## AAPG Pacific Section Annual Meeting 2017

# Program and Abstracts

***Innovating the Future, Discovery to Recovery***

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS 1925 PACIFIC SECTION

2017 AAPG
Pacific Section Annual Meeting
21-24 May • Anchorage, Alaska
Innovating the Future: Discovery to Recovery

ALASKA GEOLOGICAL SOCIETY A G S

2017 AAPG
Pacific Section Annual Meeting
21-24 May • Anchorage, Alaska
Innovating the Future: Discovery to Recovery

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2017 AAPG
Pacific Section Annual Meeting
21-24 May • Anchorage, Alaska
Innovating the Future: Discovery to Recovery

# Contents

# Welcome!

We welcome you to the AAPG-Pacific Section Annual Meeting May 21-24, 2017 in Anchorage, Alaska!

It has been six years, since this event was last held in Anchorage in 2011. Oil prices and our industry are currently experiencing a significant downturn but nonetheless Alaska remains one of the most exciting and promising locales for geologic study and oil and gas exploration and development. Hence the theme for this year's PSAAPG conference: "*Innovating the Future, Discovery to Recovery*".

The PSAAPG 2017 conference has a technical session that includes 2 ½ days of talks and posters. Before and after the main conference you may choose to attend two core workshops, or one of the ever popular Alaska field trips. If you choose to attend one of the field trips you will be treated to Alaska geology up close with learning coordinated by knowledgeable trip leaders who are among the best in the field. Field trips are planned to the Brooks Range, the Matanuska Valley and the Kenai Peninsula. You may sign up for workshops and field trips when you register for the main conference.

Recognizing that these are challenging times in the oil and gas industry, we have tiered registration pricing to encourage all to attend. We have also secured great hotel rates for our members and there will be guest activities and discounts for those of you attending with a friend or spouse.

Anchorage days in May are long and the weather is more often than not beautiful. Out of town attendees and guests will be treated to Alaska at its finest. We encourage visitors, both first time and returning travelers to spend a few extra days in The Great Land and take in the sights and perhaps enjoy the wildlife.

We are honored to serve as general chairs for this event and look forward to seeing you in May!

Sincerely,

*Monte Mabry & Tiffany Carey*
2017 PSAAPG Meeting Co-Chairs

"Innovating the Future, Discovery to Recovery"

## Sunday, May 21, 2017

| | | | |
|---|---|---|---|
| Registration | 8:00 | 19:30 | 2nd Floor Break Area |
| Core Workshop #1 | 12:00 | 16:00 | Alaska Archives, 1300 W 56 Ave |
| Poster Session Preparation | 16:00 | 18:00 | Kuskokwim E&W |
| YP/Student Meet n'Greet | 17:00 | 18:00 | The Summit |
| Ice Breaker/Exhibits/ Posters | 18:00 | 20:00 | Atrium |

## Monday, May 22, 2017

| | | | |
|---|---|---|---|
| Speakers/Judges Breakfast | 7:00 | 7:45 | The Summit |
| Registration | 7:30 | 18:00 | 2nd Floor Break Area |
| Exhibits | 8:00 | 18:30 | Atrium |
| Technical Session: Frontier Exploration in the Arctic Offshore | 8:00 | 11:15 | Howard Rock BC |
| Poster Session | 8:00 | 12:00 | Kuskokwim E&W |
| All Convention Luncheon | 11:30 | 13:00 | Howard Rock A |
| Technical Session: Structure and Tectonics: New Perspectives and Interpretations | 13:15 | 16:30 | Howard Rock BC |
| Poster Session | 12:00 | 16:30 | Kuskokwim E&W |
| Mini-breaker | 17:00 | 18:30 | Atrium |

**Key:**

- Technical Sessions (Talks)
- Poster Session
- Food and Networking
- Short Courses

## Tuesday, May 23, 2017

| | | | |
|---|---|---|---|
| Speakers/Judges Breakfast | 7:00 | 7:45 | The Summit |
| Registration | 7:30 | 17:00 | 2nd Floor Break Area |
| Exhibits | 8:00 | 18:30 | Atrium |
| Technical Session: New Research on Alaska North Slope Source Rocks and Low Perm Reservoirs | 8:00 | 11:35 | Howard Rock B |
| Technical Session: Geophysics, Petrophysics, and Reservoir Description: From Basins to Pores | 8:00 | 10:55 | Howard Rock C |
| Poster Session | 8:00 | 12:00 | Kuskokwim E&W |
| Awards Luncheon | 11:45 | 13:30 | Howard Rock A |
| Technical Session: Developments in Onshore Alaska Exploration and Production | 13:45 | 17:00 | Howard Rock BC |
| Poster Session | 12:00 | 16:30 | Kuskokwim E&W |
| Student Q&A | 16:00 | 17:00 | 305 |
| Mini-breaker | 17:00 | 18:30 | Atrium |

## Wednesday, May 24, 2017

| | | | |
|---|---|---|---|
| Speakers/Judges Breakfast | 7:00 | 7:45 | The Summit |
| Registration | 7:30 | 9:00 | 2nd Floor Break Area |
| Exhibits | 8:00 | 14:00 | Atrium |
| PSAAPG and SEPM: Sequence Stratigraphy and Sedimentology: Fluvial to Deep-Water Reservoirs | 8:00 | 10:55 | Howard Rock BC |
| Poster Session | 8:00 | 12:00 | Kuskokwim E&W |
| Core Workshop #2 | 13:00 | 17:00 | Alaska GMC, 3651 Penland Parkway |
| GSA-AGS Spring Picnic | 17:00 | 20:30 | Abbott Loop Community Park, 8101 Elmore Road |

## My Plans:

### Sunday, May 21, 2017

### Monday, May 22, 2017

### Tuesday, May 23, 2017

### Wednesday, May 24, 2017

*Bright summer days bathe Anchorage and the surrounding Chugach Mountains in late May, giving plenty of light to explore the city and mountains. Photo by Frank Flavin*

Anchorage may be Alaska's largest city, but that doesn't mean the frontier is far off. Anchorage is a modern city surrounded by spectacular wilderness, filled with outdoor adventures and urban amenities. The city is home to comfortable hotels, but also as many as 1,500 moose. There are world-class dining options, but also hundreds of miles of trails, perfect for hiking, biking and wildlife viewing. The city sits next to one of the largest state parks in the nation, Chugach State Park, with 500,000 acres of wilderness. The closest trailheads are less than 20 minutes from downtown. Iconic national parks; Denali, Kenai Fjords, Wrangell-St. Elias, Lake Clark, and Katmai are all within easy reach of the city by road, rail, or air.

Itineraries read like a wish list for those with a love of the natural world. Moose browse through city parks, eagles soar over neighborhoods, beluga whales cruise coastal waters in search of salmon.

Some of Alaska's most easily accessible glaciers are near the city, offering everything from one-hour cruises to day-long trekking, rafting, or ice climbing excursions. Travelers can watch tidewater glaciers calve into Prince William Sound on a day cruise, kayak iceberg-dotted lakes or get a dose of winter fun midsummer with a glacier dog sledding trip.

Mountain peaks in six ranges are visible from Anchorage on clear days, including Denali, the tallest mountain in North America. Visitors who want a closer look at Denali's majestic peak can book flightseeing trips departing from Anchorage.

While many of the most breathtaking Alaska sights are in the wilderness, the city itself boasts treasures not found anywhere else. Explore the heritage of Alaska Native cultures at the Alaska Native Heritage Center. Through authentic song and dance and artisan demonstrations, visitors are immersed in the traditions and lifestyles of Alaska Native peoples through the centuries and into modern day. For even more on Alaska, the Anchorage Museum is home to a treasure trove of Alaska art, history and science, including 600 rare Alaska Native artifacts at the Smithsonian Arctic Studies Center, a planetarium and the interactive science exhibits.

Getting Around - Anchorage is the hub for road and rail travel in the state, and many of the region's most popular tours and trips can be tackled as day trips based from Anchorage. Anchorage's Lake Hood is the world's busiest floatplane base, and sightseeing flights depart regularly for Denali National Park, bear viewing, glacier exploration and more.

Temperatures - Sunny summer months soak in the mid 60s.

To discover more of what the city of Anchorage has to offer, visit www.Anchorage.net.

## Finding your way around

Walking is a fantastic way to see Anchorage. With the long hours of daylight, you will have to stay out past midnight to walk home in the dark. Anchorage streets downtown are numbered north to south as avenues, and lettered east to west, with A Street three blocks west of the Sheraton. The western edge of downtown is at L Street, while the main east-west drags are 4th, 5th, and 6th Avenues.

If walking is not an option, taxis are available from Checker Cab [(907) 276-1234], Anchorage Taxi [(907) 885-6793] and Alaska Yellow Dispatch [(907) 562-6805].

The Sheraton Hotel and Spa is located at 401 East 6th Ave, Anchorage, AK 99501. Downtown is about a six block walk to the west (away from the mountains).

If you'd like to get an overview of Anchorage from the seat of a trolley, Anchorage Trolley Tour (http://anchoragetrolley.com/) runs hour-long tours until 7:15pm in late May.

## Things to do in an hour after dinner

After walking the 6-10 blocks west to dinner in Downtown Anchorage, you might consider enjoying the long hours of daylight stretching past 10 pm. You could detour past one of the numerous souvenir shops on 4th and 5th Avenues between C and G Streets. Or, if you are feeling more energetic, walk north of town to Ship's Creek to watch the salmon fishermen if the tide is in. You could also pick up an ulu at the Ulu Factory (though they are widely available elsewhere). Do check closing times – even though the sun might be out at 10pm, the shops might be closed!

## What to see

If you have half a day our so to explore Anchorage, consider exploring the Anchorage Planet Walk (http://anchorageplanetwalk.org/). The scale of the planets and the distances between them was chosen so that a leisurely walking pace mimics the speed of light. The walk starts northeast of the Alaska Center for the Performing arts at the big yellow sun, and progresses along the Tony Knowles Coastal Trail to Pluto, in Kincaid Park (5 hours and 30 minutes from the Sun).

Also along the coastal trail is Earthquake Park. Earthquake Park gives visitors insight into one of the pivotal moments in Alaska history: the 9.2M 1964 Earthquake - the largest quake ever recorded in North America. Closer to the Sheraton is the 11 block long Delany Park Strip, a former firebreak and runway. There are numerous sports fields, memorials and gardens along the Strip to enjoy on a morning run or afternoon walk.

## Further Afield

If you are thinking of traveling further afield (beyond Anchorage City Limits), a rental car is recommended, though taxis will drop you off at many of the trailheads near the city.

North

To the north of Anchorage is the Matanuska Valley, home of monster Alaskan summer produce. The Eagle River Nature Center offers nature programs and hiking trails in magnificent mountain valley. Further north is Independence Mine State Park, site of an abandoned gold mine. Matanuska Glacier (location of Local Trip #2) lies east of Palmer, while Denali National Park is 7 hours north west.

East

The Chugach Mountains create more than a dramatic skyline for Anchorage. Combined, Chugach State Park and Chugach National Forest are home to some of the most accessible outdoor adventures in the state; some are just 20 minutes from downtown. The quintessential day hike from Anchorage is Flattop, offering routes for all abilities. Flattop Mountain Shuttle can provide transportation from downtown to the trailhead and back.

South

All routes to the south follow the Seward Highway, recognized as National Scenic Byway. Turnouts at Beluga Point, Windy Corner or Bird Point are perfect spots to view the Kenai and Chugach mountains and watch beluga whales, Dall sheep, the Turnagain bore tide..

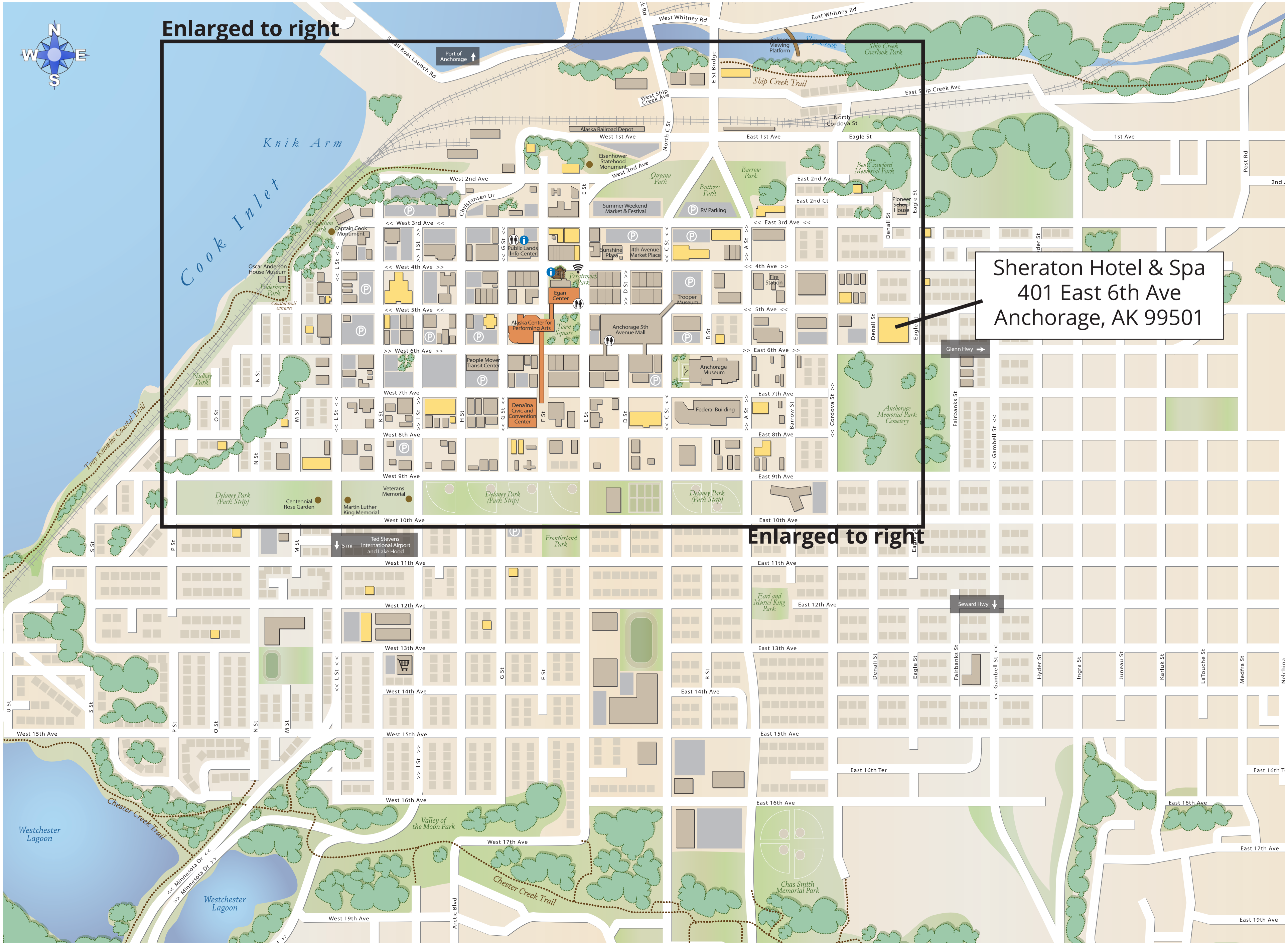
The highway also means plenty of access points into the mountains for hiking – McHugh Creek, Rainbow and Bird are favorites.

Past the trailheads lay the mountain town of Girdwood, Portage Glacier, the Alaska Wildlife Conservation Center, and fishing towns of Seward, Cooper Landing, Soldotna and Homer.

## Further Information

The Visit Anchorage webpage at http://www.anchorage.net/ has an extensive listing of other Things to Do in Anchorage.

