobrara, Fort Hayes, Wall Creek, Greenhorn, Graneros, Mowry, and Muddy formations. Development wells are proposed with three or four hydraulic frac stages of 250,000 pounds of sand per stage. Pattern drilling is anticipated on 160 then 80 and 40 acre spacing. Projected reserves are about 0.75 BCF and 25 MBO per well. Completed well cost is estimated at $750,000. Wattenberg field is the multi-zone analog.

Structure and Reservoir Characterization of Farnham Dome Field, Carbon County, Utah

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Farnham Dome in east-central Utah is an elongated surface anticline associated with ramp-style thrusting of a Sevier-aged decollment in the Jurassic Carmel Formation. Farnham Dome field includes a much broader Laramide-aged anticline along the northern plunge of the San Rafael uplift. Pennsylvanian-aged reverse faulting associated with the Uncompahgre uplift resulted in local thickening of the Pennsylvanian section creating potential stratigraphic traps.

Drilling along the crest of Farnham Dome in the 1920s and 1930s resulted in the discovery of a significant deposit of carbon dioxide (CO_2) in the Jurassic Navajo Sandstone and smaller accumulations of CO_2 in Triassic, Permian, and Pennsylvanian reservoirs. More recent additional drilling and seismic data revealed the surface anticline was a shallow feature on the west flank of the broader anticline that forms the trap for the CO_2. Most of the CO_2 may have migrated into the trap between 10 and 58 Ma. The gas accumulation is hydrodynamically displaced to the northwest resulting in a lower gas/water contact on the northwest side of the structure. Nearly 5 BCF of CO_2 was produced before field abandonment in 1979 for lack of a market. Currently, a newly drilled well is shut-in prior to construction of a plant to process the gas to food-grade liquid CO_2.

The UGS studied Farnham Dome field as an analogue for sequestration of CO_2 in Rocky Mountain aquifers. Farnham Dome field is a good example of the potential for long-term sequestration of CO_2 in Rocky Mountain aquifers.

Integrated Reservoir Characterization of the Entrada Erg-margin Gas Play, Utah: An Outcrop and Seismic Analog for the North Hill Creek/Flat Rock Field, Southern Uinta Basin, Utah

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Recent discovery of high-BTU gas-charged Jurassic reservoirs in the North Hill Creek/Flat Rock (NHC/FR) Field, southern Uinta Basin, Utah, have ignited interest in below-Tertiary reservoirs within the basin and other areas of Utah. Erg-margin rocks of the Jurassic Entrada Sandstone are of particular interest because of their potential to contain large, high quality reservoirs and develop stratigraphic traps. Entrada erg-margin sandstones exposed along the east flank of the Waterpocket Fold, south-central Utah, appear to be isolated sandstone bodies enveloped within the tidal flat "earthy" facies. Tidal flat facies are dominated by mudstones and siltstones. These outcrops are likely analogs for reservoirs in the NHC/FR Field.

Outcrop and log analyses are integrated with seismic attribute maps of the Entrada section from a 3D seismic survey acquired by Wind River Resources over the NHC/FR Field. Relative to important reservoir considerations, our study indicates: 1- eolian-influenced facies have porosities greater than 23 percent, 2- water table fluctuations during dune development affect reservoir quality, and 3- erg-margin, reservoir quality sandstone bodies can be offset vertically and isolated from each other.

Reservoir characterization studies of the outcrop include; photomosaics, identification of facies and potential baffles and barriers, porosity/permeability analysis, sedimentary petrology, grain size analysis, and measured sections including scintillometer logs. Strike- and dip-oriented, high resolution 2D seismic reflection profiles were shot in an attempt to understand the 3D architecture of sandstone bodies and their associated volumes. Further, a map delineating the Entrada erg-margin trend throughout Utah was developed.

Review of the Federal Land Use Planning Process

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Access to public lands plays an increasing role in the exploration and development of hydrocarbon resources. Federal land use planning is conducted through the resource management plan (RMP) process and the end-point of the planning process will, to varying degrees, dictate which lands will be available for leasing and what kind of restrictions will be placed on use of those lands. Review of recent draft RMPs in Colorado, Utah, and Wyoming indicates that the proposed plans contain excessive restrictions, inadequate Reasonably Foreseeable Development Scenarios (RFDS), lack of accountability for mineral decisions, failure to acknowledge valid existing lease rights, and unreasonable mitigation requirements. There are a number of opportunities in the RMP process where the public can be involved. These opportunities include scoping, development of RFDS, determination of proposed alternatives, and draft and final environmental impact statements. Decisions made during the development of RMPs have direct bearing on the ability to access, explore, and develop mineral resources and industry must have a greater role in the federal land use planning process.

Central Utah, a New Oil and Gas Province

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The Wolverine Gas and Oil central Utah thrust belt-hingeline oil discovery made on May 3, 2004, opened a new and very large oil and gas exploration-production province. It ranges from the north near Pineview field 150 miles to Beaver City, Utah on the south. It is bounded on the east by thrusted sediments near Highway 89, then extends west perhaps 50 miles to the central Delta Desert area. The play is presently defined by several producing wells, 115 wildcat dry holes, numerous thrusted ourcrops of Mesozoic and older rocks, 1970-1980's seismic, magnetic, and gravity data, plus surface hydrocarbon seeps, oil analyses, satellite defined hydrocarbon microseepage anomalies and a bevy of new seismic lines. The Jurassic Navajo Sandstone, always recognized as a world class 1,200 foot thick hydrocarbon reservoir, did not disappoint when Wolverine's KMR 17-1 well found the formation filled with 41 gravity, water driven, low sulfur oil. However, there were four major surprises: 1. The Navajo Sandstone was 1,360 feet higher than mapped, 2. The production was oil, 3. Two Navajo Sandstones were present, and 4. Oil was sourced from Paleozoic rocks with migration at least in part, post thrusting. We predict at least 30 structural anomalies will be drilled after several massive group and company seismic programs are completed along the four major, east vergent thrust segments. Paleozoic reservoir rocks may eventually provide more reserves than Mesozoic rocks. Recoverable reserves may exceed several billion barrels of oil and several trillion cubic feet of gas.

Big Sand Draw Field – The Proof is in the Details

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The Tensleep production at Big Sand Draw Field, Fremont County, Wyoming, was initiated in 1944. The Tensleep produces 33.6 gravity crude from an average depth of 7500 feet. The average pay thickness is 278 feet, with an average porosity of 2.6%. Since that time more than 54 million barrels of oil has been produced from this reservoir. The Tensleep has seen three distinct phases of development. The first phase took place in the late 1940's to early 1950's. The second phase occurred in the middle 1960's when many of the existing Phosphoria producers were deepened to the thicker, more prolific Tensleep sandstone. The third phase took place in 1972, six additional wells were drill to the Tensleep at this time. Before the drilling of the 1972 program, 43 million barrels of oil had been produced, approximately 79% of the total cumulative production. By studying the location and production histories of these 6 wells three important facts come to light. First, the six wells added 3,300 barrels of oil per day to the field production. Second, two of the six wells had initial production rates in the 2000 barrels of oil per day range. The six wells exhibited higher oil cuts than surrounding wells, indicating the potential for banked oil left in the field. Based on an integrated geologic and reservoir model of the Tensleep at Big Sand Draw it has been determined that there is considerable reserve potential remaining in this 60 year old field.

3D Strain at Transitions in Foreland Arch Geometry: Structural Modeling of the Beartooth Arch - Rattlesnake Mountain Transition, NW Wyoming

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How is 3D strain accommodated at transitions in foreland arch geometry? End-member hypotheses to explain 3D strain at foreland arch transitions include 1) uniformly directed slip on pre-existing basement structures, and 2) anomalously directed slip necessary for 3D strain accommodation. The Beartooth arch, SW Montana and NW Wyoming, transitions to the SE into a structurally complex zone characterized by a blind master thrust with anomalously oriented and backthrust hanging wall structures. The Rattlesnake Mountain anticline is a SW-vergent backthust within this hanging wall and is linked to the NE-vergent Beartooth arch by the S-vergent Pat O'Hara Mountain anticline. Inferred ideal $\sigma 1$ orientations from over 1,200 slickensided minor faults and shear bands at the southern Beartooth arch transition show a uniformly oriented 065° stress field at sites located away from anticlinal axes. Inferred $\sigma 1$ orientations at sites located within anticlinal axes are inconsistent with the regional 065° orientation, and show more northerly orientations (~030° to 045°). If the geometry of the structures is dictated by 3D strain accommodation, slip perpendicular to anticlinal axes would be predicted. Instead, slip is oblique to structural trends and also oblique to the inferred regional stress direction. These observations can be explained by uniformly directed slip on oblique pre-existing structures resulting in material rotation within zones of oblique-slip. The consistency of regional $\sigma 1$ orientations, abrupt along-strike structural terminations, and documented local extension at structural terminations further support this hypothesis, which is a first-order constraint for current modeling using 3D move software.

Coalbed Natural Gas Resource Potential of the Wyodak-Anderson Coal Zone in the Powder River Basin

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The Powder River Basin in northeastern Wyoming and southeastern Montana is the second most prolific coalbed natural gas producing play area in the United States. In 2004, coalbed natural gas production from this basin totaled 339.6 Bcf from 13,880 wells. At the end of 2004, the cumulative coalbed natural gas production from this basin totaled 1.57 Tcf. Annual coalbed natural gas production from the Powder River Basin reached a plateau in 2003. In terms of future gas production capacity, the major play area in eastern Campbell County, Wyoming is becoming mature. Increasing coalbed natural gas production capacity in this play will require drilling in the deeper areas of the basin. A detailed geologic evaluation was made of the coalbed natural gas resource potential of the Wyodak-Anderson coal zone, which is the major target for coalbed natural gas exploitation in the Powder River Basin. The analysis covered areas where the overburden thickness was 150 ft or greater and the net coal thickness was 10 ft or greater. The analysis results indicate that the Wyodak-Anderson coal zone contains an estimated 19.8 Tcf of coalbed natural gas resources. The gas-in-place resource ranges from 0.5 Bcf to as much as 15 Bcf per square mile. Based on an 85 percent recovery factor, the potentially recoverable coalbed natural gas resource in the Wyodak-Anderson coal zone totals 16.8 Tcf. Roughly 68 percent of this resource is found at reservoir depths greater than 1,000 ft, which, to date, represents a relatively unexplored reservoir interval.

Gas Origin in Coals of the Blackhawk Formation, Castlegate Coalbed Methane Field, Utah

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Coals of the Blackhawk Formation locally contain a world class in-situ methane resource base that is estimated to exceed 30 billion standard cubic feet of gas per sq mile. Following recent coring of the primary coal groups at the Castlegate CBM field, detailed carbon isotopic investigations of desorbed gases with mixed composition (C1, C2, C3, CO_2) while strongly indicating a thermogenic origin, suggest that not all gas within the coal is internally sourced from humic kerogens. Rather, the isotopic signatures and gas composition indicate that the gas in place has a mixed origin from both internal and external sources, the later likely having being generated by type I & II kerogens from the underlying Mancos Shales, and adsorbed during uplift.