# Anchorage City Maps




There are a multitude of restaurants serving everything from fresh Alaskan seafood and beer, to sushi, or fusion cuisine and wine, just blocks from the Sheraton Hotel and Spa. This is a short-listing of recommended after-conference venues, with ratings by Google.

Crush Wine Bistro & Cellar (6 blocks) 4.3/5
A huge variety of wines by the glass or bottle & shareable plates in an unpretentious atmosphere.
343 W 6th Ave, Anchorage, AK 99501

Sullivan's Steakhouse (6 blocks) 3.5/5
Steakhouse chain serving beef, seafood & cocktails in swanky surrounds & live music.
320 W 5th Ave #100, Anchorage, AK 99501

Ginger (7 blocks) 4.2/5
Stylish restaurant & lounge specializing in Pacific Rim cuisine, microbrews & cocktails.
425 W 5th Ave, Anchorage, AK 99501

Club Paris (7 Blocks) 4.2/5
Sizable cuts of aged beef & classic sides in a relaxed, family-owned institution.
417 W 5th Ave, Anchorage, AK 99501

Pangea Restaurant And Lounge (7 blocks) 4.6/5
Restaurant & lounge offering innovative world cuisine sing the freshest local ingredients available.
508 W 6th Ave, Anchorage, AK 99501

Humpy's Alaskan Alehouse (8 blocks) 3.9/5
Laid-back hangout serving seafood & pub grub, plus a huge beer selection.
610 W 6th Ave, Anchorage, AK 99501

Fat Ptarmigan (8 blocks) 4.2/5
Sleek bistro serving locally focused menu of gourmet wood-fired pizzas, craft beer & wine.
441 W 5th Ave #100, Anchorage, AK 99501

Bubbly Mermaid Oyster Bar (8 blocks) 4.6/5
Oyster bar and seafood restaurant
417 D St, Anchorage, AK 99501

Williwaw (8 blocks) 3.6/5
A multi-faceted gathering space, featuring fine American dining, craft cocktails & local brews and the finest rooftop in town.
609 F St, Anchorage, AK 99501

Uncle Joe's Pizzeria (10 blocks) 4.4/5
Made-to-order pies & ready-to-eat slices, plus gyros, salads & wings, with beer & wine.
428 G Street, Anchorage, AK 99501

Glacier Brewhouse (11 blocks) 4.2/5
Boisterous, wood-dominated dining room with local seafood, wood-grilled meats & house-brewed beer.
737 W 5th Ave. #110, Anchorage, AK 99501

49th State Brewing Co (12 blocks) 4.4/5
Brewpub offering award winning beer, fresh Alaskan foodstuffs, with a fantastic patio overlooking the Cook Inlet and Alaska Range.
717 W 3rd Ave, Anchorage, AK 99514
Open until 12:00 AM

The Crows Nest (14 blocks) 4.3/5
High-end restaurant offering French & New American cuisine, a huge wine list & scenic views of the Chugach and Alaska Ranges.
939 W 5th Ave, Anchorage, AK 99501

Anchorage has a very large and vibrant craft beer scene. Whether it's big and bold barley wines, west coast IPAs, sours, fine traditional, or experimental beers, you can find it in Anchorage.

Below is a list of local breweries, and brewpub-restaurants where you'll find tasty brews with an Alaskan flair. Check websites for hours of operation.

## Breweries:

Anchorage Brewing Co.
148 W. 94th Street, Anchorage
anchoragebrewingcompany.com
Specializing in barrel fermentation with brettanomyces and souring cultures

Cynosure Brewing
144 East Potter Drive, Unit E, Anchorage
facebook.com/CynosureBrewing/
New brewery specializes in Belgian and lager styles

King Street Brewing Co.
7924 King Street
Anchorage
kingstreetbrewing.com
Classical ales and lagers

Resolution Brewing Co.
3024 Mountain View Drive
Anchorage
resolutionbeer.com
Belgian-inspired beers and spruce ales

Odd Man Rush
10930 Mausel Street, #A-1,
Eagle River
oddmanrushbrewing.com
Ice hockey-themed experimental brewery in Eagle River

Girdwood Brewing Co.
2800 Alyeska Highway, Girdwood
girdwoodbrewing.com
New brewery with flavorful craft beer in scenic Girdwood

## Cidery:

Double Shovel Cider Co.
502 West 58th Ave, Units C&D,
Anchorage
doubleshovelcider.com
Delicious ciders with Alaskan and Washington apples & berries

## Brewpubs-Restaurants:

49th State Brewing Co.
717 West 3rd Ave.,
Downtown Anchorage
49statebrewing.com
Traditional fresh and aged beers

Glacier Brewhouse
737 West 5th Ave.
Downtown Anchorage
glacierbrewhouse.com
Traditional, cask-conditioned ales

Midnight Sun Brewing Co.
8111 Dimond Hook Drive
Anchorage
midnightsunbrewing.com
Bold ales, lagers, barrel-aged stouts and barley wines, and sour beers

Moose's Tooth Pub and Pizzeria
3300 Old Seward Highway
Anchorage
moosestooth.net
Eclectic beers and pizzas

Bear Tooth Theatrepub
1230 West 27th Ave.
Anchorage
beartooththeatre.net
Beer, food, and movies

## Beer Tours:

Big Swig Tours
Meet at 4th Ave. and F Street, Anchorage
(907) 268-0872
Half-day beer tours and bike & brew tours of Anchorage with beer tastings and appetizers

# Sheraton Anchorage Hotel & Spa

401 East 6th Ave
Anchorage, AK 99501
(907) 276-8700

The Sheraton Anchorage Hotel & Spa boasts the finest lodging in the city and is moments from downtown Anchorage's best restaurants, museums, shopping, and attractions, while still being located in the heart of the great Alaskan wilderness.

Make the most of your downtime in our 24-hour fitness facility with sweeping views of Anchorage, or treat yourself to a massage or facial in our sleek yet soothing, full service ICE Spa. With room to spare, our 370 guest rooms feature all the temptations for a great night in: room service, 42" flat screen TV, refrigerator, and high speed Internet access.

Our hotel is just blocks from the Anchorage Museum at Rasmuson Center, the vibrant 5th Avenue Mall, and the Alaska Center for the Performing Arts, making it perfect for the cosmopolitan traveler. If you're looking for traditional Alaskan outdoor adventure, Sheraton Anchorage Hotel provides the ideal launching pad to experience Alaska's famous bore tide, ever-changing glaciers, breathtaking mountain trails, and incredible wildlife.


*The Sheraton Anchorage is the base for the 2017 PSAAPG meeting. It is a short walk to busy 4th Street in the heart of downtown, and only minutes to Ship Creek, where you can watch Alaskans "combat fishing" for king salmon. If you'd prefer to fish for kings, rainbows and Dolly Varden yourself, sign up for the Kenai River Local Trip #1.*

Check in: 4:00 PM
Check out: 12:00 PM

# Available Services at the Venue

BUSINESS SERVICES
- 24-Hour Business Center

GUEST SERVICES
- Gift/Sundry Shop
- 24-Hour Front Desk
- Self-Service Laundry Facility
- Laundry/Valet Service
- Luggage Storage
- Disability Accessible Facilities

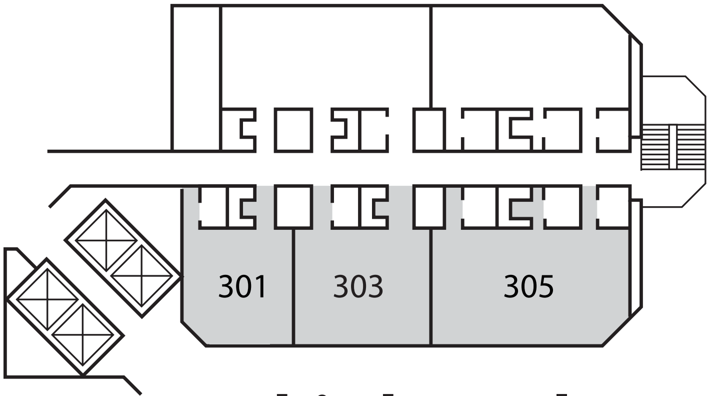
RECREATION & ENTERTAINMENT
- Complimentary MLB.TV Premium Access
- Sheraton Fitness
- Sheraton Club Lounge
- Ice Spa
- Spa Services

TRANSPORTATION
- Self-Parking Available 15 USD per day

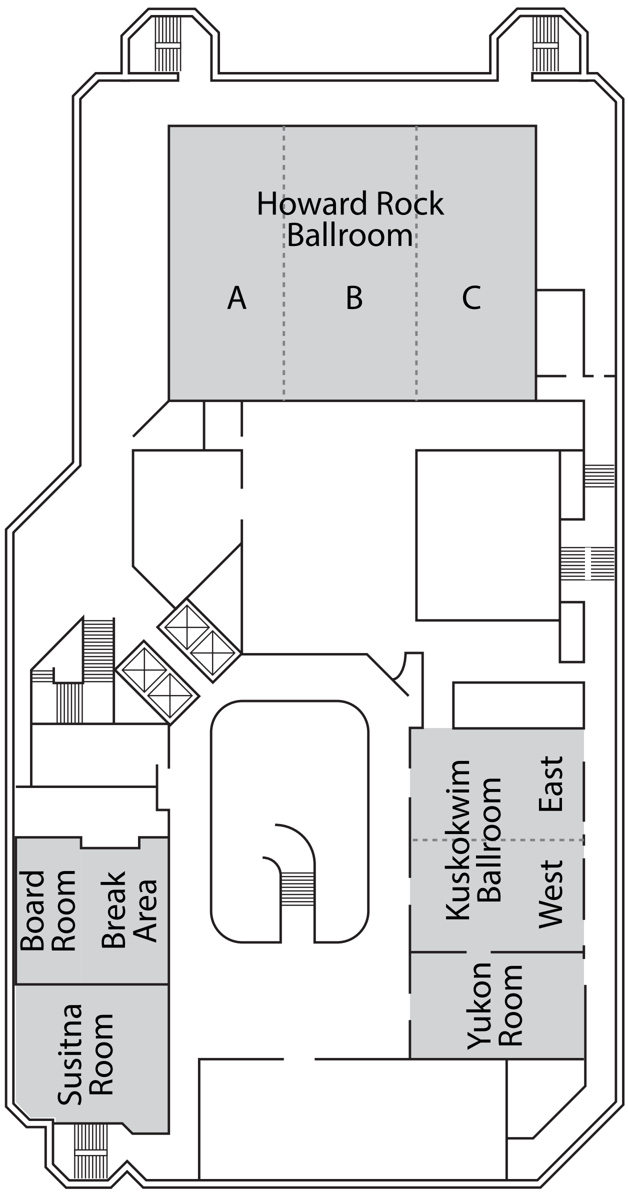
ACCESSIBLE PUBLIC SPACES
- Service animals welcome
- Registration desk
- Meeting room/ballroom
- Restaurant
- Self-Parking Area for cars & vans
- Fitness center
- Business center
- Assistive listening devices for meetings

ACCESSIBLE GUEST ROOMS
- Roll-in showers
- Bathtubs with grab bars
- Visual fire alarm & portable comms kits
- Mobility-accessible doors with > 32" width
- Portable tub seats
- TTY (Text Telephone Device)

**Find up to the minute conference information at psaapg2017.com**




Third Level




Second Level

# In Hotel Amenities

**Ptarmigan Lounge**
First Floor
Cuisine: Bar Menu
Hours Of Operation:
Atmosphere: Fireside
Setting: Rustic and Comfortable

**Starbucks Coffee**
Cuisine: Coffee
Hours Of Operation:
6:00 AM - 1:00 PM
Atmosphere: Relaxed

**Jade Steak and Seafood Restaurant**
Cuisine: Steak And Seafood
Hours Of Operation:
6:00 AM - 10:00 PM

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**Find up to the minute information at psaapg2017.com**

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**Speakers Preparation Room**

DATES: Sunday, Monday, Tuesday and Wednesday, May 21-24.
HOURS: Sunday 1-6 pm; all day Monday and Tuesday, until noon on Wednesday
LOCATION: Susitna Room, Second Floor

Laptops will be available for speakers and presenters to preview and practice their talks.

**Thanks to our Special Sponsors**

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*AAPG is the world's largest professional geological society with a focus on petroleum geosciences and alternative energy resources. Dispensing knowledge to members and the world is the primary focus of the AAPG.*

AGIA
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Tamra Beaubouef
tamrab@airborneimagingusa.com

*Airborne Imaging is a full service airborne LiDAR provider with 5 state of the art LiDAR systems and have collected over 350,000mi$^2$ of LiDAR to date with an extensive data library in the US and Canada. We are part of Clean Harbors Exploration Services, Inc. and provide our customers with exceptional data quality/customer service to find optimal solutions to their geospatial needs in O&G, Environmental, Reclamation, etc.*

Alaska Geological Society
Keith Torrance - keith.torrance@uicumiaq.com

*The Alaska Geological Society (AGS) is a not-for-profit organization of both professional geoscientists and general earth science enthusiasts, founded in 1957. We have monthly luncheon meetings that are open to the public and that feature presentations by professional geoscientists from academia, government, and industry (mostly oil & gas and mining, and are active in promoting earth science education in the community.*

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Jennifer Rose - jennifer.m.rose@cop.com

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*LMKR offers cutting edge geoscience solutions - all focused towards lowering the risk associated with exploration and production of conventional and unconventional resource plays. LMKR team will be showcasing the latest upgrades in GeoGraphix and GVERSE suites.*

Petroleum News
Marti Reeve - mreeve@petroleumnews.com

*Petroleum News is a weekly oil and gas newspaper based in Anchorage, Alaska. Our editorial objective is to provide timely and trustworthy news coverage of upstream development in Alaska and Northern Canada, including news from around the world as it impacts the arctic oil and gas industry.*

PRA
Brenda Smith - bsmith@petroak.com

PS AAPG
Larry Knauer - laknauer@aol.com

*PSAAPG covers the five western states of Alaska, Washington, Oregon, California and Hawaii'. Our focus is to promote education in geology through publications, conventions, other meetings and field trips.*

State of Alaska DNR
Kelsey Tucker - Kelsey.tucker@alaska.gov

*The Alaska Division of Oil and Gas manages state lands for petroleum leasing and licensing, exploration, development, and revenue generation. The division is dedicated to expanding industry and public outreach and improving the integration of surface and subsurface petroleum research throughout Alaska.*

Task Fronterra
Nicola Capuzzo
Nicola.Capuzzo@TaskfFonterra.com

*Task Fronterra Geoscience is a world leader in the independent processing, QC and geological interpretation of borehole image and dipmeter data. Our services include integration with core and other well bore data, petrophysical analysis, geomechanical characterization, well stability, and pore pressure prediction. Come and visit us and we'll help you to bring your vision to the surface!*

# 2017 AAPG
**Pacific Section Annual Meeting**
**21-24 May • Anchorage, Alaska**
Innovating the Future: Discovery to Recovery

## 2017 PSAAPG Organizing Committee

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Monte Mabry — *monte.mabry@live.com*
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**Find up to the minute information at psaapg2017.com**

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|---|---|
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Welcome!

It is with pleasure that I invite you to attend the 2017 Joint PSAAPG – PS-SEPM – PCS-SEG Convention in Anchorage! Anchorage is typically beautiful in late May, and the theme of this year's meeting, "Innovating the Future, Discovery to Recovery," aptly sums up where the petroleum industry stands at the moment. And with the recently announced major discoveries on the North Slope, this is surely an exciting time to be holding our convention in Alaska.

The Convention Committee has put together an outstanding program. The technical program, covering a wide range of topics and themes, promises to be excellent. The field trips look to be spectacular. There will be two excellent core workshops covering reservoirs in some of the newest plays. The luncheons are featuring excellent speakers and the social program includes a fishing trip and a visit to a glacier!

Most of all, Pacific Section Conventions provide an excellent venue for networking, meeting up with old friends, and seeing what's new in our fields of endeavor. So I encourage you to take advantage of this opportunity, register for the convention, and make plans to travel to Alaska in May.

I want to thank the Convention Committee for putting together such an exciting meeting. And I look forward to seeing everyone in Anchorage.

Bob Horton
PSAAPG President

### Speakers Preparation Room

DATES: Sunday, Monday, Tuesday and Wednesday, May 21-24.
HOURS: Sunday 1-6 pm; all day Monday and Tuesday, until noon on Wednesday
LOCATION: Susitna Room, Second Floor

Laptops will be available for speakers and presenters to preview and practice their talks.

Dear PSAAPG Delegate,

On behalf of the Alaska Geological Society it is my great pleasure to welcome you to Anchorage for the PSAAPG conference. The Alaska Geological Society promotes earth sciences within the geological community in Alaska. Our members share a passion for advancing geologic knowledge about the state by supporting scholarships, holding monthly lectures, and organizing annual technical conferences. For the society, being able to organize and support this year's PSAAPG conference is an important part of fulfilling this mission.

There are few states that can compare to the geological diversity and sheer majesty of Alaska. On a clear day from the top floor of the conference hotel, you can look north to Denali, the highest mountain in North America. You can look south and west and see no less than four active volcanoes, including Mount Redoubt. Also to the west, platforms actively produce gas from the Cook Inlet. Just south of town, the road south to Seward cuts through an accretionary prism, with excellent exposures of deep-water turbidites, pillow basalts, and chert. Most of the state's geology is only known at the reconnaissance scale, so there is a whole lot more to discover.

The economy of Alaska is closely linked to its geology, and petroleum production plays a major role. Advancing petroleum geologic knowledge is necessary for overcoming the technical challenges of maintaining production of developed reservoirs, and discovering and developing new reservoirs. This conference is organized to provide a forum to advance the knowledge of the geology of petroleum basins of Alaska and the Pacific region.

Welcome to our town. Enjoy our restaurants and the many micro-breweries that Anchorage has to offer. Enjoy the geology and wildlife. But most of all, soak in the presentations, learn from your colleagues and make some new friends.

Chad Hults
Alaska Geological Society President

***Directly following the meeting....***

# Annual GSA/AGS Spring Picnic

## A GSA Scholarship Fund Benefit Event

Wednesday, May 24th
5:00 - 8:30 PM
Abbott Loop Community Park Pavilion
8101 Elmore Road

**TICKET PRICES**
$20 - Individual
$15 - Student
$40 - Family
$35 - Student Family

Menu will include BBQ, dessert and beverages!

# Guest Activities

Two field trips are planned for guests:

### Monday Guest Program

Local Anchorage Day Trip

Includes fully guided tours through Anchorage, highlight Bootleggers Cove, Earthquake Park, Flat Top or other overlook of the city.

TIME: Monday, May 22, 8:30am to 11:45am
COST: $49 per person

### Tuesday Guest Program

Afternoon Wildlife Tour

A journey along Turnagain Arm, home of active and feeding wild animals, to the Alaska Wildlife Conservation Center.

Includes fully guided tour along Turnagain Arm with transportation to Portage, guided tour through AWCC, transportation to Anchorage.

DATE: Tuesday, May 23 12:45PM to 5:00PM
COST: $99 per person

In addition, guests are welcome to attend the "Wine Rocks" Monday night. "Wine Rocks" is an exciting evening filled with wine and geology! Come and learn about some great wines and some fun geology. Hosted by Chad Culley from Crush Wine Bistro! While there, check out the photos on display by PSAAPG Organizing Committee member Mike Unger.

Wine Rocks
COST: $65/person

crush
wine bistro and cellar

**Find the latest Guest Program information at psaapg2017.com**

# Alaskan Adventures

### Fishing on the Kenai Peninsula

Alaska's Kenai Peninsula is fishing at its best. Drifter's Lodge sits at the headwaters of the Kenai River in the Chugach Mountains in Cooper Landing.

The drive through the Chugach mountains and onto the Kenai Peninsula is spectacular!

Seasoned, professional guides will assist you in your pursuit of Trophy Rainbow Trout, Dolly Varden or King Salmon.

What's included?

- Transportation to / from Anchorage
- 2 nights accommodations at Drifter's
- All meals
- Full day of fishing on the Kenai River
- All gear including rods, waders & tackle

See the lodge at www.drifterslodge.com

OPTION A:
Friday, May 19 - Sunday May 21
OPTION B:
Thursday, May 25 - Saturday May 27
COST: $750 per Person

### Matanuska Glacier Walk

Journey 2 hours north of Anchorage and explore the Matanuska Glacier's many incredible features, like glacial blue meltwater pools, in Southcentral's beautiful Matanuska Valley.

Includes fully guided tour and transportation to Glacier View, lunch, equipment, transportation to Anchorage

DATE: Thursday, May 25
8:30AM to 6:00PM
COST: $249 per person

Conference Activities Field Trips

# Field Trip #1

## Field trip to the Mesozoic arc and accretionary complex of South-Central Alaska, Indian to Hatcher Pass

OVERVIEW

This one day field trip traverses exposures of a multi-generation Mesozoic magmatic arc that had intermittent activity and compositional variation in response to changes in the tectonic environment.

This Mesozoic arc formed many degrees of latitude to the south, was accreted to North America, and was subsequently transported along faults to its present location. Many of these translational faults are still active. Similar tectonic, igneous, and sedimentary processes to those that formed the Mesozoic arc complex persist today in southern Alaska, building on, and deforming the Mesozoic arc. The rocks we will see on this field trip will provide insights on the components of the modern arc in three dimensions, and the processes involved in the evolution of an arc and its companion accretionary complex.

The field trip starts in the Late Cretaceous accretionary prism along Turnagain Arm and finishes in the roots of the Late Cretaceous arc at Hatcher Pass. In this transect we will visit:

- The accretionary prism, represented by the Jurassic to Late Cretaceous Chugach terrane
- The terrane boundary, represented by the Border Ranges and Knik Arm faults
- The overlying arc terrane, represented by the Paleozoic to Jurassic Peninsular terrane
- The forearc basin, represented by Late Cretaceous and younger deposits that unconformably overlie the Peninsular terrane, and
- The magmatic underpinnings of the Late Cretaceous arc that was built on the Peninsular terrane after it was accreted to the continental margin.

LEADER: Sue Karl, US Geological Survey
DATE: Saturday, May 20th
COST: $150.00 per person

## Geology of Northern Alaska — A Transect Along the Dalton Highway from the Interior to the Arctic Ocean

OVERVIEW

Northern Alaska is among the more remote and inaccessible places in North America. However, the region is bisected by one main road — the Dalton Highway — constructed in the 1970's in support of oil and gas activities up along the Arctic coast. The mostly gravel road passes through scenic country, ranging from the rolling metamorphic terrain of the interior, to the rugged peaks of the Brooks Range, and the expansive Arctic tundra of the North Slope. This trip will visit key outcrops and overview stops that highlight the complex geologic history of the region. More time will be spent north of the divide, where sedimentary rocks important to the North Slope petroleum system can be observed (Ellesmerian and Brookian Sequences). In particular, we will focus on lower Brookian rocks, including the Torok and Nanushuk Formations. These two units have received substantial attention recently with the announcement of several large new oil discoveries.

In addition to compelling bedrock geology, the road passes through other interesting terrain, unique to its high latitude setting, such as "drunken forests", pingoes, and massive creeping frozen debris lobes. The trip will offer many opportunities to view the trans-Alaska pipeline, which has transported more than 17 billion barrels of oil from North Slope fields. Other highlights will include the crossing of the mighty Yukon River on a ~2300 foot long bridge and a stop at the Arctic Circle. Depending on available time, there may also be opportunities for gold panning in the Coldfoot area, a district that has produced almost 50,000 ounces of placer gold.

Trip participants should be prepared for modest, short hikes and be physically able to navigate moderately difficult terrain, such as talus at some outcrops. Depending on available time, there may be a 3/4 of a mile hike across uneven tussock-rich tundra to view an oil-saturated sandstone outcrop. The Arctic is still easing out of winter's hold in late May, so warm, layered clothing will be needed. A warm hat, gloves, lightweight rain gear and hiking boots or good ankle-fit rubber boots are also required.

LOGISTICS

The trip will begin early on the morning of Thursday, May 25th in Fairbanks (attendees will be required to arrange their own transportation from Anchorage). We will stay Thursday night in Coldfoot, which is ~30 miles from Prospect Creek, home to the coldest temperature ever recorded in the United States (-80 F). Friday will involve a long driving day over the Brooks Range and on to Deadhorse, home to Prudhoe Bay, the largest oil field in Northern America. We will spend Friday night in Deadhorse. Participants may wish to arrange commercial flights out of Deadhorse on Saturday, or return with the vehicles on the ~500 mile backhaul to Fairbanks, where the trip will end. Depending on road conditions, we hope to be back to town by ~8:00pm on Saturday, May 27th.

LEADER:

Marwan Wartes – Alaska Division of Geological & Geophysical Surveys
marwan.wartes@alaska.gov

COST - $1300 per person

*Cost includes all vehicle transportation (4wd SUV's) during the field trip, from Fairbanks to Deadhorse, and back to Fairbanks. Meals covered include two breakfasts, three lunches and two dinners. Commercial lodging is included for both Coldfoot and Deadhorse. A field trip guidebook will also be provided.*

*OPPOSITE, FROM TOP:*

*The bore tide flooding Turnagain Arm, Cook Inlet (photo by Roy Neese).*

*Chugach Range to the east of Anchorage (photo by Roy Neese).*

*The Matanuska Glacier (photo courtesy of Salmon Berry Travel Tours).*

*Spencer Glacier in Chugach National Forest in July (photo by Ashley Heimbigner).*

## BROOKIAN DW CORE WORKSHOP

SUNDAY, MAY 21, 2017 ALASKA ARCHIVES

Tarn Field, Kuparuk River Unit (KRU*), North Slope Alaska, Brookian Deepwater Core Workshop

*KRU is operated by ConocoPhillips Alaska, Inc., with BP Exploration (Alaska), Inc., ExxonMobil Alaska Production Inc., and Chevron U.S.A. Inc. as additional working interest owners.

AUTHORS

William Morris, ConocoPhillips Company, and Patrick Perfetta, ConocoPhillips Alaska, Inc.

ABSTRACT

This workshop will examine cores from three wells (Tarn 2, 2N-313, and Tarn 4) encompassing the T2, and T3 intervals at Tarn Field. Tarn was discovered in 1991 with the drilling of the Bermuda 1 well, it has since produced in excess of 100 MMBO from a two-pad development. This Alaska North Slope field is a composite of several Brookian base of slope (slope apron) deep water deposits with varying facies associations.

The workshop will briefly discuss the key characteristics of slope apron systems and how they vary from basinal turbidite systems. The primary focus will be the stratigraphic, sedimentologic and reservoir properties specific to the slope apron present at Tarn field.

We will initially examine the stratigraphic evolution of the system from a mud-rich, debris flow dominated slope apron, to a sandy, turbidite dominated slope apron based on facies types associated with each of these two systems.

Second, we will examine the facies associations of channel, levee, lobe and lobe fringe depositional elements.

Lastly, the core workshop will examine the relationship of reservoir properties (porosity and permeability) to sedimentary facies elements, and their spatial distribution within this slope apron deposit.

**Find up to the minute conference information at psaapg2017.com**

## BROOKIAN TOPSET CORE WORKSHOP

Wednesday, May 24, 2017 Alaska Division of Geological & Geophysical Surveys Geologic Materials Center

Depositional setting and potential reservoir facies in the Albian-Cenomanian Nanushuk Formation

WORKSHOP LEADERS

David LePain[1], Paul Decker[2], Ken Helmold[2], and Marwan Wartes[1]

[1]Alaska Division of Geological & Geophysical Surveys; [2]Alaska Division of Oil and Gas

ABSTRACT

This workshop will examine cores from four wells (Wainwright No. 1, Square Lake No. 1, Wolf Creek No. 3, and Fish Creek No. 1) representing a range of depositional settings in the Nanushuk Formation from marine-influenced lower delta plain to outer shelf. Two recent high-profile discoveries on state lands in the Colville Delta area (Armstrong-Repsol Pikka) and the eastern National Petroleum Reserve–Alaska (ConocoPhillips Willow) include reservoirs in the Nanushuk Formation. The currently identified contingent resource in the Nanushuk play at Pikka is approximately 1.2 billion barrels of recoverable oil (Repsol press release, March 9, 2017) and recoverable resource potential is estimated to be in excess of 300 million barrels of oil from Willow (ConocoPhillips press release, January 13, 2017). These discoveries, combined with previous discoveries such as Umiat field (discovered in 1946) demonstrate the Nanushuk's place as an important newly rediscovered play.

This workshop will:

Briefly examine the stratigraphic evolution of fluvial-deltaic-shelf depositional systems in the Nanushuk Formation

Examine a range of lower delta plain facies associations from Wainwright No. 1, shoreface-delta front and lower delta plain associations from Square Lake No. 1 and Wolf Creek No. 3, heavily oil- stained outer shelf facies from Fish Creek No. 1, and highlight potential reservoir facies

Examine the relation between sedimentary facies, sandstone composition, and reservoir properties (porosity and permeability) in distributary channel and shoreface-delta front facies associations

## Monday, May 22: John Armentrout

## All Convention Luncheon

### "Climate Change Reality: Adaptation and Mitigation Requires a Robust Economy"


John M. Armentrout
*Cascade Stratigraphics*
jarmenrock@msn.com


Climate change and global warming are issues of great concern to humankind. The geologic record documents a cyclic pattern of warm versus cool climates throughout Earth's history. Recent observations and data collections demonstrate a significant pattern of ocean and atmospheric warming. Controversy exists as to how much of this change is part of natural cycles and how much is contributed from anthropogenic greenhouse gas and aerosols. How these patterns of climate change impact society requires careful evaluation of data and predictive models for future climates. Realistically, our response must include both adaptation to change and mitigation of consequences.

Adaptation is adjustment to our environment, such as retreat from the present shoreline as sea level rises or changes in planting schedules or areas as rainfall patterns shift. Mitigation involves efforts to modify or negate the consequences of environmental change, including constructing and strengthening levees to control higher river discharge into an ocean with rising sea level.

Many professional organizations representing members active in energy and resource industries have a role in our understanding both climate change and global warming, and assessing the economic realities associated with a changing environment. These organizations exist to advance the science and profession of energy-related geosciences worldwide, through assembly and distribution of the best science related to the discovery and production of oil, natural gas, coal and other forms of energy, especially those considered as sustainable. Issues of peak production versus peak-demand, and sustained subsidy of renewables are clearly part of this discussion.

The necessary development of new technologies and the maintenance of the existing energy-supply infrastructure require investment capital from a robust global economy. Energy for that global economy will be supplied by fossil-fuels for the foreseeable future. The issue of responsible and ethical planning for environmental change is a shared task.

<u>Speakers Biography:</u>

John M Armentrout served as Co-Chair for the AAPG Global Climate Change Committee during 2008-2010, and co-convened three Climate Change Symposia and chaired a technical session on climate change at the 2008 ACE meeting. He has continued to address climate change issues and present his updated perspective locally in Oregon.

John's professional career included 26 years as an exploration geologist for Mobil Oil Corporation and 15 years as an international consultant and seminar teacher following retirement from ExxonMobil in 2001. He is an honorary member of the Pacific Section, and was AAPG Vice-President Sections 2007-2008.