Detailed study of both subsurface and outcrop data, indicate that the migration pathway for secondary thermogenic enrichment is the likely combination of coal seam positioning relative to large progradational parasequences of the Spring Canyon, Aberdeen, Kenilworth and Sunnyside Members, and vertically connecting Laramide natural fracture networks. Collectively, the petroleum system of the Castlegate

CBM field demonstrates the role that can be played by basin centered source rocks in enriching low to medium ranked coal groups.

Case Study: Greater Wamsutter Field, Wyoming—Tight Gas Reservoir

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The development and exploitation of one of Wyoming's Cretaceous tight gas plays in complex marine, marginal-marine, and coastal plain reservoirs can be challenging. Indeed, there does seem to be gas nearly "everywhere." However, the presence of associated water production and reservoir complications make economically producible rates far from guaranteed. Some specific areas of the greater Wamsutter field have proven to be particularly challenging in this regard, and lessons learned from these "failures" can broaden the understanding of risks associated with tight gas development.

The Rasmussen area (northwest side of the "Greater Wamsutter" field) has experienced particularly disappointing results over an eighteen month stretch of drilling activity in 2003-4. The targeted perforated intervals underlie a thick and extensive upper Almond marine bar that is one of the few water-wet reservoirs in the upper Almond. The presence of this water zone, linked to the rest of the usually productive Almond sands, presumably by fractures, may be at least partially responsible for the poor performance. There may also be other reservoir-compromising issues at play. The southeast side of Wamsutter is also seeing a similar relationship between an extensive, water-wet, shoreface sand and underlying reservoirs. In both areas, it is suspected that these extensive sands are plumbed to the surface, explaining their high water saturations.

A New Energy System for the Intermountain West – Built on Domestic Primary Resources and Negative Carbon Emissions

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Global energy security, anthropogenic climate change, and high energy prices combine to harness market forces and ingenuity like never before to design a fundamentally different energy supply and distribution system in our nation. The Intermountain West and adjacent Great Plains could play a leadership role in this new system because of an abundance of coal and biomass for gasification, combined with a large number of oil and gas fields ready for enhanced recovery and storage of CO_2.

Such a new system could be built around coal gasification combined cycle power plants (CGCC plants), combined with gasification of biomass such as the high-yield prairie switchgrass. This system would produce methane for conventional power generation, as in today's pulverized coal plants and at a lower cost than current use of natural gas, and allow co-generation of hydrogen, biofuels, dimethyl ethylene or any other 'designer fuel' (polygeneration), plus CO_2. Separation of the CO_2 from other gases would occur at the pre-combustion stage, making the task more efficient and much cheaper than current attempts at post-combustion separation of CO_2 from power plant flue gas.

The associated production of moderately priced CO_2 would act as a stimulus for expansion of CO_2 enhanced oil recovery (and gas recovery?); an industry that currently is supply-limited in the Rocky Mountains region. Also, widespread EOR would provide an enormous sink for anthropogenic CO_2. Some of this gas was obtained through biomass, which extracted the gas from the atmosphere during its growth cycle, hence providing an overall negative CO_2 budget for the integrated power and fuel generating system. Finally, all primary energy sources for such a system would be domestic, a blend of fossil and renewable, and in enormous supply throughout the region.

Late Cretaceous Subsidence in Wyoming

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The Farallon plate convergence with the western margin of North America during the late Cretaceous directly controlled rates and patterns of subsidence across the Rocky Mountains and Great Plains, through three linked mechanisms: 1) dynamic subsidence related to mantle convection above the subsiding slab – this subsidence mechanism operated on a wavelength of a few 1000s of miles and was in-phase along strike across most region, 2) flexural subsidence in the retroarc foreland basin landward of the Sevier orogenic belt – operating on a wavelength of less than 200 miles and probably asynchronous along strike, 3) dynamic subsidence or uplift related to plate convergence rate and subduction angle – in control of the temporal distribution of basement involved (Laramie) tectonism.

Quantitative modeling of subsidence induced by Sevier-belt flexure allows this component to be subtracted from the total subsidence across the region. One such detailed separation exercise has been performed across southern Wyoming, demonstrating that the Sevier-belt flexure influenced only the western parts of the Greater Green River basin, and that late Cretaceous subsidence from there eastward to Iowa was dominantly a product of dynamic subsidence. 3D modeling of the flexural forebulge in response to Sevier and Wind River thrusting demonstrates that this tectonic feature migrated southeastward in response to shortening on the Wyoming-Idaho salient of the Sevier thrust and the Wind River thrust, but rarely extended much farther east than the (tectonically younger) Rock Springs uplift.

This quantitative subsidence reconstruction reveals that most of the late Cretaceous Western Interior Seaway lay well to the east of the Sevier foreland basin; a finding that also is supported by mapping the forebulge as a zone of thin strata throughout the region.

Dating of Coal Bed Methane Reservoir and Surface Waters in the Raton Basin, Colorado and the Susitna Basin, Alaska

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Dating of coal bed methane (CBM) reservoir, surface, and near surface waters provides a test of the hydraulic connection between CBM reservoirs and surface hydrologic systems. Tritium and carbon 14 were used

to date surface and near surface waters. In both basins surface and near surface waters were less than 60 years old. The CBM waters were greater than 60 years old. Carbon 14 could not be used to date CBM waters since the coal itself may contaminate the sample. Chlorine 36 was used to date CBM waters. The age for the Raton Basin sample was at least 1,300,000 years old at a depth of 1,850 feet. The age for the Susitna Basin sample was at least 1,200,000 years old at a depth of 2,600 feet. No modern water was found in the CBM reservoir indicating no hydraulic connection to surface hydrologic systems. For reservoir engineers this conclusion indicates the CBM reservoir water volume is finite and the reservoir can be de-pressurized. For environmental managers this conclusion indicates no direct connection between CBM water production and surface water supplies.

Structural Analysis of a Larmide-Age, Basement-Involved, Foreland Fault Zone, Rawlins Uplift, South-Central Wyoming

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The western border of the Hanna Basin is defined by the Rawlins uplift, a north-northwest–south-southeast-trending, Laramide-age, basement-involved, faulted arch that separates the Hanna Basin on the east from the Great Divide Basin on the west. Detailed geologic mapping and serial cross-section construction, in conjunction with seismic-reflection data, indicate that the breaching faults along the western margin of the Rawlins uplift are not responsible for the net structural relief (~37,000 and ~27,000 vertical feet from the adjacent basins to the east and west, respectively) manifested in this Laramide structural feature. These exposed fault traces are interpreted to be high-angle (~70º) splays off of a shallowly dipping (<30º), blind, master fault zone within Archean granitic rocks of the Wyoming province. A low-dipping duplex structure within these Precambrian basement rocks is inferred to accommodate much of the fault displacement and consequently account for the structural relief that exists between the core of the uplift and the adjacent basins. Displacement along the breaching faults decreases from south to north. Within the map area, bedding attitudes along the west limb (forelimb) of the uplift range from ~30–90º with only local areas of overturned stratigraphic units. In contrast, the backlimb of the uplift dips shallowly (~10–15º) and homoclinally east-northeast into the Hanna Basin. Within the study area, deformation of the basement rock suggests a spectrum of mechanical behavior defined by the end-member processes of broad-scale basement folding and rotation of discrete, fault-bounded, composite blocks of basement and cover rocks.

Geomorphic Response of the Henrys Fork River to Pleistocene Volcanism, Mesa Falls Recreation Area, Caribou-Targhee National Forest, Idaho

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The Mesa Falls Recreation Area, located approximately 16 kilometers northeast of Ashton, Idaho, consists of Pleistocene volcanic units, including the Mesa Falls and Lava Creek Tuffs of the Yellowstone Group and the Gerrit Basalt. On occasion, the channel eroded by the Henrys Fork River has been partially to completely filled by basalt flows, producing multigenerational terraces as the Henrys Fork entrenched along the margins of the flows. Differences in erodibility of the tuffs and basalt seems to be the primary control on the present course of the Henrys Fork River and will likely continue to influence future migration. An inverted valley is developing as the Henrys Fork River erodes through the rhyolitic tuff at the edge of the basalt flows. Mapping and correlation of remnant basalt terraces helps to better understand the geomorphic response of river systems to concurrent volcanic activity.

Structure, Stratigraphy, And Hydrocarbon Potential of Butte Valley, White Pine County, Nevada

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Butte Valley in east-central Nevada occupies a tectonic transition zone between the weakly deformed Butte Mountains on the west and a strongly deformed core complex to the east. East-central Nevada underwent compressional tectonism in the Paleozoic and in the Mesozoic and extensional tectonism in the Cenozoic. Consequently it contains both compressional and extensional structures favoring the development of a variety of hydrocarbon traps. An essentially complete Paleozoic section (Permian strata are missing locally) exceeds 20,000 feet of predominantly carbonate strata. A relatively thin Tertiary cover (commonly only a few thousand feet thick) includes Oligocene volcanics and younger valley fill sediments. Source rocks include nearly 2000 feet of the Mississippian Chainman Shale, the primary petroleum source rock in east-central Nevada, the Pilot Shale and some organic-rich carbonates. Published geochemical data from well cuttings show the Chainman to be in the oil generating window. Multiple carbonate reservoirs with solution enhanced fracture porosity are the primary objectives. Paleozoic sandstones and Tertiary volcanics provide secondary objectives. Gravity data and detailed photogeologic mapping allows Butte Valley to be subdivided into 5 areas, each with unique geologic features. The northern areas appear less prospective than the southern areas. Residual gravity data suggest a variety of potential hydrocarbon traps, including reentrants and horsts. Photogeologic mapping suggest domal traps under the valley fill adjacent to the Butte Mountains and fault block traps adjacent to the Eagan Range. Geochemical data (primarily soil gas) indicate some of these traps may contain accumulations of hydrocarbons.

Cretaceous Lowstand Shorelines of the Middle Park Basin, Colorado

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The Upper Cretaceous (Campanian) Pierre Shale of the Middle Park Basin, Colorado, contains seven resistant benches, six of which are sand-rich. Detailed examination of the upper three benches (Hygiene, Carter, and Gunsight Pass) north of Kremmling suggests that these sand bodies formed as shorelines. The distal position of these shorelines, approximately 75 miles basinwards of highstand shorelines in the equivalent Iles and Williams Fork Formations to the west, suggests long-distance regression and deposition during relative lowstand of sea level.

The Carter Sandstone displays well-preserved sedimentary structures and serves as a type example for these lowstand shorelines. Exposure of the Carter varies in thickness from 10-30 meters. The base of the section is gradational and consists of interbedded sands, silts and shales. The upper section is sand-rich and dominated by stacked 10-75 cm trough cross-sets. Bioturbation is not abundant, but *Terebellina* and *Ophiomorpha* are present, indicating a shallow marine setting. The base of the upper section is erosional with approximately 5 meters of cut.