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**Find up to the minute information at psaapg2017.com**

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### Speakers Preparation Room

DATES: Sunday, Monday, Tuesday and Wednesday, May 21-24.
HOURS: Sunday 1-6 pm; all day Monday and Tuesday, until noon on Wednesday
LOCATION: Susitna Room, Second Floor

Laptops will be available for speakers and presenters to preview and practice their talks.

## Presenters and Judges Breakfasts

Speakers/Judges breakfasts will be held each morning between 7:00 and 7:45 in the Summit restaurant on the 15th floor of the Sheraton.

Speakers, Poster Presenters, Session Chairs and Judges should attend the breakfast on the day of their talk, poster or judging session. You will have the opportunity to meet with your chairs and fellow presenters, get logistical information, and answers to any last minute questions. Please ensure that your talk has been provided to the technician in the Speaker's Preparation Room 4 hours before your session begins..

## Speakers Preparation Room

DATES: Sunday, Monday, Tuesday and Wednesday, May 21-24.
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Laptops will be available for speakers and presenters to preview and practice their talks. Please ensure that your talks are provided to the A/V technician in the room 4 hours before your session starts (or the night before for morning talks).


*The Mesozoic rocks of the Chugach accretionary prism are spectacularly exposed along on the field trip from the Turnagain Arm to Hatcher Pass. Photo by Sue Karl*

## Tuesday, May 23: Dave Lachance

## Honors and Awards Luncheon

### "Prudhoe Bay: A 40 year perspective"

Dave Lachance
*Vice President, Reservoir Development*
BP Exploration (Alaska) Inc.

As Vice President of Reservoir Development for BP in Alaska, Dave Lachance is responsible for all aspects of subsurface delivery: resource identification, evaluation, development, production, new wells, well optimization, well work, and 130 BP subsurface employees.

Dave has a mechanical engineering degree from Oklahoma State University and is a Registered Professional Engineer in the State of Colorado. He also trained as a petrophysicist at the Amoco Research Center. He has been employed with BP for over 39 years, starting in the Rocky Mountains with Amoco in the late 1970's. His background covers seven countries and fourteen BP business units. Prior to Alaska, he was VP of Reservoir Development in Asia Pacific and in Canada. He is a member of the Society of Petroleum Engineers and has authored several technical papers.

## Thanks to our Special Sponsors

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# 2017 PSAAPG Awards

## Honorary Life Membership Award

***Kenneth P. Helmold***

The Honorary Life Membership Award is the Pacific Section AAPG's highest honor. It is bestowed upon members who have distinguished themselves in their contributions to the science and profession of geology and by outstanding service to the Pacific Section.

## Martin Van Couvering Award

The Martin Van Couvering Award is presented by the Pacific Section AAPG Foundation on behalf of the Pacific Section AAPG and the Pacific Section SEPM (Society for Sedimentary Geology). The award was created to encourage university student attendance and participation at Pacific Section meetings and field trips. At the request of the Pacific Section, deserving students are selected by faculty at universities local to the annual convention.

## Distinguished Service Award

***Robert Ballof***

***Susan M. Karl***

***George T. Morahan***

The Distinguished Service Award is presented to members who have distinguished themselves in singular and beneficial long-term service to the PSAAPG.

## A. I. Levorsen Award

***Gregory Gordon***

***"Miocene Paleogeography and Stratigraphic Evolution of the Ventura Basin"***

The A.I. Levorsen Award is presented by the national AAPG in recognition of the best oral presentation given at each AAPG Section meeting, with particular emphasis on creative thinking toward new ideas in exploration and production. AAPG members judge the presentation at each session, and scores are compiled and reviewed by the convention judging committee to determine the overall winner.

## H. Victor Church Memorial Award

***Michael A. Thompson***

***"Tectonic Evolution of the Palos Verdes Fault - Lasuen Knoll Segment, Offshore Southern California"***

The H. Victor Church Memorial Award is given by the Pacific Section AAPG in recognition of the best poster presented at the annual Pacific Section meeting. The award was established to build a lasting memorial to the technical prowess of H. Victor Church. Its focus is on creative thinking toward new ideas in exploration, development geology, or foundational geology. Peers judge the posters at each session, and scores are compiled and reviewed by the convention judging committee to determine the overall winner.

## Distinguished Educator Award

***Catherine L. Hanks***

The Distinguished Educator Award is given by the Pacific Section AAPG in recognition of distinguished and outstanding contribution to geological education and counseling of students.

## Teacher of the Year Award

***Corby Weyhmiller***

The Teacher of the Year Award is given by the Pacific Section AAPG in recognition of Excellence in the Teaching of Natural Resources in the Earth Sciences. The winner of the PSAAPG TOTY award advances for consideration of the National AAPG TOTY award.

## YP Distinguished Service Award

***Trystan M. Herriott***

The YP Distinguished Service Award is bestowed upon practicing petroleum geologists who are under 35 years of age or who have been employed as a petroleum geologist for less than 10 years. The Honoree has volunteered and demonstrated excellence, enthusiastic participation, organization creativity, leadership and passion for the geological sciences.

# Frontier Exploration in the Arctic Offshore

*Chairs: Dave Houseknecht*
*Tom Homza*

**8:00 Introductory Remarks**

8:05 David Houseknecht
*Diving into the deep end of Arctic Alaska - Geology, tectonic origin, and petroleum potential of the North Chukchi Basin*

8:25 Annie Walker
*New insights into the structure and tectonic provenance of the Chukchi Borderland terrane: Implications for Arctic reconstructions*

8:45 Ibrahim Ilhan
*Meso-Cenozoic evolution of the Chukchi Borderland | Constraints on the tectonic development of the Amerasia Basin, Arctic Ocean*

9:05 Thomas Homza
*New geologic interpretations from beneath the Chukchi Sea: offshore Alaska, USA*

**9:25 Break (30 minutes)**

9:55 Christopher Connors
*Hanna and her sisters: structural inheritance in the Chukchi Sea, Alaska*

10:15 Kristin Elowe
*Abnormal Formation Pressure in the Chukchi Shelf, Alaska*

10:35 Allegra Hosford Scheirer
*Value added to exploration teams by integrating basin modeling, rock physics, and quantitative seismic interpretation*

10:55 Gary Player
*Recovery of unconventional resources of dissolved gas from non-potable Kenai Group aquifers in Cook Inlet Basin, Alaska and California's Great Valley*

11:15 End of morning session

## Diving into the deep end of Arctic Alaska – Geology, tectonic origin, and petroleum potential of the North Chukchi Basin

*Houseknecht, Dave; Connors, Christopher; Ilhan, Ibrahim; Coakley, Bernard; Altenbernd, Tabea*

The North Chukchi Basin (NCB) straddles U.S., Russian, and international waters beneath the outer Chukchi and East Siberian shelves. Although minimal geophysical and geological data for this region historically have been available, recently collected multi-channel seismic (MCS) data can be integrated with potential-field and sparse well data to present (1) an overview of the geology of the NCB, (2) an interpretation of its tectonic origin, and (3) an initial evaluation of its petroleum resource potential.

The NCB extends more than 950 km from the North Chukchi High (U.S.) to the De Long High (Russia). The basin widens from 150 km (U.S.) to 450 km (Russia) and covers more than 300,000 km$^2$. Strata commonly exceed ~20 km thick along the basin axis. The basin fill comprises sediment derived mainly from the Chukotkan and Brooks Range orogens, and routed generally northward across the basin. These strata onlap the low-accommodation Chukchi Borderland along the northeastern basin margin, and downlap (via prograding shelf-margin depositional systems) the high-accommodation Chukchi Abyssal Plain (likely underlain by oceanic crust) along the northwestern basin margin. The stratigraphy of the NCB includes: (1) Hauterivian(?) strata, only locally present and likely comprising condensed, basinal deposits. (2) A Lower to middle Cretaceous succession comprising thick clinothems in the east, which subsequently were deformed, and that thin westward into a thin condensed basin-floor deposit. (3) A middle Cretaceous to Paleogene succession comprising thick clinothems in the west, which thin to the east by onlap onto deformed unit 2. (4) A Paleogene to Neogene succession comprising a single, giant clinothem. (5) Upper Neogene and Quaternary strata comprising thin glacio-marine and deposits.

Based on stratigraphic and structural evidence, we interpret the NCB as a rift basin whose opening occurred no later than the Hauterivian, approximately coeval with opening of the Canada Basin. The widest part of the NCB (Russia) may be floored by either exhumed mantle or oceanic crust (Granath et al., 2015, AAPG Search and Discovery Article

#10811), whereas the narrower part (U.S.) likely is floored by extended (transitional) continental crust. The overall geometry of the basin and deformation recorded near its eastern end suggest that basin opening was accommodated by clockwise rotation. Petroleum potential of the NCB depends mainly on the presence of oil-prone source rocks and their thermal history. Based on the age and distribution of known source rocks across the western Arctic and acoustic character in the NCB, it is likely that source rocks were deposited during Hauterivian–Early Cretaceous, middle Cretaceous, and early–mid Paleogene. Preliminary thermal maturation modeling indicates that any source rocks in the Cretaceous are now over mature. Any preservation of oil generated from these older strata would require vertical migration over a distance of several km, likely along abundant normal faults, as younger strata were deposited. Potential source rock intervals in the Paleogene likely entered the oil window during the mid-Cenozoic and reside in the lower part of the oil window today. Optimum oil potential lies in Eocene to Miocene strata in the giant clinothem, where source-rock potential likely exists in a basal condensed section and reservoir-trap potential exists in overlying basin-floor fan, slope channel and lobe, and shoreface to deltaic deposits.

## New insights into the structure and tectonic provenance of the Chukchi Borderland terrane: Implications for Arctic reconstructions

*Walker, Annie*

The provenance and tectonic histories of many Arctic terranes remain suspect because sparse data and overprinting by an unknown number of subduction and accretion events make kinematic reconstructions highly uncertain. The Chukchi Borderland is a conspicuous topo-bathymetric feature adjacent to the Chukchi Sea and East Siberian Sea shelves—and one of the least understood features in the Amerasia basin. Its isostatic elevation suggests continental and/or arc affinity, but resolving its provenance and emplacement history have been problematic due to the paucity of physical data. It is often interpreted as a fragment of continental crust rifted from the south–central Canadian Laurentian margin. But recent results from published dredge-sample studies, and ION's newly reprocessed Chukchi Borderland 2D seismic survey suggest the Chukchi Borderland is a

**Notes:**

peri-Laurentian volcanic arc terrane, and may be exotic relative to the Arctic Alaska–Chukotka superterrane. As interpreted here, the top of acoustic basement is defined by high-amplitude events that display seismic structures and geometries consistent with subaerial basalt flows and isolated seaward-dipping reflections. These are underlain by a zone of semi-transparent reflections ~50–5000 m thick we interpret as synrift volcanoclastic deposits and possible pre-rift basement. High-amplitude horizontal and sub-vertical events within acoustic basement suggest volcanic intrusion by dikes and sills. Published geochemical and geochronological analyses of dredged rock samples indicate the Chukchi Borderland has Grenvillian basement affected by subduction, deformation, and magmatism related to events recorded in both Svalbard and the Pearya terrane. We interpret a domain of structures on the northern edge of the survey to be salt-cored bodies and diapirs with rim-synclines - suggesting this area originated in the vicinity of salt provinces on Axel Heiberg and Ellesmere islands, Svalbard, or the Barents Sea shelf. Isolated, but well-defined seaward-dipping reflections imaged in the northwest corner of the survey suggest the Chukchi Borderland may also be genetically related to the North Chukchi basin. The volcanoclastic assemblage and possible salt domain interpreted here support published dredge-sample data, and indicate the Chukchi Borderland has a complex history of episodic arc construction, extension, and rotation related to currently unknown arc or back-arc systems outboard of the Canadian Laurentian margin.

## Meso–Cenozoic evolution of the Chukchi Borderland | Constraints on the tectonic development of the Amerasia Basin, Arctic Ocean

*Ilhan, Ibrahim; Coakley, Bernard J.*

Any model for the tectonic development of the Amerasia Basin requires structures to accommodate the continental Chukchi Borderland in a plate-tectonic framework. We have interpreted 2D multi-channel seismic reflection data and tied these data to the late 80's Crackerjack and Popcorn exploration wells in order to: (1) develop a tectono-stratigraphic framework for the Chukchi Shelf and Borderland, and (2) indirectly test existing models for the development of the Amerasia Basin. Based on sequence stratigraphic principles, we have mapped four regional unconformities and used these to subdivide the basement and basin fill into tectono-stratigraphic sequences. These sequences are: (1) pre-Brookian deformed strata (Mesozoic–Paleozoic); (2) pre-Brookian Syn-rift#1 and Dipping Reflectors; (3) Post-rift#1, inferred condensed section and Lower Brookian orogenic sediments (Barremian–pre-Cenozoic); (4) Syn-rift#2 (inferred upper Cretaceous–Paleocene); (5) Post-rift#2, Upper Brookian progradational wedge (Cenozoic); and (6) Glacio-marine (Quaternary). The angular relationship between the inferred lower Cretaceous unconformity and the underlying Syn-rift#1 sequence along the north striking normal faults of the Chukchi Plateau is inconsistent with clockwise rotation of the Chukchi Borderland away from the East Siberia. This falsifies one popular model for the Chukchi Borderland and its role in the development of the Amerasia Basin. The Dipping Reflectors underlying the lower Cretaceous unconformity are associated with volcanism that may be concurrent with east-west rifting of the Borderland. The recognition of condensed section and continuity of the overlying lower Cretaceous orogenic sediments across the southern Chukchi Borderland substantially constrains other models that require significant discontinuity between the Chukchi Shelf and Borderland since the Early Cretaceous proposed for tectonic development of the Amerasia Basin, Arctic Ocean.

## New geologic interpretations from beneath the Chukchi Sea: offshore Alaska, USA

*Homza, Thomas X; Bergman, Steven C.*

In the context of Shell's recent suspension of exploration activities in the Chukchi Sea and in the spirit of knowledge retention, we present some key details of Shell's regional geologic model for the US Chukchi Sea. Our model builds on the work of many predecessors, including those from the USGS and BOEM, and it comprises interpretations from modern 3D seismic data as well as re-interpretations of well data.

We present a Devonian-through-Cenozoic tectono-stratigraphic evolutionary model that includes several previously under-reported elements and events. These include: regional Devonian orogenic collapse; Jurassic karst formation on the Crackerjack Ridge; rift-related Jurassic mafic submarine magmatism in the Burger area; regional Berriasian-Hauterivian foreland flexural uplift that produced the Lower Cretaceous unconformity; Neocomian salt withdrawal from the Popcorn Trough; Barremian contractional tectonism above the northern Hanna Trough; widespread Cenomanian uplift and erosion; extensive Maastrichtian-aged transpressional inversion that drove the formation of a regional anticlinorium beneath the central Chukchi Shelf and, among others, several stages of Paleogene transtensional collapse.

Although we contend that the US Chukchi Sea is a prolific petroleum province, we don't discuss petroleum systems here; rather our focus is on observations and geologic interpretations that we hope will contribute to the understanding of the tectono-stratigraphic evolution of the Chukchi Sea and the wider circum-Arctic region.

## Hanna and her sisters: structural inheritance in the Chukchi Sea, Alaska

*Connors, Christopher; Houseknecht, Dave*

The main tectonic element of the U.S. Chukchi shelf is the Hanna Trough (HT), a north-south failed rift that accommodated more than 10 km of Carboniferous–Jurassic syn-rift and post-rift (sag) strata buried beneath >2 km of Cretaceous and Cenozoic foreland deposits. Interpretation of over 100,000 line-km of reprocessed 2D, time-migrated, seismic-reflection data documents that the HT area has been the focus of deformation and a significant structural boundary from at least early Devonian to Paleogene time, and perhaps to the present day.

The HT is flanked by high-standing crustal blocks or platforms of mostly pre-Carboniferous basement. The Chukchi Platform on the west comprises mainly seismically opaque basement and is characterized by significant magnetic highs. The Arctic Platform on the east comprises well stratified basement whose internal geometry clearly defines a pre-Carboniferous, thin-skinned fold-and-thrust belt, striking parallel with the HT, that accommodated west-east (present coordinates) shortening. Below the basal detachment are well-imaged parallel strata of probable lower Paleozoic to Neoproterozoic age. Carboniferous rifting of the HT apparently was localized along the contrast in basement character and structure between the Chukchi and Arctic Platforms. Many rift-phase normal faults detach along pre-Carboniferous thrust faults, and others cut across stratigraphy in the basement.

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The entire section is cut by north-south striking strike-slip faults of likely late Cretaceous to Paleogene age, localized in the HT. Apparent vertical offset can be over 1 km on steeply dipping faults that cannot be easily followed to depth but appear to localize above older rifts, suggesting reactivation of rift-phase normal faults. Several inverted highs of a similar age are present in the Arctic Platform with the most significant displayed in the North Chukchi High. Clear east-west striking, deep, crustal-involved thrusts contribute to north-south contraction in the area; these resulted in uplift of the pre-Carboniferous section to essentially the seafloor in places. Notably, the North Chukchi High also has a significant positive magnetic anomaly. The fact that differences in the seismic character and potential field response of the basement are associated may indicate different crustal affinities across the HT. Thus the region around the HT has been the focus of at least 3 distinctly different, crustal-scale deformational events in the last 400 Ma.

## Abnormal Formation Pressure in the Chukchi Shelf, Alaska

*Elowe, Kristin; Sherwood, Kirk*

This study provides an improved interpretation and delineation of pore pressure in the Chukchi shelf region. Between 1989-91, five exploration wells were drilled on the Chukchi shelf and an array of drilling performance and petrophysical data were acquired. Resistivity, conductivity, sonic travel time, sonic porosity, and drilling exponent data were used to evaluate formation pore pressure. Normal compaction trendlines were established using depth-dependent relationships then integrated with Eaton and adapted Eaton equations to estimate formation pressures. Four of the five wells were found to contain significant overpressure at onset depths ranging from 3600 to 7600 feet subsea. The overpressure is mainly associated with organic-carbon-rich source rocks that have experienced thermal exposures sufficient for hydrocarbon generation. The driving mechanism for the origin and maintenance of the overpressure appears to be linked to hydrocarbon generation at the wellsites and access to hydrocarbons migrating from the regional generation center beneath the Colville basin to the east.

## Value added to exploration teams by integrating basin modeling, rock physics, and quantitative seismic interpretation

*AlKawai, Wisam; Hosford Scheirer, Allegra; Mukerji, Tapan; Graham, Stephan A.*

Predicting the lithologic composition of both known and potential reservoir rocks is challenging in areas where well penetrations are limited. We present a new method that combines basin modeling with rock physics and quantitative seismic interpretation to predict the composition - sandstone or shale - away from well control. Traditionally, this basin modeling part of the workflow was missing. In this study, we first use basin modeling to predict thermal and pressure history across a basin. Effective stress and temperature from the basin model are then used to calculate seismic velocity and density, which in turn are used to determine impedance across the study area. This impedance solution forms the basis for honoring spatial trends of impedances into the background model (or initial guess) used to invert for impedances from seismic data. Also, the impedance solution extends the training data (or well data) beyond well control to preserve spatial trends. The final step is lithofacies classification from the final inverted impedance volume. This methodology is applied to three scenarios. The base case is the reference scenario in which data from two wells are used to determine acoustic and elastic impedances. Scenario 1 uses data from just a single well and follows the traditional method of predicting lithofacies (i.e. without basin modeling). Scenario 2 uses that same well but uses the new workflow with basin modeling predictions of impedances at the location of the second well. The relative proportions of sandstone and shale are nearly indistinguishable between the base case and Scenario 2, whereas Scenario 1 significantly underestimates the amount of sandstone. This new methodology, demonstrated in a salt withdrawal mini-basin in the Gulf of Mexico, can be applied to all potential reservoir intervals in a study area, thus allowing the determination of stacked pay.

## Recovery of unconventional resources of dissolved gas from non-potable Kenai Group aquifers in Cook Inlet Basin, Alaska and California's Great Valley

*Player, Gary F.*

Commercial extraction and marketing of naturally occurring dissolved methane from non-potable ground water in Cook Inlet Basin and the Great Valley of California will provide a new, plentiful, and secure fuel. Dissolved methane is present throughout both basins in usable concentrations at depths ranging from about 750 meters to at least 5,000 meters below the surface of the earth. The supply is virtually inexhaustible, exceeding 1,300 Trillion Cubic Feet (at STP) in Cook Inlet Basin and 2,200 Trillion Cubic Feet in California's Great Valley.

### Presenters and Judges Breakfasts

Speakers/Judges breakfasts will be held each morning between 7:00 and 7:45 in the Summit restaurant on the 15th floor of the Sheraton.

Speakers, Poster Presenters, Session Chairs and Judges should attend the breakfast on the day of their talk, poster or judging session. You will have the opportunity to meet with your chairs and fellow presenters, get logistical information, and answers to any last minute questions. Please ensure that your talk has been provided to the technician in the Speaker's Preparation Room 4 hours before your session begins..

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# Structure & Tectonics: New Perspectives and Interpretations

*Chairs: Simon Kattenhorn*
*Robert Humphreys*

**13:15 Introductory Remarks**

13:20 Thomas Moore
*Structural and Tectonic Elements of the North Slope Depicted in New Tectonic Map of Alaska*

13:40 William Craddock
*Timing and possible mechanisms of tilting of the Barrow arch, Arctic Alaska, revealed by low-temperature thermochronology*

14:00 Christopher Connors
*Influence of inherited sequence stratigraphic geometry on the structure of the foreland fold-and-thrust belt, central Brooks Range, Alaska*

14:20 Simon Kattenhorn
*Role of structural inheritance on the evolution of rift-scale segmented normal faults: examples from northern California and the East African Rift*

**14:40 Break (30 minutes)**

15:10 Trevor Waldien
*New insights to Alaska Range orogenesis from the northern margin of the Copper River basin*

15:30 Peter Haeussler
*The Peters Hills basin, a Neogene piggyback basin on the Broad Pass thrust fault, south-central Alaska*

15:50 Richard Stanley
*Geology and petroleum potential of the Susitna basin, south-central Alaska*

16:10 Shirzad Nazhat
*Fracture modeling of the Main Limestone reservoir rocks, in the Kirkuk anticline in Kurdistan- N. Iraq*

16:30 End of Afternoon Session

## Structural and Tectonic Elements of the North Slope Depicted in New Tectonic Map of Alaska

*Moore, Thomas E.; Box, Stephen E.*

We present a new tectonic map of Alaska north of 60°N that shows the age and present-day distribution of known contractional and penetrative extensional deformational events as well as major faults and folds, magmatic bodies, and tectonically significant sedimentary, igneous, and metamorphic complexes. This map is the result of construction of the Alaska segment of the Tectonic Map of the Arctic, now nearing publication through the Commission for the Geologic Map of the World (CGMW) in Paris. Our new map indicates that Alaska can be divided into three general deformational domains: a northern domain consisting of terranes lying generally north of the Tintina and Kaltag faults characterized by north-vergent arc-continent collision events formed during the Late Jurassic to Early Cretaceous early Brookian orogeny; a central domain consisting principally of the large continental Farewell and Yukon-Tanana terranes, both of which feature Permian deformational events of different origins but displaying different subsequent deformational histories; and a southern domain lying south of the Denali fault that consists of the Alexander, Wrangellia, and Peninsular (AWP) island-arc terranes and the adjoining southern Alaska accretionary complex which were amalgamated by Permian and Middle and Late Jurassic tectonic events before collision against the western margin of North America in the mid- to Late Cretaceous. Various Cretaceous and Cenozoic successor basins overlie these domains but except for the northern Colville Basin all Cretaceous basins and many Cenozoic basins are themselves deformed by subsequent deformational events. The remainder of this presentation focuses on the northern domain on the North Slope.

Early Brookian deformation in northern Alaska resulted from the subduction of the northern margin of North America beneath oceanic arcs of the Paleo-Pacific Ocean and was followed by counter-clockwise rotation of Arctic Alaska as a consequence of rotational rifting of the Amerasia basin in the Early Cretaceous. The termination of this collisional event resulted in widespread ductile extensional deformation in interior Alaska. Late Brookian thrusting began in the Paleogene after about 30 m.y. of tectonic quiescence, forming a thick-skinned north-vergent thrust belt in the Brooks Range and a thin-skinned fold belt in the Colville Basin. Later in the Cenozoic, this deformation became restricted to northeastern Alaska and the adjacent Beaufort Shelf where north-vergent deformation continued into the Neogene and Quaternary. In addition to these principal events, north-vergent folding and thrusting of Devonian age (Romanzof Orogen) is evident in the basement rocks of the northeastern Brooks Range and in the subsurface of the North Slope. This deformation was acquired during an earlier collisional event while the North Slope was still part of the Ellesmerian orogenic belt along the northern margin of Canada.

## Timing and possible mechanisms of tilting of the Barrow arch, Arctic Alaska, revealed by low-temperature thermochronology

*Craddock, William H; Houseknecht, Dave; O'Sullivan, Paul B.*

Along the western Barrow arch of Arctic Alaska, seismic reflection and thermal maturity and compaction data from wells reveal an onshore area of ~104 km$^2$ where more than 1 km of post- Cenomanian section has been removed, approximately in the Cenozoic. Along the strike of the arch to the east, about half of the oil that was originally reservoired at Prudhoe Bay spilled during Paleogene, down-to-the-east tilting. Particularly in light of three recent oil discoveries, there is a practical need to better understand vertical motions along the strike of this geologic element.

We present apatite fission track (AFT) and (U-Th)/He (AHe) data from full-diameter cores from wells along the strike of the Barrow arch. From the NW coast to Point Barrow, AFT data from six wells indicate exhumational cooling was ongoing by ~55 Ma, and persisted into the Neogene. The magnitude of cooling decreased subtly to the east by ~10°C over ~200 km. AHe data resolve the later part of this cooling and corroborate the rates of ~0.5-1.0°C/Myr. 260 km east of Point Barrow, AFT data from the Kalubik Creek 1 well show that maximum paleo-temperatures are similar to modern temperatures.

Although the exhumation mechanism remains unclear to us, we highlight several attributes of the western Barrow Arch that may be relevant. First, Mississippian–Triassic strata pinch out by onlap

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against a long-lived paleo-high in the west, which encompasses the exhumed area and is known as the Arctic Platform. Second, seismic reflection profiles along the Beaufort shelf show that a zone of north-dipping normal faults is truncated to the west by the northern flank of the Arctic platform. The first two observations suggest a rheologic and/or compositional contrast between the Arctic Platform and surrounding crust. Third, the timing of exhumation along the western Barrow Arch is similar to the Paleogene rejuvenation of contraction in the Brooks Range to the south. Although exhumed Cretaceous strata are broadly warped, they are not otherwise internally deformed. At least some of the exhumation along the Barrow Arch may have been caused by crustal flexure related to northward emplacement of northeastern Brooks Range. Finally, bottom-hole temperatures and depth-vitrinite reflectance gradients indicate that the Arctic platform is flanked at present and/or during times of maximum paleo-temperature by areas of elevated heat flow, suggesting an additional mechanism that could have modified crustal buoyancy.

## Influence of inherited sequence stratigraphic geometry on the structure of the foreland fold-and-thrust belt, central Brooks Range, Alaska

*Connors, Christopher; Houseknecht, Dave*

The south-facing ultimate shelf margin of the Upper Jurassic to Neocomian Kingak Shale in the southern National Petroleum Reserve in Alaska (NPRA) results in the stacking of three significant condensed sections, the Triassic Shublik Formation, the Lower Jurassic lower Kingak Shale, and the composite Hauterivian pebble shale unit and Barremian to Albian gamma-ray zone (GRZ) of the Hue Shale. This stratigraphically localized concentration of organic-rich shale controlled the northern limit of the master thrust detachment in the foreland during Paleogene deformation. Northward-vergent thrusting along this master detachment ramps up section to a less well-developed upper detachment to the north. The Carbon Creek Fault Zone, an oblique imbricate system whose orientation is controlled by the geometry and orientation of this shelf margin and corresponding facies changes, segments the foreland into two distinct structural domains that are expressed geomorphically as the southern and northern foothills. Imbrication and uplift are more significant in the southern foothills, but imbrication also is present in the northern foothills, with thrusts that locally ramp up to the paleo-surface. Along trend to the east, this zone transitions into a triangle zone at the Tuktu escarpment, analogously segmenting the foreland into a more deformed southern belt and a less deformed northern belt with similar detachment levels. Across the foothills structural domain in NPRA, shale-rich slope facies in the Lower to middle Cretaceous Torok Formation are structurally thickened to form distinctive fault-bend folds, with superimposed gentle detachment fold segments localized within the slope facies. The map-view geometry of these folds in southern NPRA lacks the large aspect ratio common in many foreland fold-and-thrust belts with more locally plunging and en echelon segments. Along trend east of NPRA, similarly localized structural thickening occurs in parts of the Torok Formation and in the Upper Cretaceous Seabee Formation, but with more pronounced detachment folding and duplexing in the less competent cores of larger folds. In places, imbricate stacking caused steep-limbed folds to form above roof thrusts with more continuous lateral extent. This change in the amount of thickening in incompetent units also appears to have been influenced by the presence of north-south trending lowstand sequence boundaries draped by transgressive shale in both the Torok and Seabee Formations. Subsequent north-vergent thrusting during the Paleogene preferentially detached along many of these transgressive shale drapes. Thus, folds terminate laterally at this boundary.

## Role of structural inheritance on the evolution of rift-scale segmented normal faults: examples from northern California and the East African Rift

*Kattenhorn, Simon A; Krantz, Bob; Muirhead, James D*

Oil and gas reservoirs in extensional environments are commonly associated with segmented normal faults that create permeability barriers and result in compartmentalized systems. For example, producing fields on the North Slope of Alaska are structurally controlled and reflect the end-result of multiple phases of extensional deformation dating back to the Devonian and culminating in Early Cretaceous break-up and opening of the Canada Basin. In response to this polyphase history, structural inheritance was likely an important component of the ultimate reservoir architectures that developed. Analog field studies of structural inheritance in normal faulting environments provide insights into the role of pre-existing structures during polyphase deformation events. We examine two examples from active extensional systems in predominantly volcanic rocks, in which fault architectures and fault evolutionary evidence is well preserved: (1) The Hat Creek fault is the most prominent normal fault within the broadly extending region of the Modoc plateau in Northern California. The fault dissects Late Pleistocene lavas, the oldest of which (~925 ka; maximum cumulative throw of ~570 m) indicates that the Hat Creek fault developed in <1 Myr. Despite this young age, the fault experienced a multi-stage growth history that resulted in three systems of segmented scarps with different ages, throws, and orientations. Our field analysis unraveled the relative timing of fault segments and control on localization by structural inheritance. A polyphase fault history that responded to a progressive ~45° clockwise rotation of the horizontal principal stresses resulted in significant fault geometric complexity as older structures were reactivated during consecutive fault growth stages over a relatively short time frame (~1 Myr). (2) Normal faults dissect volcanic rocks of an active rift system in the ~7 Ma southern Kenya (Magadi) portion of the East African Rift Valley. Stress rotations occurred over similar time scales to those at the Hat Creek fault in response to migrating magma systems and rift segment interactions during the early stages of continental rifting. Evolving fault systems in the Magadi rift were strongly influenced by structural inheritance associated with tectonic fabrics within underlying Proterozoic rocks of the Mozambique orogenic belt. This inheritance is manifested in the segmentation of the primary rift border fault, the Nguruman fault, which exhibits a ~1600-m-high surface scarp but has likely accrued ~5 km of cumulative throw. Younger faults at the rift center, such as the <1.4 Ma Kordjya fault, have developed prominent fault scarps (up to 350 m high) oblique to the dominant rift-fault fabric and parallel to the inherited basement fabric. At the surface, this fault has also cannibalized Pliocene rift faults in an en echelon pattern in response to temporal changes in the horizontal principal stress orientations. The Hat Creek fault and East Africa Rift examples reveal the importance of evolving fault complexity in extending basins influenced by polyphase faulting episodes that resulted from changes in both regional-scale (e.g., plate boundary forces) and basin-scale (e.g., rift-axial magmatism) rift processes. Such changes strongly impact rift basin evolution, the distribution of depositional

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sequences, fluid pathways, and reservoir compartmentalization.