Paleocurrents within the Carter Sandstone suggest sand transport towards the southwest, in contrast to the overall east-west shoreline progradation within the Mesaverde Group. Distinct shingled bars above the erosional surface may represent deposition of shoreline sand bars into migrating tidal channels. These bars seem to be oriented NE-SW to E-W. The bars are 100-500 meters in width and vary in thickness from 2-10 meters. Longshore currents amplified by lowstand narrowing of the seaway could explain the anomalous direction of transport.

Same Day Downhole Critical Gas Content Without the Core

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[1]WellDog Inc, Laramie, WY

Gas desorption methods to analyze coal gas content require expensive sample retrieval methods and extended desorption and analysis times. WellDog has adapted its new downhole Raman spectrometer to measuring gas content in coalbed wells without sampling and in a matter of hours.

This technology, which has been successfully calibrated in three independent laboratories using state-of-the art Boyle's Law isotherm apparatus, accurately measures gas content in wells containing one or more coal seams, in-situ.

This presentation will show the methods behind the analysis, share laboratory calibration and field case study results. It will also review how same-day analysis of gas content is leading to new, more efficient development methods for clients.

Same Day Downhole Gas Content Analysis with Raman Spectroscopy

Pope, John Michael[1]
[1]WellDog Inc, Laramie, WY

Gas desorption methods to analyze coal gas content require expensive core retrieval methods and extended desorption and analysis time. These methods have inherent problems and errors associated with the retrieval process and testing in a laboratory environment. WellDog has adapted its new downhole Raman spectrometer to measuring gas content in coalbed wells without core sample retrieval, and in a matter of hours. This technology, which has been successfully calibrated in three independent laboratories using state-of-art Boyle's Law isotherm apparatus, accurately measures gas content in wells containing one or more coals seams, in situ. This presentation will show the methods behind the analysis and share laboratory calibration and field case study results. It will also review how same-day analysis of gas content is leading to new, more efficient coalbed natural gas development methods for our customers.

Overview of Oil and Gas Permitting – Issues Faced by the Bureau of Land Management in Wyoming

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Wyoming has become the focus intense drilling activity in recent years, and much of that drilling activity has been on lands managed by the Bureau of Land Management (BLM). As drilling activity has increased, there have been increasing demands on the bureau in terms of processing drilling permits, impact analysis, and mandated planning. This presentation will review a number of issues: the status of drilling permits, latest statistics, backlogs, BLM staffing levels, budgets, and improving efficiency in the permitting process. Other issues that impact the permitting process include appeals, protests, and other challenges. In addition, this presentation will also review the status of Resource Management Plans in several field offices in Wyoming and how the BLM planning process affects oil and gas leasing and operations.

A New Technology for 3-D Seismic Exploration and Development of Fractured Tight Gas Reservoirs

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A 3D seismic exploration method for fractured tight gas reservoirs is developed in a study conducted for the U.S. Department of Energy. The interpretation methodology is based on three principal reservoir attributes, fracture density, clay volume, and gas content.

Seismic lineament analysis is used to map lineaments through the reservoir zone using horizon slices and time slices. We interpret that in a probabilistic sense where lineaments swarm and cluster together is where reservoir fractures are most likely to be found. Leads identified using lineament density are further screened using rock typing to identify reservoir that is more likely to fracture. A collocated cokriged clay volume map using near trace seismic amplitude (an AVO attribute) is used to identify reservoir having low clay that is interpreted to be more brittle and more prone to fracturing. Fractured reservoir and good reservoir rock do not necessarily make a drillable prospect, as reservoir fractures may provide a plumbing system to both water and gas. For prospect development a gas sensitive phase gradient AVO attribute is used to further screen the leads to insure that gas is present.

In a gas field previously plagued with poor drilling results in the San Juan Basin of New Mexico, four new wells were spotted using the methodology and recently drilled. The wells have estimated best of 12-months production indicators of 2106, 1652, 941, and 227 MCFGPD.

Almond Reservoir Stratigraphy and Its Impact on Well Density Rule Changes in the Greater Wamsutter Development Area

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The Greater Wamsutter Development Area (GWDA) includes the Red Desert and Washakie Basins within the Greater Green River Basin, southwest Wyoming. GWDA tight gas fields have produced 2 TCF since the 1970's, mainly from the Late Cretaceous Almond Formation. Initial development was on 640-acre spacing, one well per governmental section. Additional increased density wells were drilled in measured stages, typical of gas developments in the continental United States. By 2002, a limited number of 80-acre density wells were being approved by the Wyoming Oil and Gas Conservation Commission. Concurrently, a number 80-acre pilot wells were being drilled within various Federal Exploratory Units.

From many perspectives it made sense to address 80-acre infill development on a more systematic basis, given the GWDA's the existing level of development and the immense area of 2500 square miles. In 2003, BP initiated a consortium with the five GWDA operators then actively pursuing 80-acre development, to collectively pursue the rule change. Reservoir stratigraphy of the Almond provided the foundation for these regulatory changes. Specifically, the cases for higher well density was made on the basis of significant variability of both thickness and lateral continuity of reservoirs in the Upper, Middle, and Lower Almond coastal plain, shoreline, and tidal sandstones. This was then compared to a modern-day analog. Historical production data was shown to be consistent with such a stratigraphic interpretation. Regulatory changes required to accommodate 80-acre development with flexible well placement were approved in 2004 and 2005.

Source-rock Analysis of the Lower Member of the Lewis Shale, Washakie Basin, Wyoming

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Turbidite sandstones within the Lewis Shale (upper Cretaceous) comprise an emerging tight-gas resource in the eastern Green River Basin, Wyoming. The purpose of this research was to provide a Lewis Shale source-rock characterization. This study helped to clarify the relationship between the potential source-rocks and the gas-oil production and rock properties from the lower 600 ft (183 m) of the Lewis Shale. A total of 145 representative shale samples from nine cores were collected from 411 ft (125 m) of core; 3-ft (1-m) composite samples were analyzed to determine source-rock richness, kerogen type and thermal maturity. Rock-Eval pyrolysis and total organic carbon (TOC) data interpretations show that many of the samples have good to very good (1.0 – 5.5 wt.%) organic carbon contents. The samples are thermally mature and the depth of burial is between the beginning and peak of the "oil window". Hydrogen index (HI) and oxygen index (OI) data were plotted on a modified van Krevelen plot to determine kerogen type. The plot indicates that the organic matter is Type II and III kerogen and is likely to generate gas and minor oil. A relationship between TOC and wireline gamma ray log response was observed, which suggests that high gamma ray response in the formations corresponds to intervals with high TOC values. TOC data and normalized gamma ray values were plotted to determine the nature of the dependency between these parameters. A good correlation factor (76%) was found, indicating that TOC and gamma ray responses are correlated.

The Waltman Shale Total Petroleum System: Does it have a favorable future?

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The 2005 USGS assessment of undiscovered petroleum resources in the Wind River Basin, Wyoming, includes an evaluation of Paleogene rocks in the Waltman Shale Total Petroleum System (TPS). Source rocks in this TPS are organic-rich lacustrine shales that charged conventional accumulations in stratigraphic or structural/stratigraphic traps within the Shotgun Member of the Fort Union Formation. To date, more than 2.5 million barrels of oil and 6 billion cubic feet of associated gas have been produced from this petroleum system in the Fuller Reservoir, Haybarn, and Greater Madden fields.

Previous studies indicate that the Waltman Shale Member of the Fort Union Formation contains a mix of Type-II and Type-III organic matter; total organic carbon averages about 2.7 weight percent. Waltman oil is high gravity (>40˚API) with a high paraffin content; associated gas is isotopically lighter than gas produced from Upper Cretaceous and Tertiary reservoirs underlying the Waltman Shale Member. Thermal maturity of the Waltman in the deep Wind River Basin generally ranges from 0.75–0.80 percent Ro, and approaches 1.10 percent Ro in areas west of the Madden anticline.

Sandstone and conglomerate deposited in fluvial, shoreface, and deltaic systems prograding from western and southern margins of Lake Waltman, and fan-delta complexes present along the northern lake-basin margin are potential reservoirs for additional Waltman petroleum accumulations. Future exploration might target areas where these contiguous depositional systems are interbedded with thermally mature Waltman source rocks, and areas where faults or fractures provide pathways for petroleum migration to shallow reservoirs from mature source rocks at depth.

Acquisition and Analysis of Multicomponent Seismic Data, Anadarko Basin, Oklahoma, U.S.A

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Multicomponent three-dimensional seismic data were acquired in the Anadarko Basin, USA. Acquisition involved simultaneously recording a co-located spread of individual multicomponent digital sensors with conventional arrays of single-component vertical geophones. Conventional P-wave data and compressional-to-shear converted-wave data were recorded from reflectors exceeding 13500 feet in depth. Differing P-wave and converted-wave reflectivity suggests that additional information can be extracted from the combined interpretation of both modes of wave propagation.

Interpretation of multicomponent data holds great promise for the exploration and development of oil & gas. Shear wave propagation is sensitive only to rigidity and density, while compressional wave propagation is sensitive to rigidity, density and compressibility. Interpreting both P-wave and S-wave data offers the ability to discriminate lithology, porosity, fractures and possibly fluid content.

Integration with well control using both P-wave and converted-wave data shows good correlation to natural gas production from the Springer Formation at an approximate depth of 11000 feet. We observe changes in both reflectivities that differentiate between commercial and non-commercial gas wells. The multicomponent data are integrated with the well control at 14 well locations penetrating the Springer. Given the actual cumulative gas production at each well, the Hampson-Russell EMERGE algorithm used the multicomponent seismic data to predict the gas production. Predicted gas production using both compressional P-wave and shear converted-wave data is more accurate than using the P-wave data only.

Improved Imaging of the Darby Thrust Fault using Multi-Component Seismic Receivers

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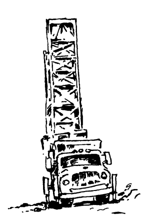
Seismic imaging in rough terrain where Paleozoic rocks are thrusted to the surface over Cretaceous sediments, can be a challenge using conventional methods. Advances in acquisition technology include multi-component (3C) receivers. Conventional single- component (1C) systems consist of coiled geophones which record only the vertical component of the seismic wavefield whereas new 3C digital sensors utilize Micro-Electro-Mechanical Systems accelerometers to record all three components of the full wavefield. To evaluate the applicability of such new 3C sensors in rough terrain we conducted a test over the Darby thrust fault in southwest Wyoming. Over the thrust, near the center of the line, the elevation varied 200m vertically over a horizontal distance of 400m. The source was 5kg Pentolite at 18m hole depth, with 50m shot interval. The wavefield was recorded by both 12-element linear and 36-element areal geophone group arrays at 50m interval as well as by 3C sensors at 25m interval. The processing sequence included tomographic refraction statics, coherent and random noise attenuation, surface consistent deconvolution, two iterations of velocity analysis and residual statics, and pre-stack migration. We applied polarization filters to the 3C data to separate signal and noise. No such polarization filtering is possible with any 1C data. All types of receivers provided good data away from the more complex, thrusted area. However, the 3C sensors provided much better resolution and imaging of the complex structure of the Darby thrust. We thank Marvin Johnson and Vinny Buffenmeyer of ExxonMobil for initiating, funding, designing, and supervising the data acquisition.