## New insights to Alaska Range orogenesis from the northern margin of the Copper River basin

*Waldien, Trevor; Roeske, Sarah; Allen, Wai*

The stratigraphic and structural evolution of basins in south-central Alaska record the Cenozoic development of the Alaska Range orogen in response to the actively evolving Denali fault system. Published work on the Tanana basin north of the Alaska Range shows fault-bounded Mio-Pliocene strata contain a transition between fine-grained lacustrine strata and proximal alluvial gravels, interpreted to record unroofing in the Alaska Range. Geophysically imaged thrust faults and associated growth strata in the Susitna basin south of the Alaska Range are interpreted to reflect interaction between the Denali and Castle Mountain fault systems and related topographic development. East of the Susitna basin, the Copper River basin remains an under studied basin at the southern periphery of the Alaska Range, primarily due to the lack of exposed Cenozoic strata.

We report new 1:10,000 scale geologic mapping, provenance data, and geochronology from inverted Cenozoic strata at the northern margin of the Copper River basin. Our analysis focuses on the region surrounding the headwaters of the Delta River, where the Trans-Alaska pipeline crosses the Alaska Range. New mapping reveals that conglomerate strata at the northern margin of the Copper River basin have been incorporated into a south vergent thrust system splaying from the south side of the Denali fault. Major thrusts in this zone include the Broxson Gulch fault west of the Delta River and the McCallum Creek fault east of the Delta River. Published ages show that conglomerate strata are as young as mid Pliocene in the footwall of the McCallum Creek fault and as old as Oligocene in the footwall of the Broxson Gulch fault. The fault-bounded conglomerate strata contain an array of meta-volcanic, intrusive, and metamorphic clasts, which match to provenance areas within the Wrangellia composite arc terrane to the south, the Yukon-Tanana composite metamorphic terrane north of the Denali fault, and the Maclaren metamorphic belt in between. New and existing detrital zircon U/Pb age spectra from conglomerate matrix sand supports sediment input from nearby uplifted terranes and recycling from inboard terranes. Existing low-temperature cooling ages from the adjacent regions of the Alaska Range show Oligocene-Miocene rapid cooling in the Alaska Range west of the Delta River and late Miocene-recent rapid exhumation in the range to the east. This pattern matches the apparent age progression exhibited by footwall conglomerate strata and indicates a causal link between unroofing in the Alaska Range and adjacent basin development.

Collectively, fault bounded Oligocene-Pliocene conglomerate strata at the northern margin of the Copper River basin record unroofing in the adjacent eastern Alaska Range. Oligocene-recent thrust stacking via slip in the Broxson Gulch and McCallum Creek fault systems has overtaken the proximal portion of the Copper River basin, causing the boundary between the Alaska Range and Copper River basin (i.e. the range front) to migrate southward. Since the last glacial maximum, active shortening structures at the current range front have allowed the Delta River to capture streams from the Copper River watershed. The Oligocene-Present evolution of the northern margin of the Copper River basin augments results from the Tanana and Susitna basins, illustrating how the Denali fault and associated splays fundamentally control the morphology and stratigraphy of basins peripheral to the Alaska Range.

## The Peters Hills basin, a Neogene piggyback basin on the Broad Pass thrust fault, south-central Alaska

*Haeussler, Peter J; Saltus, Richard W; Stanley, Richard G; Ruppert, Natalia; Lewis, Kristen A; Karl, Susan M; Bender, Adrian M*

The Neogene Peters Hills basin formed along the south flank of the Alaska Range and lies northwest of the Susitna basin and south of Denali. Northeast of these basins, a long-hypothesized-but-never-observed fault has been inferred to lie along the linear trend of Broad Pass. If this hypothetical fault were to extend to the southwest, it would lie between the two basins. Here, we infer this fault is a large southwest-vergent thrust fault that is inextricably linked to the development of the Peters Hills basin. The sedimentary fill of the Peters Hills basin consists of weakly lithified, middle Miocene to Pliocene terrestrial sedimentary rocks deposited by braided and meandering streams. The basin is no longer a depocenter, and it was incised by the major glaciers of the Alaska Range. Gravity modeling indicates a 2,200-m maximum thickness of sediments in the basin. There were several pulses of deposition and deformation of the basin strata, and now the mean dip is 10° to the southeast. The basin formed during a time in which there was regional shortening as evidenced by the exhumation of Denali, but it also has a northeast-striking active normal fault within it. These seemingly contradictory observations of the formation of a basin concurrently with regional contraction and normal faulting are most consistent with the formation of the Peters Hills basin as a piggyback basin, which formed on top of a Neogene, southwest vergent, Broad Pass thrust fault. Movement along this thrust raised a ridge of Jurassic and Cretaceous rocks, which then trapped Miocene and Pliocene fluvial sediments behind it that were derived from the growing Alaska Range. The presence of a Broad Pass thrust fault is consistent with regional structural, stratigraphic, seismicity, gravity, and aeromagnetic data. Activity on the Broad Pass thrust would help explain the westward decrease in Quaternary slip rate along the Denali fault system, and if so, it would constitute a seismic hazard that could produce earthquakes in the $M_w$7.6-7.8 range.

## Geology and petroleum potential of the Susitna basin, south-central Alaska

*Stanley, Richard G; Haeussler, Peter J; Lewis, Kristen A; Lillis, Paul G.; Shah, Anjana K; Potter, Christopher J; Phillips, Jeffrey D; LePain, David L.; Gillis, Robert J; Helmold, Kenneth P; Shellenbaum, Dianne; Saltus, Rick*

The U.S. Geological Survey and Alaska Department of Natural Resources are cooperating in scientific investigations to provide increased understanding of the geology and petroleum potential of the Susitna basin, south-central Alaska. This joint effort has generated new information through interpretation of 425 line-miles of seismic data, gravity and magnetic modeling, stratigraphic and structural studies, and organic geochemical analyses.

The Susitna basin is adjacent to the oil-and-gas producing Cook Inlet basin and separated from it by the Castle Mountain fault, a strike-slip fault with more than 100 km of post-Jurassic right-lateral displacement. The Susitna basin consists of Paleogene and Neogene nonmarine coal-bearing strata about 4-5 km thick that are broadly similar in lithology and age to the Cook Inlet basin but have been

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penetrated by only seven exploratory wells that found indications of gas associated with coaly horizons but no commercial petroleum production. Mesozoic marine shales that are the source rocks of oil in the Cook Inlet basin have not been found in the Susitna basin or in the surrounding uplands.

The deepest strata in the Susitna basin comprise a 2-km-thick sequence of late Paleocene to middle Eocene nonmarine coal-bearing sedimentary and volcanic rocks that are hypothesized to record crustal extension, volcanism, and sedimentation related to subduction of an oceanic spreading ridge. This Paleogene sequence is unconformably overlain by Miocene and younger nonmarine coal-bearing strata greater than 2.5 km thick in a depocenter that is bounded by steep, north-striking reverse faults and likely formed during contractional tectonism associated with subduction of the Yakutat microplate beneath south-central Alaska. The Peters Hills basin, located northwest of the main Susitna basin depocenter, consists of a 2-km-thick sequence of Miocene and younger coal-bearing nonmarine strata that may have been deposited in a thrust-top or “piggyback” basin above a hypothesized Broad Pass thrust fault. Basement rocks beneath Paleogene strata in the Susitna basin have not been reached by wells but are inferred from surface geologic mapping and aeromagnetic information to include pre-Cenozoic metamorphic and plutonic rocks similar to those in the nearby Talkeetna Mountains as well as strongly deformed Jurassic and Cretaceous flysch.

The Susitna basin appears to be prospective mainly for microbial methane. Coal and carbonaceous shale of Paleocene to Miocene age are likely source rocks of microbial methane and are shown by Rock-Eval pyrolysis and other laboratory analyses to be possible sources of oil and thermogenic gas. Potential reservoir rocks include Eocene and younger fluvial sandstones, many with more than 30 percent porosity and more than 1 Darcy permeability. Potential seals include fine-grained fluvial overbank deposits. Several undrilled structures have been identified on seismic profiles. Vitrinite reflectance values of strata in the Trail Ridge Unit 1 well, the deepest well in the basin with a true vertical total depth of 3.85 km, suggest that the projected depth to the top of the oil window (Ro of 0.6 percent) is about 5.1 km. A hypothetical and very speculative oil play may be present along the southwestern margin of the basin where coal-bearing strata may have been structurally buried and reached thermal maturity at depths of 5.1 km or deeper beneath the northeast-directed Beluga Mountain thrust fault.

## Fracture modeling of the Main Limestone reservoir rocks, in the Kirkuk anticline in Kurdistan- N. Iraq

*Nazhat, Shirzad B*

This study describes the fractures and other related features observed from eighteen thousand feet of core, covering the Main Limestone section(Eocene/Paleocene-Oligocene) of the Kirkuk Anticline, in Kurdistan-North Iraq, with emphasis on fracture orientation, frequency, type, pattern, vugs, stylolites, and macroporosity.

The results confirm that the kirkuk structure is extensively fractured and that good fluid connection exists along the longitudinal axis of the structure. Less fluid connection is observed across the structure. Total tension strike fracture sets are twice the total tension dip sets and about the total opened diagonal sets. Vertical and nearly vertical fractures are the most dominant; also filled and closed fractures are frequent in the basinal units, in contrast to non-basinal units where fractures are the more frequent type.

*On Field Trip #3 - Geology of Northern Alaska, you will drive the Dalton highway alongside the Trans Alaska Pipeline, stopping at Canning River (above) and the Marsh Fork Fold (left). This 500 mile transect of the Brooks Range and North Slope visits key outcrops to explain the complex geologic history of the region and see in outcrop many of the reservoirs encountered in the sub-surface.*

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# Geophysics, Petrophysics, and Reservoir Description: From Basins to Pores

*Chairs:* *Shuvajit Bhattacharya*
*Leo Brown*

**8:00 Introductory Remarks**

8:05 Sean Wagner
*Impact of Independent Simultaneous Source (ISS®) survey in Arctic Alaska*

8:25 Tiffany Carey
*Evolution of Land Seismic Acquisition with CSI on the North Slope*

8:45 Leo Brown
*Compressive seismic imaging application at Lookout Field, Alaska*

9:05 James Ballard
*Undeveloped petroleum potential of the offshore Santa Maria basin, California*

**9:25 Break (30 min)**

9:55 Kelley Brumley
*Regional multibeam surveys for seep exploration and geochemical coring in frontier areas*

10:15 Shuvajit Bhattacharya
*Application of Data Analytics and Geostatistics for Integrated Shale Facies Modeling*

10:35 Chaipornkaew Laainam
*Basin-scale geomechanics of poroelastoplasticity and its influence on predicting stress-strain behaviors and flow dynamics, a case study from Anadarko Basin, Oklahoma*

10:55 End of Morning Session

## Impact of Independent Simultaneous Source (ISS®) survey in Arctic Alaska

*Wagner, Sean; Alexander, Gino; Bailey Emerson, Rebecca; Fishter, Kristin; Urban, Dennis*

Independent Simultaneous Sources (ISS®) was deployed in the Arctic for the first time in order to achieve a step change in data quality by acquiring high trace density, broadband, vibroseis data. Data quality, noise, HSE, and productivity issues were analyzed in an effort to more efficiently deliver the data in fewer days than previous surveys. Data acquisition faces numerous challenges including a short operating season bounded by tundra closure, ice thickness, extreme weather conditions and darkness. Additionally, legacy data has been challenged with issues such as wind noise, cultural noise in a major oil field and flex wave on floating ice. The ISS method combined with autonomous node recording technology offered operational advantages delivering an order of magnitude increase in trace density and source productivity (over 11,000 VPs on the best day). This efficiency improvement translated to less HSE exposure hours and allowed us to complete the survey in fewer days during the short operating season.

Additionally, improved imaging was required to resolve structures and position faults with less uncertainty for future well placement. This acquisition method provided data that produce a significant uplift in imaging quality, attributes, S/N ratio, delivered broadband reflectivity and ability to build a more accurate velocity model. In addition to the operational advantages, we will show examples of the uplift and impact the data has had on business delivery and discuss the overall improvement in data quality.

## Evolution of Land Seismic Acquisition with CSI on the North Slope

*Carey, Tiffany; Williams, Laurence; Li, Chengbo*

Seismic acquisition methods in the Arctic have evolved significantly over the past decade from both a technical and operational perspective. New and enhanced techniques have allowed for the acquisition of much higher quality 3D seismic data with less operational effort, decreased HSE expo-

sure and increased efficiency and productivity over the course of a full acquisition season. Land acquisition in an Arctic environment does not come without a spectrum of difficulties and sensitivities due to operating in a remote and climatically challenging setting. The biggest limitations of the Arctic environment are the short season length and the difficulty in accessing tundra in remote areas. Operational capability in the Arctic is generally dictated by available quantity of equipment, suitability of recording systems and crew experience. Balancing this with stringent HSE requirements, cost effective survey design and incorporating new technologies plays a significant role in the overall success of each seismic season.

ConocoPhillips has used compressive sensing theory coupled with other modern acquisition concepts such as nodal technology and simultaneous sourcing, to develop a new acquisition method called Compressive Seismic Imaging (CSI). Simultaneous sourcing consists of using of several single vibrators, each transmitting a single sweep independently, rather than arrays of vibrators taking multiple sweeps at each source point. CSI allows for acquiring source points with minimal temporal and spatial separation, and afterward uses a deblending method to separate individual shot records when the data are processed. Deblending simultaneously acquired source points has been verified by several case studies designed to demonstrate that it was possible to achieve the same or better quality data than from earlier surveys using fleets of multiple vibrators. The high efficiency of simultaneous sourcing relative to historical methods allows a significant increase in both source points and trace density, and therefore a notable improvement in signal to noise ratio (S/N).

Non-Uniform Optimal Sampling (NUOS) is another component of the CSI method. This implementation of compressive sensing theory has allowed for the optimization of source and receiver stations in a program, meaning a reduction in and more flexibility in the positioning of both. Source and receiver stations may be offset around obstacles such as water bodies and rugged terrain, and can be dropped in areas that pose a safety and/or environmental risk. The impact on subsurface data coverage, as a result of relocated or dropped points, is compensated for during the reconstruction stage of the processing flow. Therefore, there is less of a requirement to acquire every planned source and receiver point than has historically been the case.

**Notes:**

CSI has evolved Arctic seismic acquisition in several significant aspects. Coalescing NUOS, nodal and simultaneous source techniques, the number of source stations acquired in a 24-hour period has now increased by an order of magnitude. Concurrently, the amount of receiver stations required per spatial unit of area (i.e. $mi^2$) has dropped. The result is higher quality data with an overall reduction in operational effort. Moving forward, this concept will allow for the acquisition of much larger 3D seismic surveys within a single season on the North Slope than previously possible.

## Compressive seismic imaging application at Lookout Field, Alaska

*Brown, Leo; Staples, Evan; Chang, Juntao*

This is the 2nd of two talks on compressive seismic imaging (CSI), with the 1st covering acquisition. The emphasis in this presentation is on imaging in the Lookout area, showing examples from the overburden, reservoir section, and deeper intervals. Significant improvements in imaging of structural and stratigraphic features were realized. The new data is also suitable for quantitative seismic interpretation, as amplitude fidelity was preserved in processing.

The Lookout Field is located onshore on the western North Slope of Alaska, inside the National Petroleum Reserve – Alaska (NPR-A). The discovery well, Lookout 1, was drilled in 2001, and found oil in Upper Jurassic sandstone at around 7800 ft. depth. Expected field startup is in 2018.

The legacy seismic data over Lookout is an exploration-quality 3D survey: 1999 NPRA East. Compared to current development-quality 3D surveys on the North Slope, it has low fold, large bin size, and narrow azimuthal coverage. Lookout field was originally identified as a stratigraphic trap with an anomalous seismic amplitude response (DHI) on this legacy survey. Heading into development, important uncertainties remained regarding position of field margins, internal stratigraphy, and fault compartmentalization. It was determined to acquire a new seismic survey in 2015 for reservoir characterization, prior to well planning and development.

There are several challenges to imaging in the Lookout area that are common to much of the western North Slope. These include surface ice lakes, variable permafrost conditions, and imaging through the Fish Creek slumps. The acquisition parameters and processing methods of the new survey were designed to overcome these imaging difficulties. The new survey has high fold, smaller bin size, and full azimuthal coverage. The CSI design offered the potential for greater acquisition efficiency, meaning that in this case a larger area and/or higher density coverage could be acquired for the same cost and time. The Lookout CSI was also a relatively small (~80 $mi^2$) project that proved up the concept and practicality of CSI for future larger surveys. Since the 2015 Lookout survey, additional CSI surveys have been acquired on the North Slope.

## Undeveloped petroleum potential of the offshore Santa Maria basin, California

*Ballard, James H.*

Offshore seismic surveys (now in the public domain) and exploration drilling led to the discovery of several potential oil fields in the offshore Santa Maria basin, California. The seismic and well data also help to better understand this tectonically complex area. The current transpressional stress regime has created thrusted anticlinal trends extending from onshore, with a long history of oil production, to the offshore discoveries. The anticlinal trends change orientation offshore and merge into the Hosgri fault system. The Hosgri has strike-slip displacement, but the structures are dominantly compressional with strikes sub-parallel to the San Andreas.

The offshore wells discovered heavy oil in the Miocene Monterey formation, eight fields north of Point Arguello. Only one of these was developed, Point Pedernales field (106 MMBO). The others were unitized under the federal OCS statutes but became the focus of state political opposition.

The wells encountered oil in fractured siliceous rocks and carbonates in the Monterey. These zones have high matrix porosities, but fractures provide most of the permeability. Many of the wells tested relatively low gravity oil (< 15 deg API) at potentially economic rates (100’s to 1000’s BOPD). Producing this oil offshore has unique challenges. Conservative estimates for the undeveloped fields total 974 MMBO, technically recoverable. They are now on “open acreage”. Politics, and low oil prices, will keep them from being produced for many more years.

Note: this is a companion paper to "Undeveloped petroleum potential of the western-most Santa Barbara Channel, offshore California" presented at the PCS and RMS AAPG Joint Meeting in 2016.

## Regional multibeam surveys for seep exploration and geochemical coring in frontier areas

*Brumley, Kelley; Mitchell, Garrett; Jamshid, Gharib*

Chemosynthetic benthic communities are distributed throughout the oceans where hydrocarbon-rich gases and fluids permeate through the seafloor. Hydrocarbon "cold seeps" and associated sessile fauna physically modify the seafloor as fluid seepage creates topographically-distinct features such as mud volcanoes, pockmarks and depressions, methane hydrate deposits, flanks of salt domes, and characteristic patterns of seafloor faulting. Additionally, cold seeps and associated chemosynthetic communities are commonly associated with authigenic carbonate deposits which are the product of the anaerobic oxidation of methane, as well as aggregations of cold seep clam and mussel shells, which are relatively hard and/or rough compared to the seafloor around them. Oil droplets and gas bubbles are also commonly observed in the water column in association with hydrocarbon cold seeps.

The seafloor morphology, character of the seafloor material, hydrocarbons in the water column, and subsurface indicators of shallow gas, can all be investigated using geophysical remote sensing techniques based on their acoustic reflectivity properties. Interpreting these geomorphologic and reflective patterns from multibeam echosounder data (bathymetry, backscatter and water column) integrated with subbottom profiler datasets is a fundamental component of seep hunting and geochemical exploration surveys in frontier regions. Integration of these data sets allow for precise targeting of piston cores at hydrocarbon seeps to collect sediment samples for geochemical analysis.

Multibeam seafloor mapping allows for identification of seep-related features and, through analysis of several terrain variables, characterization of their geomorphological signature, which can be used to constrain seafloor seep distribution on a regional scale. This approach can help identify areas of

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potentially high benthic biodiversity that lack the classic geophysical reflective indicators. In the Arctic, a regional multibeam dataset would not only provide information on seeping hydrocarbons, but could also be used for charting, habitat characterization, baseline studies, geohazard assessments (e.g. extent of ice gouge stamukhi zone), and providing other information necessary for infrastructure development. Here we will discuss methods for the utilization of multibeam data for regional studies in general and seep studies in particular, especially as it relates to the Alaskan Arctic.

## Application of Data Analytics and Geostatistics for Integrated Shale Facies Modeling

*Bhattacharya, Shuvajit; Carr, Timothy R.*

Application of data analytics and geostatistics are becoming increasingly popular to analyze subsurface data and better understand geologic history at multiple scales. The upper and lower shale members in the Bakken Formation of the Williston basin in North Dakota are selected for this study. The objective of this study is to classify, predict, and model shale lithofacies at core, well, and regional scales for better understanding of depositional history of shale lithofacies. Based on core samples and advanced geochemical spectroscopy logs, a quantitative workflow is designed to classify lithofacies, in terms of mineralogy, Total Organic Carbon, and petrophysical properties. Five different shale lithofacies are identified, such as organic mudstone, organic siliceous shale, gray siliceous shale, gray mixed shale, and gray mudstone. Support Vector Machine, a data analytics algorithm, is used to identify the pattern of different lithofacies, associated with petrophysical parameters from conventional well logs from ~500 wells. Bayesian network theory is applied to understand the causalities of petrophysical relationships to lithofacies. The classification accuracy of different lithofacies is more than 87%. After core and log-based lithofacies classification and prediction, Sequential Indicator Simulation, a geostatistical algorithm, is used to generate 3D stochastic geocellular lithofacies models spanning an area of ~13,000 sq. miles. The results show that both upper and lower Bakken shale members are vertically and laterally heterogeneous at multiple scales. Several factors, such as source of elements, paleo-redox conditions, and organic matter productivity etc. appear to have controlled the depositional pattern of different shale lithofacies.

## Basin-scale geomechanics of poroelastoplasticity and its influence on predicting stress-strain behaviors and flow dynamics, a case study from Anadarko Basin, Oklahoma

*Chaipornkaew, Laainam; Schoellkopf, Noelle; Hosford Scheirer, Allegra; Mukerji, Tapan*

Basin and petroleum system modeling (BPSM) simulates the stress history in sedimentary basins. In tectonic-driven regimes, the stress state is controlled by the overburden load and tectonic forces. Thus, at least a poroelastic model is needed to derive 3D stress tensors in porous media using a fully-coupled deformation and fluid flow formulation. However, poroelasticity alone is not enough. The elastic constitutive equations allow the modeled material to sustain high levels of shear with minimum deformation; simply implementing the poroelastic model yields unrealistic high shear stress values on materials that have gone beyond yield strength. It is necessary to go beyond poroelasticity to poroelastoplasticity. This study investigates the effects of plastic deformation for shear failure and compaction at geological timescale for the Anadarko Basin. We started with a 3D BPSM project supplied by the USGS Digital Data Series 69-EE. Because that model did not incorporate pressure effects, we integrated pressure and paleo-pressure data and utilized a poroelastoplastic workflow in BPSM to realistically capture the effects of plastic deformation in predicting stress and overpressure in the context of sedimentary basin. The effects of variable lithological facies and rock strength anisotropies arising from sub-grid heterogeneity will be incorporated. Additionally, we plan to include available production data, emerging from the new petroleum plays of this rejuvenated basin, to track the response of migrating fluids to plastic deformation. Plastic constitutive equations predict shear stresses that facilitate porosity loss and permanent deformation, this workflow should allow for a more realistic estimation of stress and flow dynamics in this ultra-deep basin. Beyond the Anadarko basin, this study will serve as a case study to test the most appropriate poroelastoplastic constitutive relations for modeling basin-scale deformation.

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# New Research on Alaska North Slope Source Rocks and Unconventional Plays

*Chairs:* *Allegra Hosford Scheirer*
*Palma Jarboe*

**8:00 Introductory Remarks**

8:05 Julie Dumoulin
*Triassic facies patterns in northwestern Alaska: insights into Chukchi Shelf-Hanna Trough source rocks and Mesozoic tectonics*

8:25 Katherine Whidden
*Middle - Upper Triassic Shublik Formation: Lateral and vertical facies variability within a revised sequence stratigraphic framework.*

8:45 William Rouse
*Middle - Upper Triassic Shublik Formation: Surface to subsurface correlation within a revised sequence stratigraphic framework*

9:05 Palma Jarboe
*New observations on oil-source rock correlations in Arctic Alaska*

**9:25 Break (30 minutes)**

9:55 Zachary Burton
*Advanced geochemical technologies determine source-rock depositional environment, crude oil thermal maturity and the extent of oil cracking in the frontier Pegasus Basin, New Zealand*

10:15 April Knox
*Petrographic and microfacies analysis of the Shublik Formation, northern Alaska: implications for an unconventional resource system.*

10:35 Rachael Moreland
*Petrophysical techniques for asset analysis on the North Slope*

10:55 Paul Lillis
*Are Tertiary coals from central and southern Alaska source rocks for oil?*

11:15 Allegra Hosford Scheirer
*A new methodology for determining source rock quality and quantity with applications to the Alaska North Slope*

## Triassic facies patterns in northwestern Alaska: insights into Chukchi Shelf–Hanna Trough source rocks and Mesozoic tectonics

*Dumoulin, Julie A; Whidden, Katherine J*

The main oil charge encountered on the Chukchi shelf has been attributed to a facies of the Triassic Shublik Formation that has more detrital components and less carbonate than well-known Shublik strata on Alaska's North Slope. A unique exposure of Triassic rocks at Surprise Creek (SC), near the Chukchi coast, displays characteristics transitional between those of the North Slope Shublik and the Otuk Formation, a distal, deeper water equivalent exposed in the Brooks Range. Petrographic and geochemical studies of the SC section allow us to characterize what may be an outcrop analog for source rocks in the Chukchi shelf. New data from Otuk sections on Cape Lisburne (CL) 100 km to the west provide additional insight into Triassic facies patterns in this area. The base of the ~25 m SC section is the core of an anticline and the top is a Jurassic unconformity, overlain by Oxfordian to Valanginian Kingak Shale (the same succession penetrated by the Klondike well on the Chukchi shelf). The main lithofacies at SC is siliceous to calcareous mudstone that is variously organic-rich (0.3-9.5% TOC; >2% TOC for 22 of 44 samples) and contains sparse to abundant Ladinian and Carnian-Norian flat clams. Subordinate lithologies include phosphatic nodules (typical of the Shublik but rare in the Otuk) and siliceous radiolarite (characteristic of the Otuk but absent from the Shublik). Yellow-weathering bentonite(?) layers (2 to 3 cm thick) are similar to beds seen elsewhere in the Otuk. Concentrations of large *Tasmanites* algae resemble ~coeval occurrences in Svalbard, the Barents Shelf, and Siberia. Vitrinite reflectance data from SC strata span the oil window (VR 0.74-1.38%). The SC section has similarities to the Otuk in the area of the giant Red Dog Zn-Pb-Ag deposits ~100 km to the south, but differs in that SC contains phosphate and more abundant megafossils and lacks chert. SC strata also lack the glauconitic siliciclastic facies typical of upper Shublik sections in petroleum exploration wells of the northwest North Slope (e.g., Peard) and Hanna Trough margin (Diamond). Overall, the SC section is most like the "Shublik equivalent sequence" in the Klondike well (TOC 2-8%), although that section did not contain phosphate. The Otuk section at CL resembles that in the Red Dog area, and both contain organic-rich zones of probable early Norian age (9% TOC at Red Dog). The CL section differs in that it contains a 10-m-thick interval of sandstone interbedded with flat clam wacke-packstone and cherty mudstone. New stratigraphic data indicate that the Otuk sandstone at CL is ~coeval with the Sag River/Karen Creek Sandstone (late Norian?), but it differs in composition, provenance, and setting. CL sandstone yields abundant young (~220-330 Ma) detrital zircon U/Pb ages (Miller et al., 2006), is heterolithic, and formed as turbidites. In contrast, Sag River/Karen Creek sandstone lacks young zircons, is quartz-rich, and formed in a shallow shelf setting. Structural analysis indicates that the Otuk at CL was deposited in a distinct sub-basin that received siliciclastic input from the (present-day) northwest. Detrital zircon U/Pb age spectra from CL resemble those of Triassic sandstones in Chukotka and the northern Sverdrup basin but differ greatly from those of Triassic strata elsewhere in northern Alaska.

## Middle - Upper Triassic Shublik Formation: Lateral and vertical facies variability within a revised sequence stratigraphic framework

*Whidden, Katherine J; Dumoulin, Julie A; Rouse, William A*

A revised stratigraphy for the Middle and Upper Triassic of northern Alaska has been developed, which facilitates the understanding of spatial and temporal variability of facies patterns within the Arctic Alaska Basin (AAB). The Shublik and partially age-correlative Otuk Formations can be broken into three units that illustrate lithologic changes from proximal (north in present-day coordinates) to distal (south in present-day coordinates) settings through time. The lower clastic (LC) unit consists of proximal sandstone, siltstone and interbedded mudstone, and distal mudstone with lesser amounts of calcareous mudstone. This unit contains relatively little carbonate or biogenic silica content across the basin. Proximal strata of the overlying middle carbonate-chert (MCC) unit are predominantly interbedded limestone and mudstone, whereas the more distal MCC strata consist of interbedded chert, limestone and mudstone. Deposition of this middle unit was mainly from biogenic accumulation of proximal calcareous and distal siliceous components. The upper clastic-carbonate (UCC) represents a return to mainly siliciclastic deposition in proximal strata, with mudstone overlain by sandstone. Distally, interbedded chert and

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mudstone are overlain by an interval of limestone and mudstone, which underlie another interval of interbedded chert and mudstone in the west. Late Triassic siliciclastic input seen in the proximal parts of the UCC unit did not significantly affect distal sedimentation. Overall bedding thicknesses in proximal strata are on the centimeter to decimeter scale, whereas bedding thicknesses in distal strata are on the centimeter scale. All three units have sections that possess measured total organic carbon in excess of 2 weight percent. These data imply that the depositional and diagenetic conditions for the production and preservation of organic matter occurred episodically within the AAB throughout the Middle and Late Triassic. Thus, the most promising unit for self-sourced reservoirs is the MCC unit, where organic-rich mudstone is interbedded with brittle, carbonate-rich and chert-rich intervals. The three lithologic units can be further subdivided into five stratal packages that are bounded by widespread transgressive surfaces. The transgressive surfaces are defined by both lithologic changes and changes in well log response. These five stratal packages are interpreted to represent five transgressive-regressive sequences that range in duration from 6 to 10 million years, based on the revised stratigraphic framework. Thus, the five sequences recognized in the Shublik Formation are likely 2nd order cycles.