Syntectonic and Release Fracturing in Doubly-Plunging, Basement-Involved Anticlines, Northern Rocky Mountains: Results of Integrated Surface and Subsurface Analyses

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Five hypotheses can explain joint and fault genesis in crests of doubly-plunging basement-involved anticlines: 1) pre-orogenic fractures due to prior compression; 2) syntectonic fracturing by folding and faulting processes; 3) hydrofracturing due to pore fluid pressure; 4) release fractures due to uplift and erosion; and 5) post-orogenic tectonic rebound resolving residual elastic strain. Each mechanism predicts different fracture systems which may influence subsurface reservoir heterogeneity.

This research tests fracture hypotheses by integrating surface data from Elk Basin, Wyoming with subsurface geometries from Teapot Dome, Wyoming revealed by 3D seismic data. Observations at Elk Basin include: 1) two dominant joint systems are orthogonal and strike ~N60E and ~N30W, perpendicular and parallel to the fold hinge, respectively; 2) N60E joints strike parallel to normal faults and shear bands with vertical acute bisectors, all of which are independent of cliff face and slope direction; and 3) N30W joint density is inversely proportional to distance from cliff faces. Subsurface geometries of Teapot Dome indicate similar axis-perpendicular faults dominating the fold hinge, with normal separations defining a NE-SW-striking graben. These faults do not extend into basement, suggesting formation due to axis-parallel curvature. Preliminary conclusions for these structures indicate two stages of fracturing in basement-involved, doubly plunging anticlinal structures: 1) syntectonic fracturing related to folding locally dominated by stretching of the anticlinal axis; and 2) post-orogenic release fractures due to rebound from a combination of uplift/erosion and residual strain.

Detached Silt-rich Lowstand Shoreface Deposits of the Western Interior Seaway: Known and Prospective ‘Shale’ Gas Reservoirs

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Within the thick Mancos Shale (Upper Cretaceous) succession of the southern Western Interior Seaway silt- and fine sand-rich intervals possess characteristics of detached lowstand deltaic and shoreface deposits. The overall sedimentologic and stratigraphic features of these deposits are remarkably consistent: (1) relatively low-energy deposits situated 30-60 miles basinward of coeval wave-dominated highstand shorelines, (2) planar and ripple laminated, coarsening-upward silt/sand successions usually encased in organic-rich shale and mudstone, (3) sedimentologic and trace/body fossil evidence for partial deposition under comparatively shallow marine to rare subaerial conditions, (4) very low matrix porosity and permeability (less than 6% porosity; microdarcy or nanodarcy permeabilities), but considerably greater than encasing shale and mudstone, (5) relatively brittle successions due to the higher silt/sand content, prone to natural fracturing and receptive to fracture stimulation, and (6) low average TOC (about 1%)

and abundance of terrigenous plant debris. These silt/sand-rich low-TOC strata are partly self-sourcing in the manner of normal gas shales, and partly charged externally in the manner of tight sandstone reservoirs. Within the San Juan Basin of New Mexico, the Lewis Shale is already a proven gas reservoir containing total gas-in place in the 1,500 ft thick interval on the order of 125 MMscf/acre or 80 Bscf/mi2. Analogous basinward silt/sand-rich successions in Utah are the Prairie Canyon and Juana Lopez Members of the Mancos Shale; numerous examples occur in other Rocky Mountain states. Where sufficiently buried to generate and/or retain natural gas, all analogues are likely 'shale' gas reservoirs of great resource importance.

Shale Gas Reservoirs of Utah

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Organic-rich shales are found throughout Utah, several of which are possible candidates for future shale gas production. The criteria for assessing the natural gas potential of these shale units included (1) probable gas content as estimated from kerogen/bitumen content, level of organic maturity and petrophysical properties; (2) thickness and lateral extent of the shale under conditions for gas generation/retention; and (3) suitability for successful fracture stimulation. The open lacustrine black shale facies of the Green River Formation (Eocene) possesses good potential for large gas yields where in the gas generative window beneath the Uinta basin, but resource development may be difficult and expensive. Shallow microbial gas from this black shale is known, but commercialization in significant quantities is unlikely. The Prairie Canyon (Mancos B) and Juana Lopez Members of the Mancos Shale (Upper Cretaceous), neither a conventional black shale, are excellent candidates for developing large volumes of add-on gas in the southern Uinta basin. The lithologically similar and slightly older Tropic Shale (Turonian) may locally produce significant quantities of add-on gas in association with future deep CBM development in southern Utah. The Mowry Shale (Lower Cretaceous) has excellent potential as a shale gas reservoir, but future exploitation will be restricted to just limited areas north of the Uinta Mountains. The Manning Canyon Shale (Mississippian-Pennsylvanian) and Delle Phosphatic Shale Member (Mississippian) are organic-rich and widespread through western Utah, but due to a variety of inherent problems these deposits are likely to be exploited for gas only in very restricted areas and quantities.

Geochemical Exploration Surveys in the Rockies: Strategies for Success

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Geochemical exploration for petroleum is the search for surface or near-surface occurrences of hydrocarbons and their alteration products. Geochemical and microbiological surveys document that hydrocarbon microseepage from oil and gas accumulations is common and widespread, is chiefly vertical (with obvious exceptions in certain geologic settings), and is dynamic (responds quickly to changes in reservoir conditions).

Geochemical exploration techniques can be direct or indirect, and measurements can be instantaneous or integrative. Direct techniques analyze small quantities of hydrocarbons that occur in the pore space of soil, are adsorbed onto clay minerals, or are incorporated in soil cements. Indirect methods detect seepage-induced changes to soil, sediment, or vegetation. Bacteria and other microbes play a profound role in the oxidation of migrating hydrocarbons, and are directly or indirectly responsible for many of the suface manifestations of petroleum seepage.

Onshore hydrocarbon microseepage surveys require careful planning and implementation. Microseepage data are inherently noisy data and require adequate sample density to distinguish between anomalous and background areas. The sampling pattern and sample number must reflect survey objectives, expected size and shape of the target, expected variation in surface measurements, and probable signal-to-noise ratio Defining background values adequately is an essential part of anomaly recognition and delineation. Undersampling and/or the use of improper sampling techniques is a major cause of ambiguity and leads to interpretation failures. This presentation will be illustrated with examples from Wyoming, Colorado, and Utah.

Geochemical exploration data have found their greatest value when integrated with subsurface geological and geophysical data. Properly applied, the combination of surface and subsurface exploration methods leads to better prospect evaluation and risk assessment.

Coalbed Methane in the San Juan and Powder River Basins: Differences and Similarities

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The San Juan Basin of Colorado and New Mexico and the Powder River Basin of Wyoming and Montana are major coalbed methane plays in the United States. Cretaceous coal seams in the San Juan Basin contain an estimated 84 Tcf of gas, whereas Tertiary coals of the Powder River Basin contain approximately 39 Tcf. Ultimate recoveries for these two basins are more than 10 and 24 Tcf, respectively, with the higher recovery efficiency in the Powder River due to unusually high permeability.

San Juan and Powder River Basin coals differ significantly in terms of coal rank and gas content values, yet both basins are economic successes. Understanding the synergistic interplay among key factors affecting coalbed methane producibility explains why basins with markedly different hydrogeologic characteristics are economically viable. Most of the coal beds in the San Juan Basin have reached the thermal maturity level required to generate significant amounts of thermogenic gases. Secondary biogenic gas generation associated with meteoric recharge after basin uplift and cooling has locally increased gas contents (150 to 600+ scf/ton). All key hydrogeologic factors come together synergistically to make the San Juan Basin the most prolific coalbed methane basin in the world. The Powder River coal beds coal beds are low rank (subbituminous) and gas contents are generally less than 30 scf/ton; only secondary biogenic and, possibly, early thermogenic gases are present. However, the basin is economic for coalbed methane because of the presence of highly permeable, shallow, thick, coal beds and lower drilling costs.

Surface Geochemical Tools for Hydrocarbon Exploration and Structural Mapping in the Great Basin of Nevada and Utah

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The innovative application of both organic and inorganic surface geochemical tools has facilitated exploration and structural mapping in the Great Basin. More specifically, the interrelationship of C1-C8 hydrocarbons in soils is used to predict "oil-prone" areas and the major and trace element concentrations in soils map the spatial distribution of underlying hydrothermal dolomites and faults. Soils over normal faults that bound oils typically have higher concentrations of heavy hydrocarbons (>C5), carbon dioxide, carbon monoxide, uranium, halogens, alkaline earth metals (i.e. Mg, Ca, and Sr) and lower concentrations of transition metals (e.g. Fe, Mn, Ni, etc.). Soils directly over the oil fields have unique multivariate hydrocarbon ratios that distinguish them from barren unproductive areas. These hydrocarbon ratios are used to predict oil potential in unknown areas. Case studies from several areas of the Great Basin in Nevada and western Utah compiled over a seven-year period will be presented to emphasize the potential of these tools for both oil exploration and structural mapping in this extensional geological environment.

The Upper Birdbear Formation (Nisku) of Western North Dakota: Another Emerging Williston Basin Horizontal Play

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A two to three foot thick dolomite reservoir in the upper portion of the Devonian Birdbear Formation has become a target for horizontal development drilling in Golden Valley and Billings Counties, North Dakota. This reservoir may cover over three hundred square miles and may yield reserves in excess of 45 million barrels of oil. Oil is trapped by anhydrite occlusion of porosity updip along the subcrop. Downdip of the oil column, the reservoir is wet except on some closures. Reservoir depths vary from 10,400 to 10,800 feet.

The upper Birdbear Formation consists of three upward-shallowing carbonate-cycles; the middle cycle is the drilling target. The middle cycle starts with a one foot thick black shale which is overlain by a one to three foot thick very-porous dolomite that is capped by two to three feet of tight anhydrite and dolomite. The dolomite has porosities in excess of 25% and oil saturations greater than 75%. Log analysis is confounded by thin bed effects on tool resolution in the varied lithologies. The reservoir is relatively continuous, but varies in thickness and quality.

Horizontal wells have initial rates that exceed 500 barrels of oil per day and may ultimately produce in excess of 300 thousand barrels of oil per well. Vertical wells were discouraging because of low initial production rates and small ultimate reserves. Current practice is to drill two opposing laterals from a single vertical borehole, spaced upon 1280 acres, at a cost of about $2 million.

Exploration History and Petroleum Geology of the Central Utah Thrust Belt

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Central Utah has seen cycles of petroleum exploration for the past 50 years because explorationists viewed the geology as a natural extension of successful plays elsewhere in Utah. Early efforts tested anticlines identified from surface mapping and seismic reflection data. During the late 1970s to early 1980s companies drilled thrust belt-style structures in the wake of the Pineview discovery in northern Utah. Although these efforts failed, companies confirmed the area was similar in structural style, reservoir types, and timing to the productive thrust belt to the north. The lack of a Cretaceous source seemingly was to blame for these failures; however, oil and gas shows were common in Mississippian, Permian, Triassic, and Jurassic rocks. The recent discovery of Covenant field by Wolverine Oil and Gas Company in the Jurassic Navajo Sandstone along the Sanpete-Sevier Valley antiform has rekindled thoughts of exploration in central Utah; however, this time exploration is based on local success.

Exploration in the central Utah thrust belt will focus on a thrust belt of Paleozoic-cored blind thrusts east of the exposed Charleston-Nebo and Pavant thrusts, which formed during the Cretaceous and early Tertiary Sevier orogeny. Likely targets include anticlines associated with thrust imbricates (or imbricate fans) and possible antiformal stacks of horses forming duplex structures in the Navajo and other reservoirs such as the Permian Park City-Kaibab Formations, Triassic Moenkopi Formation, and Jurassic Twin Creek Limestone. These features are obscured by complex surface geology, but may be closely related to regional antiforms in the Jurassic Arapien Shale.

A Structural Model of Jonah and South Pinedale Fields, Wyoming

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Despite different structural styles, the South Pinedale anticline and the Jonah gas field share the same timing of deformation. These structures are part of a detached, transpressional system formed in the Green River Basin (GRB) in response to NE-SW compression where the structural strike of the Wind River Range (WRR) changes from a NW-SE orientation to an approximate E-W trend.

The youngest evidence of the deformation is post-early Middle Eocene age, as indicated by faulting and warping of the shallow Wasatch Formation strata seen on seismic and the involvement of outcrops of the Wasatch and basal Green River formations. Coeval folds, thrusts, strike-slip faults, and oblique-normal faults were formed during this time, consistent with transpressional shortening in the GRB, and located above basal detachments fed by slip on basement faults of the WRR. Structural accommodation in Jonah field is controlled by left-lateral (synthetic) displacement on the South Jonah Fault zone (SJF of Hanson and Others, 2004), and associated right-lateral (antithetic) offset along NE-SW-trending faults that terminate downward below the

Ericson Fm. Enhanced reserves and rate of recovery on the east flanks of these antithetic, strike-slip faults indicate that production has been influenced by structural development.

Of particular note, is documentation of one mile of left-lateral slip on the SJF by: 1) reconstruction of northeastward-thickening regional isopachs, 2) reconstruction of piercing points defined by depositional patterns on an RMS amplitude attribute map and 3) offset of fold axes.

Structural Geology and Petroleum Systems of the Newly Discovered Covenant Field Area, Central Utah Thrust Belt

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Structural analysis, seismic interpretation, and organic geochemistry are all part of the petroleum systems synthesis that contributed to the Covenant Field discovery in Central Utah by Wolverine Gas and Oil Corporation. The Kings Meadow Ranch 17-1 penetrates a highly porous and permeable reservoir in the Jurassic Navajo sandstone which contains a 450 foot oil column. The field is located along a frontal structural uplift to the Central Utah thrust belt, where Late Cretaceous-Early Tertiary compressional deformation resulted in the development of thrust faults and associated hanging wall anticlines buttressed against the ancestral Ephraim extensional fault. The traps are charged from Mississippian foreland basin sediments to the west of the discovery, and hydrocarbon generation was driven by the initial sedimentary loading (oil generation) followed by tectonic loading (gas generation) associated with the evolving thrust belt. Evaporite deposition in the overlying Arapien formation provides a highly effective seal for the accumulations. Jurassic extensional faults may be critical in defining the location of thrust faults and antiformal stacks, which in turn define structural traps along this newly discovered onshore hydrocarbon province.

A Strategy to Reduce Risk in Searching for Gas Accumulations in Tight-Gas Sand

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In Rock Mountain Laramide Basins, many commercial gas accumulations occurring in the lower Tertiary/Mesozoic strategraphic sections are characterized by the following critical attributes:

1) anomalously pressured (both over- and underpressured), but can appear to be normally pressured;
2) occur beneath a regional velocity inversion surface;
3) compartmentalized and gas-charged;
4) located at intersections of reservoirs facies and gas-charged domains;
5) productive intersections are typically enhanced by a combination of structural, stratigraphic, and diagenetic elements;
6) the reservoir facies commonly are considered tight-gas sands;
7) no apparent meteoric water connection.

In order to maximize risk reduction in searching for these types of gas accumulations, the highest priority tasks are: 1) evaluating gas distribution in the fluid system; and, 2) determining the distribution of reservoir facies in the rock system. Our work in the past 10+ years has documented that the distribution of gas-charged domains can be effectively delineated by detailed sonic/seismic velocity evaluations. More recent work suggests that a variety of seismic attributes can be used to adequately define the distribution of reservoir facies. Thus, at present, there are tools to determine the spatial intersections of gas-charged domains and reservoir facies. This approach has been tested in six known gas-producing fields in the Wind River Basin. The results have been positive; and, in each field, the productive intersections of reservoir facies and gas-charged domains were accurately located.

Deep Gas Potential in Wyoming

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The National Energy Technology Laboratory estimates that there is a huge natural gas resource (>1000 tef) in Wyoming at depths greater than 15,000 ft depth. The key question is with current technology how much of this gas can be converted to energy reserves? The answer to this question is predicated on the accomplishment of 2 tasks. The first task is to detect gas distribution at depths greater than 15, 000 ft. The second task is to delineate commercial porosity/permeability at depths greater than 15,000 ft.

The first task can be accomplished by combining detailed velocity analyses with hydrocarbon maturation modeling. The second task can be accomplished by diagenetic modeling based on burial history, thermal evolution, and reaction kinetics.

Work on deep gas accumulations has shown that significant commercial porosity/permeability can occur at depths >20,000 ft. These deep high porosity/permeability domains result from the convergence of critical determinative elements.

The convergence of these critical elements can be modeled with the following reactions:

1) $CaSO_4 + CH_4 \rightarrow CaCO_3 + H_2S + H_2O$
$CaSO_4 + 3H_2S + CO_2 \rightarrow CaCO_3 + 4S^o + 3H_2O$

2) $Fe^{+3} + 0.5S^o + 1.5H_2S \rightarrow FeS_2 + 3H^+$
$Fe^{+2} + S^o + H_2S \rightarrow FeS_2 + 2H^+$

3) $CaCO_3 + 2H^+ \rightarrow Ca^{+2} + H_2O + CO_2$

The Mesozoic and Paleozoic stratigraphic sections, plus structural settings in Wyoming provide an ideal framework for the convergence of the geologic elements required for deep commercial gas accumulations.

Low Flood Rate Residual Saturations in Carbonate Rocks

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Carbonate reservoirs commonly exhibit great morphological complexity from pore to field scale. Interpretation of laboratory waterfloods for estimations of reserves and production strategies is often problematic because of unexpected sensitivity of oil recovery to flood rate at rates comparable to field values. The circumstances under which rate sensitivity occurs need to be further identified. In this work, three outcrop limestones with distinct differences in petrophysical properties were selected for investigation of the combined effect of pore structure and wettability on residual saturations. Petrophysical observations and measurements include optical and UV reflectance, thin section analysis, SEM, BET surface areas, cation exchange capacities, mercury injection capillary pressures, and water adsorption isotherms. The rocks were tested at very strongly water-wet (VSWW) conditions followed by preparation of mixed-wet (MXW) states. A comparative study of waterflood recovery was made for mixed wetting states with crude oil (MXW) or mineral oil as the test oil. Mineral oil was tested after either direct displacement of crude oil (MWX-F-DD) or first displacing crude with an intermediate solvent to avoid surface precipitation of asphaltenes (MXW-F). Flooding rates ranged from below to well above field rates. Sensitivity of residual oil saturation to flood rate ranged from slight for a homogeneous grainstone to distinctly significant for both a heterogeneous grainstone and a boundstone of very high porosity and permeability. The mechanism by which incremental oil is produced with increase in flood rate was investigated by using a tracer test technique to track the production of connate water.

Late Paleozoic Tectonism in the Central Great Basin Requires Revision of Stratigraphic and Structural Interpretations

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Recent studies in central Nevada show that stratigraphy of Mississippian through Permian rocks is largely driven by late Paleozoic tectonism. At least eight tectonostratigraphic boundaries have been identified. Most coincide with lithostratigraphic boundaries and many are associated with regional unconformities. Some are dramatic, preserving folding and faulting beneath the unconformity. Others are subtle disconformities. All are regionally important markers recording tectonic activity after the Antler orogeny and before the Sonoma orogeny.

A dramatic example is an upper Carboniferous unconformity at Carlin, NV, where gently deformed Missourian strata overlie highly folded and faulted Desmoinesian rocks. Map-scale folds and thrust faults with 100s of meters of stratigraphic throw record regional NW-SE contraction, with vergence primarily to the NW. Biostratigraphy constrains this deformation to early Missourian. The angular unconformity can be mapped regionally, and correlated with equivalent disconformities and facies changes related to uplift.

Using these tectonostratigraphic boundaries, we are reassessing the upper Paleozoic stratigraphy of the Great Basin. This genetic approach has both simplified correlation, and created some problems. Some units, especially coarse clastic strata related to uplift and reworking, take on new significance as indicators of tectonic activity. Other units need to be redefined because they contain regional unconformities. In addition, the recognition of upper Paleozoic deformation, some of which coincides with Ancestral Rockies deformation to the east, requires revision of tectonic models for western North America.

Regional Subthrust Fracture Arrays in Outcrop: Guide to Attributes of Tight Gas Sandstones

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Cambrian Eriboll Group Sandstones beneath the Moine Thrust Zone (MTZ), NW Scotland, contain arrays of opening-mode fractures that range in size from microfractures having lengths of microns to macrofractures having trace lengths of more than 100 m. Diagenetic, size scaling, and intensity patterns of these fractures match those found in horizontal cores of tight gas sandstones in the Rocky Mountain region and elsewhere. In this field example, fractures can be divided into at least three regionally extensive sets based on crosscutting relations. From oldest to youngest these sets strike N to NNE, WNW, and WNW to NE. Microfractures and associated macroscopic opening-mode fractures are sealed or locally lined with authigenic quartz that crosscutting relations and crack-seal texture suggests is in part contemporaneous with pore-filling quartz cement in the rock mass. Cumulative apertures along a line of observation record strains of as much as 4.9 percent for the oldest, N to NNE-striking fracture sets. Based on increased abundance near the fault zone, some WNW-striking fractures may be associated with WNW emplacement of the MTZ. Some WNW- to ENE-striking fractures, which are youngest based on crosscutting relations, are locally bridged by quartz containing crack-seal texture but otherwise retain porosity in fractures having apertures >0.1 mm. Residual porosity in fractures implies that after they formed fractures cooled to less than a quartz accumulation threshold of about 80ºC. These field observations show that porous opening-mode fracture arrays can persist for great lengths of time in the subsurface. Cement precipitation is the primary cause of fracture porosity destruction. Large fractures have great lateral persistence and large apertures, showing that they likely have significant impact on fluid producibility. Fluid-flow modeling shows that such fracture arrays could have effects comparable to those observed in the Rockies.

Sandstone Lithofacies Within the Icebox Fm (Ordovician), Williston Basin, North Dakota and Montana

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The Icebox Fm (Ordovician) is the middle of three formations within the Winnipeg Group. It is a regionally extensive shale, typically dark green to black, and reaches a maximum thickness in excess of 200 ft (61 m)in North Dakota. The Icebox contains significant organic carbon and is considered to be an important source rock for the Lower Paleozoic in the Williston Basin.

Wireline log gamma-ray traces were digitized and converted to a uniform scale and format. Traceable coarser facies and discontinuities were established by correlating the digitized wireline log curves across

North Dakota and Montana. Forty traceable sandy lithofacies were identified. Five have regional extent, and a maximum thickness of at least 20 ft (6 m); one is 72 ft (22 m) at its thickest. Five additional sand bodies each extend across several tens of miles, and have maximum thicknesses ranging from 10 ft (3 m) to 23 ft (7 m).

In North Dakota, six cores have been taken through the sandy intervals, all in the lower part of the Icebox Fm. Based on the existing cores, it appears that the sandy lithofacies represent intervals of bioturbated sandstone and siltstone within the shalier Icebox Fm.

The Icebox Fm in the Williston Basin was deposited in the epeiric sea distal to shore, but not in deep water The sandy bodies represent environments that were somewhat shallower, perhaps even marginal marine. Many of the less extensive bodies appear to represent deposition on top of local topographic or structural features.

Active Biogenesis of Methane in Ft. Union Coals of Wyoming's Powder River Basin

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The Powder River Basin, Tertiary Ft. Union coalbed methane gas is a classic example of gas formed through secondary biogenesis. In order to better scientifically understand the evolution of this process, numerous Powder River Basin coal cores were carefully obtained to limit exposure to air during the course of their extraction and examination. These coal samples were examined for their indigenous anaerobic microbial populations and their ability to support methanogenesis. Rates of active methanogenesis were detected in nearly all of the tested coals. Conditions were identified that stimulated or inhibited this microbial methane production. Extrapolated results suggest that a huge potential bioreservoir for natural gas production exists in the Powder River Basin coals.

Using the EORI Scoping Tool to Assess the Potential Suitability of a Wyoming Oil Field for Enhanced Oil Recovery

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Scoping tools such as that developed by Kinder Morgan for CO_2 floods provide operators with a useful intermediate-level assessment of the potential suitability of an oil field for enhanced oil recovery—intermediate between applying simple screening "rules of thumb" and going to the expense of applying a full-fledged field simulation model. An important limitation of these scoping tools, however, is that they are based on experience with EOR at a given field. If the particular field being assessed is not sufficiently "similar" to the field used to build the scoping tool, then the tool's predictions will be unreliable. An analysis of CO_2-flood experience at fields in Wyoming suggest that these fields in fact differ substantially from the fields (located in West Texas and Oklahoma) underlying the KM tool, which points to the need for a Wyoming-specific scoping tool. The tool currently under development at the University of Wyoming's Enhanced Oil Recovery Institute will address this need. Other limitations of the KM tool are its exclusive focus on a single EOR method and its assumption of a fixed price path when assessing the economic viability of EOR. In contrast, the EORI tool will allow operators to assess non- CO_2 methods as well, and to explicitly account for price uncertainty when performing the economic analysis.

Facies and Architecture of the Chimney Rock Member, Rock Springs Formation (Mesaverde Group), Southwest Wyoming

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An outcrop study, a core well drilled through the outcrop, and well logs along the northern margin of the Rock Springs Uplift of southwestern Wyoming document the facies, architecture, and key stratigraphic surfaces within the Chimney Rock Member (basal clastic wedge) of the Rock Springs Formation. The Chimney Rock Member is comprised of three facies associations. The lowermost sections of the Chimney Rock Member are representative of deposition within a wave-dominated shoreface, with the overlying medial parts of the section consisting of incised-valley deposits (wave-dominated estuarine and tidal deposits). These two sections of the Chimney Rock Member are separated by a significant erosion surface, a sequence boundary that marks a relative fall in sea-level. The upper reaches of the Chimney Rock Member consist of a mixed strandplain and coastal plain succession. A throughgoing flooding surface and transgressive lag (likely TSE) separates the incised valley fill from the overlying mixed strandplain and coastal plain deposits.

Application of Fractured Reservoir Simulation Concepts-Teapot Dome

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Around the oil patch there has been much grumbling about the complications, inefficiencies and disappointments that seem to multiply in fractured reservoirs. Oil fields start out fine, but "fall apart" as they exhibit their fractured nature.

An overview of the evolving methods applied to fractured reservoir characterization is presented to set the stage for three topics; 1) Flow characterization concepts formed during a six-year DOE-funded effort to develop and apply new fractured reservoir characterization tools, 2) Current simulation approaches for fractured reservoirs, and 3) Example applications at the Teapot Dome Field, Wyoming.

The concepts applied to Teapot Dome Field will be visually emphasized using outcrop photos, physical fracture models, simulated fracture networks, and fluid flow models. Improved assessment of the relative degree of reservoir fracturing improves reservoir modeling and justifies data collection for improved simulation constraint.

Fractured reservoir modeling is improved by a parallel effort in reservoir storage and reservoir flow characterization (beyond classification by permeability and porosity levels). Flow characterization recognizes the hierarchy of flow across scales; reservoir, area, pattern, well, and completion. Assessment of reservoir oil mobility and our ability to impact it is improving as the range is expanded for scale-dependant relative permeability, capillary number, and matrix to fracture fluid transfer.

A fractured reservoir is broken, but it may still perform in a predictable and profitable manner.

Fractured Sandstone Outcrops in Northeast Mexico: Guides to the Attributes of Fractures in Tight Gas Sandstones

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Opening-mode fractures are potential fluid conduits in deeply buried sedimentary rocks yet critical attributes of fracture patterns, such as spacing, size distribution, and porosity are challenging to measure in the subsurface and are rarely clearly preserved in outcrop. An exception is the fracture patterns in Triassic La Boca Formation, exposed near Galeana, northeastern Mexico. Diagenetic features and intensity patterns of these fractures is identical to those found in many tight gas sandstones in the Rocky Mountain region. At least three fracture sets are well exposed in road cuts and canyons. Synkinematic quartz bridges preserved in these fractures match those found in fractures sampled in deep cores in the Gulf of Mexico Basin, demonstrating that these fractures are representative of fluid conduits in deeply buried sedimentary rocks. We measured clustered fracture spacing, size distributions having power-law size scaling, and highly heterogeneous porosity preservation. We used SEM-based cathodoluminescence to analyze fracture opening histories. Quartz cement along fracture walls is pervasive as both euhedral crystals and bridging cement. Imaging reveals crack-seal textures in quartz bridges. Such texture demonstrates incremental fracture opening of fracture sets in the outcrop. Heterogeneous sealing of some parts of the fracture system occurs by late (postkinematic) carbonate and iron oxide cements. In some outcrops, postkinematic calcite in the rock matrix corresponds to calcite-sealed fractures. Elsewhere postkinematic calcite in the rock matrix is rare or absent, and this corresponds to open, quartz-lined fractures.

Reservoir Modeling and Simulation for CO_2 Flooding: the Effect of Reservoir Heterogeneity on Simulation Forecasts

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[1]University of Wyoming, Laramie, WY

CO_2 flooding has proven to be a viable enhanced oil recovery process in many geographic locations. The Tensleep Sandstone in the Bighorn and Wind River basins, Wyoming, contains the largest oil reserves in the state. Because of reservoir heterogeneity, as little as 10-15% of discovered oil in the Tensleep Formation is recoverable by current primary and secondary techniques. Many of the Tensleep reservoirs are potential candidates for CO_2 flooding. To evaluate the effect of reservoir and fluid properties on CO_2 flooding performance, a sensitivity study of reservoir modeling was performed on a five-spot injection-production pattern. A variety of reservoir configurations were simulated based on the large range of API gravities of the oils produced from the Tensleep Formation as well as its spatial variation and anisotropy of relative permeability published from previous studies. CO_2 flooding is generally not sensitive to lithology but is sensitive to reservoir characteristics. For the Tensleep reservoirs, the actual performance of CO_2 flooding will largely be controlled by the local compartmentalization. The ECLIPSE compositional simulator was used for this study.

Regulatory Framework for 80-acre Development Created in the Greater Wamsutter Development Area

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The Greater Wamsutter Development Area, located in portions of Carbon and Sweetwater Counties, Wyoming was initially developed in the 1970’s and 1980’s on 640-acre spacing. Beginning in the early 1990’s and continuing through the late 1990’s infill drilling had resulted in a significant portion of the area being developed on a 160-acre well density, with wells located in the approximate center of governmental quarter sections. In 2002 the first 80-acre density wells were drilled. As industry moved towards possible 80-acre development it became apparent that previous development was inconsistent with a traditional 80-acre pattern.

BP recognized that there was an opportunity to work with industry and the agencies to develop a comprehensive regulatory framework, as opposed to the historical development by exception. Project objectives included recognition that 80-acre development be optional, that the regulatory changes be equitable, did not disrupt existing equity or contractual relationships and honored the technical data. To this end BP invited the four companies that were actively pursuing 80-acre development to participate in a cooperative effort to identify and pursue the appropriate regulatory changes. In addition, actions were undertaken to secure input from other industry members as well as the regulatory agencies. The final recommendations of the working group addressed 80-acre development in existing spaced lands, unspaced lands and within Federal Exploratory Units. As of February 2005, the regulatory changes have been approved by the WOGCC and the area is now positioned to accommodate 80-acre development.

Characterization of Tensleep Sandstone Reservoirs

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Three important components must be considered in the characterization of the Tensleep Sandstone reservoirs: (1) depositional boundaries, (2) petrophysical facies, and (3) permeability directionality. Depositional boundaries, resulting from grain size variation and diagenetic modification, potentially act as flow barriers and buffers in reservoir simulation. Regularly-oriented, high-ordered, depositional boundaries can also cause permeability directionality. Petrophysical facies are characterized by depositional texture, diagenetic fingerprints, porosity, and permeability. Six petrophysical facies are suggested in the Tensleep reservoir sandstones, including (1) uncemented, dolomite-sand-free, dune sandstone facies, (2) cemented, dolomite-sand-free, dune sandstone facies, (3) cemented, dolomite-sand-rich, dune sandstone facies, (4) uncemented, dolomite-sand-rich, interdune sandstone facies, (5) cemented, dolomite-sand-rich, interdune sandstone facies, and (6) cemented, dolomite-sand-rich sand sheet facies. Permeability directionality is very clear on the core-plug scale. In checked Tensleep sandstone cores, the maximum permeabilities range from 1.2 to 2.2 times the 90-degree permeabilities, and from 2.2 to 14.2 times the vertical permeabilities; and the 90-degree permeabilities range from 2.3 to 10.6 times the vertical permeabilities. Precise characterization of the depositional boundaries, petrophysical facies, and permeability directionality is critical for the geological modeling of Tensleep sandstone reservoirs.

Stratigraphy, sedimentology and petrophysics of the Tensleep Sandstone at Teapot Dome and in Outcrop

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Two outcrops at the Middle Fork of the Powder River and at Fremont Canyon are chosen as analogs for the Tensleep Sandstone at Teapot Dome. Outcrop data include measured sections, high quality photomosaics, gamma ray logs, thin sections, drill plugs and GPS. Subsurface data include cores, well logs, thin sections and porosity and permeability data.

The Tensleep Sandstone contains multiple sequence boundaries in response to frequent and high-amplitude sea level changes. Evidence for sequence boundaries include paleosols, conglomerates, carbonate breccia, root traces and karst, all developed on top of marine carbonates. Generally, from bottom to top, the Tensleep Sandstone changes from dominantly marine, with abundant crinoids and corals, thick tabular carbonate beds and thin sandstone layers, to dominantly continental, with thick eolian cross-bedded sandstones, scarce fossils, and thin and discontinuous carbonates. The basal onlap of the Tensleep Sandstone from north to south reflects the presence of the Pathfinder Uplift to the south during Tensleep deposition.

The Tensleep Sandstone at Teapot Dome and in the upper part of outcrops consists of eolian deposits, interbedded with sabkha and shallow marine dolomites. Dolomites, even with lots of vugs, fractures and stylolites, do not form permeable reservoir because of extremely low permeability, and dead oil exists in many vugs and fractures. Sandstones are reservoir rocks, and six sandstone petrophysical facies are described according to deposition and diagenesis. Porosity and permeability are controlled by the petrophysical facies, and reservoir compartments are separated by sequence boundaries and bounding surfaces internal to the eolian deposits.

Paleotectonic Control and its Relationship to Wyodak Coal Deposition and Production in the Powder River Basin, Wyoming

Zilinski, Robert E.[1], Donna M. Goldstein[1]
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Recent mapping of the Wyodak coal in the eastern portion of the Powder River Basin suggests a relationship exists between present-day structure, paleostructure, and depositional controls of the Wyodak coal. Mapped structural lineaments define depositional limits and net coal thickness, which are two key factors controlling gas production.

Slack (1981) mapped several northeast-southwest trending lineaments. These lineaments have been active and controlling facies deposition from at least the Paleozoic Era through the Cretaceous Period. Slack's work showed that stratigraphically trapped hydrocarbons in the Permian Minnelusa Formation and the Cretaceous Dakota, Muddy, Turner, Shannon and Sussex Formations were governed by the relative up-down position of these lineaments.

New work suggests that paleostructure also controlled the depositional environment within the Paleocene Wyodak coal member of the Fort Union Formation. Structural mapping of the Wyodak coal member, along with dip-angle algorithms, show that the eastern part of the Powder River Basin is segmented into several structural blocks. These blocks are controlled by northeast-southwest trending faults. Faults identified in this study have a similar location and orientation to those described by Slack. These structural trends correlate well with abrupt changes in coal thickness shown by the Wyodak Coal isopach map, areas where the coal splits and possibly the location of fluvial channels (no coal zones). Gas production from the Wyodak coal is controlled by the segmentation and coal thickness variability of the Wyodak coal swamp relative to these paleo-lineaments.

Pinedale Field: Geophysical Applications in a Major Tight Gas Field, Green River Basin, Wyoming, USA

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The Pinedale Field, one of the largest gas fields in the Greater Green River Basin of southwest Wyoming, is being developed along with Jonah Field, as a significant over-pressured, tight-gas sandstone reservoir in the Upper Cretaceous Lance Pool. The Pinedale Anticline has a 5000 foot thick gross hydrocarbon bearing section comprised of fluvial and flood-plain facies rocks deposited in a broad alluvial valley nearly coincident with the anticline structure. Since the acquisition of the initial 3D seismic survey in the Mesa area in late 1999, Ultra has used 3D seismic data to guide drilling location selection, define drilling hazards, and extend Lance Pool production laterally and vertically on the anticline. Specialized seismic processing has facilitated ability to identify stratigraphic sweet spots in the field, over-pressure, and handle azimuthal anisotropy. Efforts to better understand the inter-well geometry of sand bodies and the behavior of the massive hydraulic frac'ing techniques used to enhance production has lead to the use of cross well tomography and micro-seismic frac monitoring to map the orientation and fabric between wells. The interpretation and understanding from these applications has enhanced the reservoir model and validated much of the geological and geophysical understanding of the Pinedale Field.

Presenter Cross-Reference and Email Address

Presenter Name	Email Address	Session Title	Day	Time or Booth
Abplanalp, Jason M.	abpl0311@uidaho.edu	Geologic Developments in the Rockies 2	Mon AM	8:30
Anderson, Paul B.	paul@pbageo.com	General Poster Session 1	Sun PM	1
Arbogast, Jeff S.	arbogast@pstware.com	Advanced Technologies for Exploration and Production 1	Sun AM	9:10
Ashley, Mark	mashley@ypcnm.com	Gas Supply: The Role of CBM 1	Sun PM	1:40
Bakun, Frederick E.	bakunfe@bp.com	Reservoir Models and Case Studies	Mon PM	2:40
Bartov, Yuval	ybartov@mines.edu	General Poster Session 1	Sun PM	2
Batt, Liselle	batt6553@uidaho.edu	Geologic Developments in the Rockies 2	Mon AM	8:10
Blackstone, Michael J.	greywacke42@yahoo.com	Gas Supply: The Role of CBM 1	Sun PM	2:00
Blakeney DeJarnett, Beverly	bev.dejarnett@beg.utexas.edu	General Poster Session 2	Mon AM	6
Bortz, Louis C.	loub@advantage-resources.com	Exploration Challenges of the Great Basin and Utah Hingeline	Mon PM	4:00
Boyles, J. Michael	jmboyles@uwyo.edu	Reservoir Models and Case Studies	Mon PM	2:20
Carvajal, Cristian R.	ccarvajal@mail.utexas.edu	Geologic Developments in the Rockies 2	Mon AM	9:50
Chamness, James S.	jschamness@nrginc.com	Gas Supply: The Role of CBM 1	Sun PM	4:00
Chidsey, Thomas C.	tomchidsey@utah.gov	General Poster Session 1	Sun PM	3
Cramer, David D.	dcramer@bjservices.com	Advanced Technologies for Exploration and Production 1	Sun AM	9:50
Cumella, Stephen P.	scumella@billbarrettcorp.com	Gas Supply: Geologic Aspects	Mon PM	2:20
Curtis, J. B.	jbcurtis@mines.edu	Gas Supply: Economic and Technologic Aspects	Sun AM	10:10
De Keyser, Thomas L.	dekeyser@wispertel.net	General Poster Session 1	Sun PM	6
Dechesne, Marieke	marieke.dechesne@dmns.org	Geologic Developments in the Rockies 2	Mon AM	9:10
Duncan, K. A.	kaduncan@utep.edu	General Poster Session 3	Mon PM	6
Duncan, Peter M.	pduncan@microseismicinc.com	Advanced Technologies for Exploration and Production 2	Mon AM	9:10
Ellis, Margaret S.	mellis@usgs.gov	Gas Supply: The Role of CBM 1	Sun PM	3:20
Erslev, Eric	erslev@cnr.colostate.edu	Geologic Developments in the Rockies 1	Sun PM	3:00
Fassett, James E.	jimgeology@qwest.net	Gas Supply: Geologic Aspects	Mon PM	2:00
Ford, G.L.	grace_ford@eogresources.com	General Poster Session 2	Mon AM	5
Gilbertson, Nathaniel J.	ngilbert@mines.edu	General Poster Session 3	Mon PM	4
Hansen, Christine	c.hansen@iogcc.state.ok.us	Gas Supply: Economic and Technologic Aspects	Sun AM	9:10
Hansen, Jerome B.	jha2570@comcast.net	Exploration Challenges of the Great Basin and Utah Hingeline	Mon PM	4:20
Harris, Nicholas B.	nbharris@mines.edu	Gas Supply: Geologic Aspects	Mon PM	2:40
Hassler, Bryan G.	uep1@comcast.net	Gas Supply: Economic and Technologic Aspects	Sun AM	9:50
Hausel, W. Dan	dhausel@uwyo.edu	Geologic Developments in the Rockies 1	Sun PM	3:40
Hayes, Tom	tom.hayes@gastechnology.org	Gas Supply: The Role of CBM 2	Mon AM	10:30
Hendricks, Mike	OILMLH@aol.com	Geologic Developments in the Rockies 2	Mon AM	10:10
Hoffman, Kent	kent_hoffman@blm.gov	Environmental Forum	Sat PM	1:35
Hollis, Stephen H.	sh81450@aol.com	Gas Supply: The Role of CBM 2	Mon AM	11:10
Inks, Tanya L.	tlinks@is-interpret.com	Advanced Technologies for Exploration and Production 2	Mon AM	8:30
Isaacson, Peter E.	isaacson@uidaho.edu	Geologic Developments in the Rockies 2	Mon AM	11:10
Johnson, Ronald C.	rcjohnson@usgs.gov	Resource Plays	Sun PM	3:00
Johnson, Ronald C.	rcjohnson@usgs.gov	General Poster Session 2	Mon AM	3
Jones, Nick R.	njones@uwyo.edu	Gas Supply: Economic and Technologic Aspects	Sun AM	8:30
Keach, R. William	bkeach@lgc.com	Advanced Technologies for Exploration and Production 2	Mon AM	10:30
Kennedy, John	koil@vcn.com	Environmental Forum	Sat PM	2:35
Kieschnick, John	jkieschnick@terratek.com	Resource Plays	Sun PM	1:40
Klein, Donald A.	dakspk@lamar.colostate.edu	Gas Supply: The Role of CBM 1	Sun PM	3:00
Klusman, Ronald W.	rklusman@mines.edu	Advanced Technologies for Exploration and Production 1	Sun AM	10:30
Kneller, Stephen	skneller@ultrapetroleum.com	Gas Supply: Economic and Technologic Aspects	Sun AM	11:10
Lamarre, Robert A.	lamarregeo@qwest.net	Gas Supply: The Role of CBM 2	Mon AM	8:50
Larson, Richard A.	rich.larson@vermejo.com	Gas Supply: The Role of CBM 2	Mon AM	8:30
LeFever, Julie A.	jlefever@state.nd.us	Resource Plays	Sun PM	3:20
Lillis, Paul G.	plillis@usgs.gov	General Poster Session 2	Mon AM	2
Lisle, George L.	george@gravitydata.com	Exploration Challenges of the Great Basin and Utah Hingeline	Mon PM	3:20
Luo, Hongjun	hongjun@uwyo.edu	Geologic Developments in the Rockies 1	Sun PM	2:00
Mattocks, Bruce	bruce_mattocks@veritasdgc.com	Advanced Technologies for Exploration and Production 2	Mon AM	8:50
Mavor, Matt	mavor@xmission.com	Gas Supply: The Role of CBM 2	Mon AM	8:10
McBride, John H.	jhm@geology.byu.edu	Advanced Technologies for Exploration and Production 2	Mon AM	11:10
McClain, Tony	MCCLAIT1@bp.com	Gas Supply: Geologic Aspects	Mon PM	3:40
McCutcheon, Timothy J.	mec@coffey.com	General Poster Session 2	Mon AM	4
McDermott, Robert W.	bmcdermott@ultrapetroleum.com	Reservoir Models and Case Studies	Mon PM	3:40
Millard, Mark	mil02013@byui.edu	Geologic Developments in the Rockies 1	Sun PM	3:20
Miller, Brad	brad_miller@anadarko.com	Gas Supply: The Role of CBM 2	Mon AM	10:50
Milliken, Mark D.	mark.milliken@rmotc.doe.gov	General Poster Session 3	Mon PM	3
Morel, John	JMorel@davcos.com	Resource Plays	Sun PM	2:20

continued

Presenter Cross-Reference and Email Address *continued*

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Morgan, Craig D.	craigmorgan@utah.gov	Reservoir Models and Case Studies	Mon PM	1:40
Morris, Thomas H.	tom_morris@byu.edu	Reservoir Models and Case Studies	Mon PM	2:00
Morrow, Norman R.	morrownr@uwyo.edu	Advanced Technologies for Exploration and Production 1	Sun AM	8:10
Moseley, Claire	Claire@publiclandsadvocacy.org	Environmental Forum	Sat PM	1:05
Mullen, Christopher E.	cmullen@woldoil.com	Reservoir Models and Case Studies	Mon PM	4:00
Neely, Thomas G.	thomas.neely@colostate.edu	Geologic Developments in the Rockies 1	Sun PM	2:40
Nelson, Charles R.	charles.nelson2@att.net	Gas Supply: The Role of CBM 1	Sun PM	3:40
Niemann, Martin	niemann@uvic.ca	Gas Supply: Geologic Aspects	Mon PM	4:20
Nummedal, Dag	nummedal@mines.edu	Geologic Developments in the Rockies 1	Sun PM	1:40
Nummedal, Dag	nummedal@mines.edu	Gas Supply: Economic and Technologic Aspects	Sun AM	8:10
Oldaker, Paul R.	PAUL_OLDAKER@Compuserve.com	Gas Supply: The Role of CBM 2	Mon AM	9:10
Otteman, Aaron S.	aaron.otteman@exxonmobil.com	Geologic Developments in the Rockies 1	Sun PM	2:20
Painter, Clayton S.	pai02001@byui.edu	General Poster Session 1	Sun PM	5
Pekarek, Alfred H.	apekarek@fallsnet.com	General Poster Session 1	Sun PM	4
Petter, Andrew L.	petter@mail.utexas.edu	Geologic Developments in the Rockies 2	Mon AM	10:50
Pinnell, Michael L.	mlpinnell@yahoo.com	Exploration Challenges of the Great Basin and Utah Hingeline	Mon PM	2:00
Pope, John	jpope@welldog.biz	Gas Supply: The Role of CBM 2	Mon AM	9:50
Pope, John Michael	jpope@welldog.com	General Poster Session 3	Mon PM	5
Rabinoff, Alan	Alan_Rabinoff@blm.gov	Environmental Forum	Sat PM	2:05
Reeves, James J.	jreeves@geospectrum.com	Advanced Technologies for Exploration and Production 2	Mon AM	10:50
Riggert, Virginia L.	riggervl@bp.com	Gas Supply: Geologic Aspects	Mon PM	4:00
Rigoris, A.V.	arigoris@mines.edu	Gas Supply: Geologic Aspects	Mon PM	3:20
Roberts, Stephen B.	sroberts@usgs.gov	General Poster Session 2	Mon AM	1
Roche, Steven L.	steve_roche@veritasdgc.com	Advanced Technologies for Exploration and Production 2	Mon AM	10:10
Ronen, Shuki	shuki_ronen@veritasdgc.com	Advanced Technologies for Exploration and Production 2	Mon AM	8:10
Schamel, Steven	geox-slc@comcast.net	Resource Plays	Sun PM	2:00
Schamel, Steven	geox-slc@comcast.net	Resource Plays	Sun PM	2:40
Schumacher, Dietmar	deet@gmtgeochem.com	Advanced Technologies for Exploration and Production 1	Sun AM	8:30
Scott, Andrew R.	andrew@altuda.com	Gas Supply: The Role of CBM 2	Mon AM	10:10
Seneshen, David M.	dseneshen@directgeochemical.com	Exploration Challenges of the Great Basin and Utah Hingeline	Mon PM	3:40
Sperr, Jay T.	tsperr@billbarrettcorp.com	Resource Plays	Sun PM	3:40
Sprinkel, Douglas A.	douglassprinkel@utah.gov	Exploration Challenges of the Great Basin and Utah Hingeline	Mon PM	1:40
Stiteler, T. Chris	chris@tcstiteler.com	Reservoir Models and Case Studies	Mon PM	3:20
Strickland, Doug	dstrickland@wolvgas.com	Exploration Challenges of the Great Basin and Utah Hingeline	Mon PM	2:20
Surdam, Ronald C.	rsurdam@uwyo.edu	Gas Supply: Economic and Technologic Aspects	Sun AM	10:30
Surdam, Ronald C.	rsurdam@uwyo.edu	Gas Supply: Geologic Aspects	Mon PM	1:40
Trexler, James	trexler@mines.unr.edu	Exploration Challenges of the Great Basin and Utah Hingeline	Mon PM	2:40
Tushman, Kira	steve.laubach@beg.utexas.edu	General Poster Session 3	Mon PM	2
Ulishney, Aaron J.	ulishney_aaron@hotmail.com	Geologic Developments in the Rockies 2	Mon AM	8:50
van 't Veld, Klaas	klaas@uwyo.edu	Advanced Technologies for Exploration and Production 1	Sun AM	8:50
VanHolland, Adam R.	adam.vanholland@encana.com	Geologic Developments in the Rockies 2	Mon AM	10:30
Wadleigh, Eugene E.	gwadleigh@aol.com	Advanced Technologies for Exploration and Production 1	Sun AM	10:10
Ward, Meghan E.	steve.laubach@beg.utexas.edu	General Poster Session 3	Mon PM	1
Weber, Jeffrey	jweber@lucatechnologies.com	Gas Supply: The Role of CBM 1	Sun PM	2:40
Wo, Shaochang	swo@uwyo.edu	Advanced Technologies for Exploration and Production 1	Sun AM	10:50
Wood, C. Alan	woodca@bp.com	Gas Supply: Economic and Technologic Aspects	Sun AM	10:50
Yin, Peigui	rockpetr@uwyo.edu	Advanced Technologies for Exploration and Production 1	Sun AM	11:10
Zhang, Qingsheng	qzhang@mines.edu	Reservoir Models and Case Studies	Mon PM	4:20
Zilinski, Robert E.	rzilinsk@westerngas.com	Gas Supply: The Role of CBM 1	Sun PM	2:20
Zinke, Sally G.	szinke@ultrapetroleum.com	Advanced Technologies for Exploration and Production 2	Mon AM	9:50

Notes

Notes

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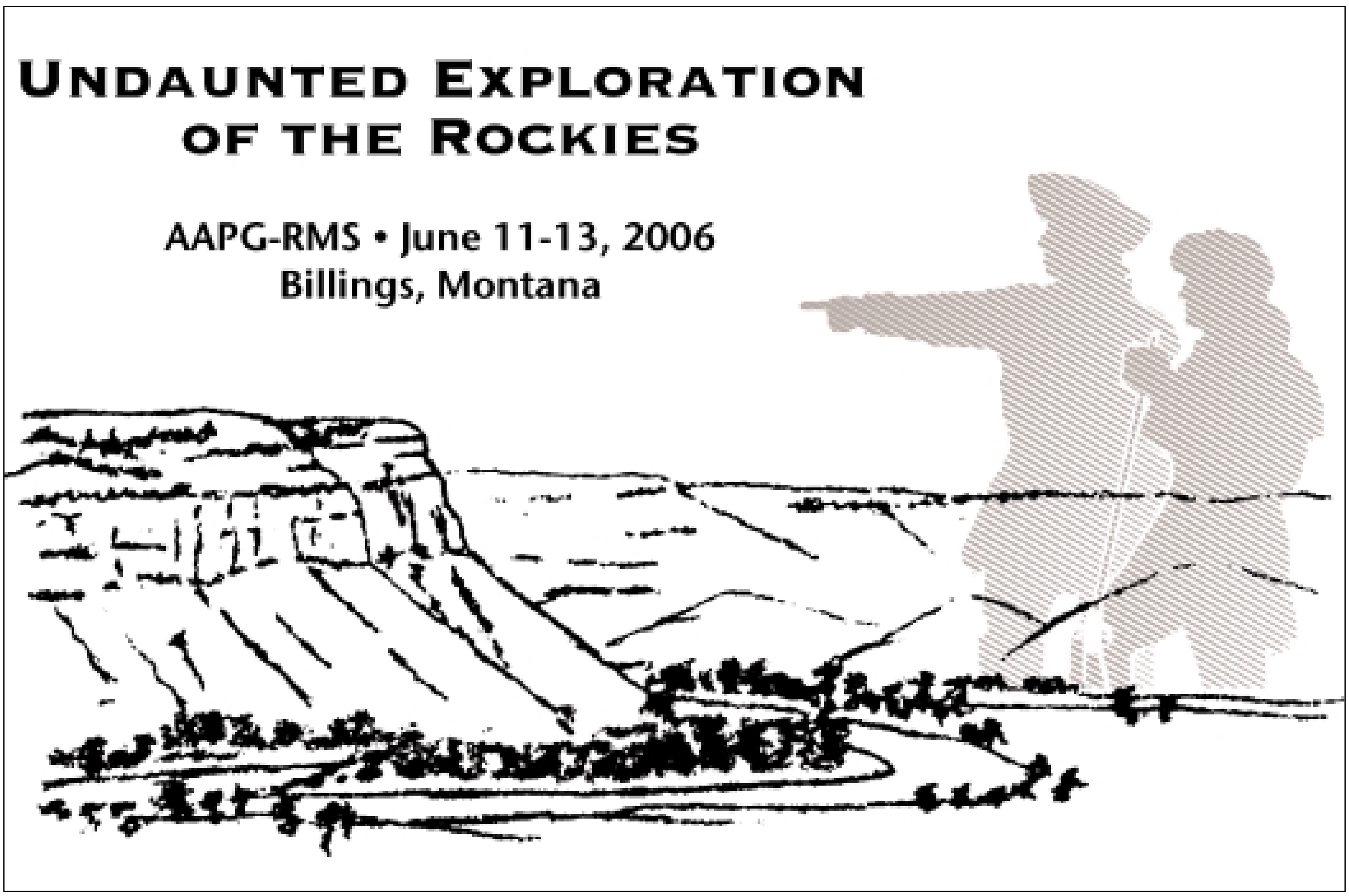
UNDAUNTED EXPLORATION
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