## Middle – Upper Triassic Shublik Formation: Surface to subsurface correlation within a revised sequence stratigraphic framework

*Rouse, William A; Whidden, Katherine J; Dumoulin, Julie A*

Recent work on cores and outcrops of the Middle – Upper Triassic Shublik Formation has facilitated surface to subsurface correlations across the Alaska North Slope within a revised sequence stratigraphic framework. Five stratal packages have been identified and interpreted to represent five transgressive-regressive sequences, each of which ranges in duration from 6 – 10 million years. Each of the five sequences generally consists of a thin (~2.5 m) transgressive systems tract that exhibits a "bell shape" log motif with an abrupt base and an upward trend of increasing gamma-ray values overlain by one or more progradational parasequences within the regressive systems tract, each of which exhibits a "funnel shape" log motif with an upward trend of decreasing gamma-ray values and an abrupt top. Maximum flooding surfaces are commonly associated with the highest gamma-ray values within a sequence.

Outcrop spectral gamma-ray profiles from the eastern Brooks Range were used to correlate observed stacking patterns into nearby exploration wells. Petrophysical log data from 123 wells were used to conduct a regional correlation of the Shublik Formation. Fourteen wells with cored intervals within the Shublik Formation were identified to corroborate regional correlations. Isochore maps constructed for each sequence illustrate the influence of paleohighs on Shublik Formation depositional patterns, and suggest the timing of reactivation of several older tectonic elements during Shublik deposition. Middle Triassic isochore maps show the development of localized depositional thickening within an embayment bounded by the Barrow and Colville highs, along with southward thickening off of the Mikkelsen High. This depositional pattern persisted until the middle of the Late Triassic, during which accommodation decreased in the embayment and large amounts of sediment were routed to and accommodated in the Ikpikpuk and Meade basins, and between the Fish Creek Platform and Mikkelsen High. These depocenters suggest reactivation of the Fish Creek Platform, Ikpikpuk Basin, and Meade Basin during the Late Triassic. The broad thickening around Point Barrow during the Late Triassic may reflect initial sediment influx from rift shoulder uplift to the north, and foreshadow a similar thickening in the lower part of the overlying Jurassic Kingak Shale.

## New observations on oil-source rock correlations in Arctic Alaska

*Jarboe, Palma J.; Moldowan, J. Mike; Barbanti, Silvana M; Lillis, Paul G.; Houseknecht, Dave*

The USGS has initiated research to develop a better understanding of Arctic Alaska petroleum systems. The main objectives of this effort are to establish a set of advanced geochemical criteria for a) conducting oil-source rock and oil-oil correlations, b) distinguishing sources of mixed provenance, c) evaluating compositionally-altered oils (i.e., biodegraded, highly mature), and d) reconstructing migration pathways from source rock to reservoir by incorporating seismic and other subsurface data. Initial work involved geochemical analyses of bitumen extracts from whole cores of known source rocks and oils from producing fields and well tests.

Samples have been analyzed by quantitative whole oil gas chromatography-flame ionization detection (GC-FID), GC-mass spectrometry (GC-MS) and GC-tandem mass spectrometry (GC-MS/MS) of biomarkers, and quantitative diamondoid analysis (QDA).

Bitumen has been extracted and analyzed from multiple samples throughout three source-rock cores to evaluate vertical and facies-related variability: the Amerada Hess Northstar 1 and Tenneco OCS YO338 Phoenix 1 from the Triassic Shublik Formation, and the USGS North Kalikpik 1 from the Lower Cretaceous pebble shale unit (PSU) and gamma-ray zone (GRZ) of the Hue Shale. Bitumen extracted from the Phoenix core displays an unusually wide variation in geochemical character, suggesting the presence of both indigenous bitumen and migrated oil. In contrast, bitumen extracted from the Northstar core displays uniform geochemical character indicative of a more clay-rich facies than the widely recognized calcareous facies. This result helps delineate a clay-rich Shublik source-rock, the presence of which has previously been suggested based on geochemistry of produced oil from Northstar, NW Milne Point, and Sandpiper accumulations. Bitumen extracted from the North Kalikpik core displays a distinct vertical change in organic facies reflecting the gradation from the PSU into the GRZ. This result suggests the potential for developing criteria for distinguishing oils sourced from these units.

Oils have been analyzed from seeps and wells in the National Petroleum Reserve in Alaska (NPRA), and from multiple reservoirs in producing fields and new discoveries east of NPRA. Representative source-related and taxon-specific biomarker parameters have successfully constrained depositional environment, age, and source organic matter input for most oil samples in this study. These results indicate a positive correlation between several of the oils and the calcareous facies of the Shublik Formation as the primary source. Still, many of the oils appear to be mixed, with both high- and low-maturity source contributions. Thus far, it is unclear whether the secondary contributions are from a different source formation, facies, or thermal-maturity setting. Initial QDA results and GC-FID profiles have identified the presence of multiple sources and provided evidence in support of a secondary gas charge into the producing reservoir for most of the oils.

Although a certain amount of ambiguity exists in

**Notes:**

our preliminary data, we are encouraged that advanced geochemical analyses will enable us to distinguish oil-groupings, reveal end-member sources and/or co-sources, and evaluate the proportion of each contributing source. Our goal is to integrate these results with other subsurface data to interpret oil source to sink relationships, including likely migration pathways.

## Advanced geochemical technologies determine source-rock depositional environment, crude oil thermal maturity and the extent of oil cracking in the frontier Pegasus Basin, New Zealand

*Burton, Zachary F.M.; Moldowan, J. Mike; Hosford Scheirer, Allegra; Magoon, Leslie B.; Peters, Kenneth E.; Graham, Stephan A*

New Zealand's East Coast Province contains over 300 oil and gas seeps and shows, proving at least one active petroleum system and opportunity for successful oil and gas exploration. Despite more than 100 years of petroleum exploration interest, understanding of petroleum systems in the province's sedimentary basins is limited. Efforts thus far have focused primarily on the structurally complex East Coast Basin, while the nature of the deepwater Pegasus Basin is even less constrained.

We performed biological marker (biomarker) and diamondoid analysis from five onshore oil seeps to investigate the origin of petroleum in the deepwater Pegasus Basin. The geochemical properties of each oil sample help to constrain the depositional setting and age of potential source rock(s) within the basin. Our results suggest an overall marine source-rock depositional environment but highlight distinctions in the relative amount of terrigenous input. We confirm previous assumptions of a Cretaceous or younger source rock age. We also present new evidence on the thermal maturity of potential source rock(s) and the extent of thermal cracking of oil in both the Pegasus and East Coast basins. Our study presents the first diamondoid-based assessment of these oils, and, to the extent of our knowledge, of any New Zealand oil samples.

We place our results within a framework of previously compiled oil sample geochemical analyses for the whole of New Zealand. Taken together, these analyses may help to guide future exploration work in the Pegasus Basin.

## Petrographic and microfacies analysis of the Shublik Formation, northern Alaska: implications for an unconventional resource system

*Knox, April; Whalen, Michael T*

The North Slope of Alaska includes a world-class conventional petroleum system, one of the most prolific in the United States, that has been producing for approximately 40 years. The decline in conventional hydrocarbon production and the presence of high quality source rocks inspire the evaluation of an unconventional petroleum system where oil or gas are produced directly from source rocks. The regional stratigraphy includes multiple proven source and reservoir rocks including the Middle to Upper Triassic Shublik Formation (Fm.). The Shublik Fm. is heterogeneous, and has been interpreted to indicate deposition influenced by marine upwelling. Lithofacies include phosphatic siltstone, nodular phosphorites, organic-rich carbonate mudstones, packstones, grainstones, and glauconitic and non-glauconitic sandstones. Lithofacies observed in outcrop comprise intervals of non-resistant organic-rich packages juxtaposed with resistant phosphatic and carbonate packages that exhibit coarsening upward rhythmic depositional successions. Pore space and networks provide potential storage and migration pathways within unconventional resource systems. Pore types were imaged and quantified at a high resolution using electron microscopy. Pore types that are present within the Shublik Fm. include interparticle, intraparticle, moldic, and microfracture. The data collected from high resolution pore imaging is used to estimate the storage capacity of the Shublik Fm. as an unconventional resource system. Building upon previous work, utilizing sequence stratigraphic models and connecting the genetically related units with observed microfacies will permit the identification of the intervals that have the greatest storage potential. Facies stacking patterns identified through core, outcrop, and petrographic analysis are calibrated to well logs to map relevant stratigraphic intervals on a regional scale. The phosphatic limestone and flat clam facies will be the focus for pore types and the abundance. The phosphatic limestone facies contains the greatest amount of porosity including interparticle, intraparticle, and moldic within the phosphate nodules and matrix and fractures surrounding phosphate nodules. Fracture and intraparticle porosity are the primary pore types within the flat clam facies. Combining the proposed methods provides an important component to evaluating the Shublik Fm. as a potential unconventional resource system.

## Petrophysical techniques for asset analysis on the North Slope

*Moreland, Rachael E.*

Three things that factor into proving the value of an oil and gas asset are whether or not that asset consists of quality acreage, is accompanied by a solid analysis, and has available producible reserves. By utilizing petrophysical data, insight can be gained into where an asset holds its current value, and how much potential it may have for future further development.

The stratigraphic focus of this investigation is the Shublik Formation, the lower part of the Jurassic (Kingak Shale), and the Cretaceous Brookian Shale. By utilizing petrophysical models, log calculations, and cross plotting methods, with available well and log data spanning the North Slope, an accurate assessment of the hydrocarbon potential, and key reservoir characteristics of the area can be made.

Considering a series of assumptions delineated from previous research methods, (1)organic-rich sediments have a higher resistivity than organic-lean sediments, (2)organic-rich rocks decrease in sonic transit time and increase in resistivity, and (3)organic-rich rocks can have a higher gamma-ray reading than ordinary shale and limestone. Keeping these assumptions in mind, the total organic carbon (TOC) of formations throughout this area can be isolated using log calculations and cross plotting techniques, focused on a modified $\Delta$ log R method that incorporates sonic vs. resistivity data. Petrophysical log curves for porosity, volume of shale, permeability, and water saturation are then calculated and generated from available log curve data, to further indicate the potential of this area. These log curves are utilized in a zone attribute analysis to calculate the water saturation and porosity at each formation. Utilizing the modified $\Delta$ log R method, the logs for wells in this area indicate that the shale benches appear to have good TOC, and therefore, are pro-

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spective for hydrocarbon production. Attribute maps of generated porosity and water saturation values throughout the area show an increase in porosity with each subsequent formation and variable water saturation throughout each zone, displaying fluid distribution trends. Further analysis of petrophysical log curve data incorporated into area cross sections highlights geological complexities and potential pay zones.

## Are Tertiary coals from central and southern Alaska source rocks for oil?

*Lillis, Paul G.; Lewan, Michael D.; Stanley, Richard G; LePain, David L.; Wartes, Marwan A*

In order to determine whether Tertiary coals from central and southern Alaska are potential sources of oil, hydrous pyrolysis (HP) experiments (360 °C/72 hours) were performed on two samples of Miocene Suntrana Formation from Nenana basin and two samples of Paleogene Chickaloon Formation from Matanuska Valley, Alaska. The hydrogen index values of the coals, prior to the HP experiments, range from 152 to 330 mg $S_2$/g total organic carbon (TOC) and the maceral composition is dominantly huminite/vitrinite (~ 90% by volume). The HP experiments increased the thermal maturity of the coals from immature-early mature (0.46 to 0.69% vitrinite reflectance, and 394 to 423 °C Tmax) to late mature-postmature (1.48 to 1.71% vitrinite reflectance, and 464 to 499 °C Tmax). All four coals generated waxy, low-sulfur (less than 0.2 wt% S) oil with yields ranging from 59.5 to 101.4 mg expelled oil/g TOC, similar to an Upper Cretaceous to Tertiary Latrobe Group coal from Gippsland Basin, Australia (82 mg oil/g TOC). Gas chromatograms of the oils show strong odd carbon preference of the normal alkanes (n-$C_{23}$ to n-$C_{33}$) and high pristane/phytane values (>4) typical of oils generated from humic coal. Although HP exaggerates oil expulsion by as much as 50%, given sufficient burial history (time-temperature) these Alaska coals could generate and expel waxy oil.

## A new methodology for determining source rock quality and quantity with applications to the Alaska North Slope

*Hosford Scheirer, Allegra; Magoon, Leslie B.; Bird, Kenneth J; Duncan, Edward*

The values of total organic carbon (TOC) and hydrogen index (HI) before a source rock generates petroleum determine the quantity and quality, respectively, of that petroleum. These so-called "original values" can be challenging to obtain because pyrolysis experiments (in which the immature sample is heated to generate petroleum) require a thermally immature sample. This is problematic for at least three reasons. First, it can be difficult to find truly thermally immature samples from core or cuttings because exploration wells are usually drilled near where the source rock has already generated oil and/or gas. Second, outcrop samples often are thermally immature, but they may be altered due to weathering so may not be representative of the organic facies in the subsurface. Third, original TOC and HI can be calculated via a fractional conversion equation, which is based on mass balance, present-day values of TOC and HI, and several assumptions. Because original TOC and HI are key inputs to basin and petroleum system models, an observation-based approach is warranted.

We present a new method for obtaining the original TOC and HI of organic-rich source rocks. The methodology depends on a rich catalog of geochemical analyses, which is available on Alaska North Slope, and statistical analyses of the data. This statistical method organizes the geochemistry data in three thermal maturity classes: immature, defined as vitrinite reflectance (Ro) less than 0.6% or Tmax from Rock-Eval of less than 435°C; early to peak oil, defined as Ro between 0.6 and 0.9 or Tmax between 435° and 450°C; and late oil, defined as Ro greater than 0.9 or Tmax greater than 450°C. Distribution functions calculated for the two datasets (TOC and HI) in each of the maturity classes reconstruct original TOC and HI at each level of thermal maturation. Although we report mean values here, this analysis can be easily extended to different geographic regions where organic facies differ.

We applied this method to five source rocks: the Hue Shale above its basal Highly Radioactive Zone (HRZ), the HRZ itself, the pebble shale unit (Kalubik Formation), the Kingak Shale, and the Shublik Formation. Where thermally immature, all five source rocks exhibit TOC values ranging from 2 wt. %, our minimum for consideration, to as high as 10 wt. %, with a mean of about 2 to 3 wt. %. The original HI values, on the other hand, exhibit large variability due to different kerogen types in the source rocks. The pebble shale unit has the lowest mean original HI (165 mg HC/g TOC) whereas the Shublik Formation has the highest (550 mg HC/g TOC). Our results are generally consistent with earlier values determined with the fractional conversion method, although the original HI for the Shublik Formation in this study is considerably higher (550 mg HC/g TOC for this study vs. 300 to 400 mg HC/g TOC with fractional conversion method). A new insight gained from this method is the ability to examine the relative behavior of carbon and hydrogen depletion with thermal maturation. The hydrogen index precipitously decreases with maturation as expected but the total organic carbon does not; rather it drops off slowly through the oil window. In summary, this new method for determining source rock quality and quantity is easy to implement, provides needed input for basin and petroleum system modeling, and serves as an independent check on established methods.

## Speakers Preparation Room

DATES: Sunday, Monday, Tuesday and Wednesday, May 21-24.
HOURS: Sunday 1-6 pm; all day Monday and Tuesday, until noon on Wednesday
LOCATION: Susitna Room, Second Floor

Laptops will be available for speakers and presenters to preview and practice their talks.

**Find up to the minute information at psaapg2017.com**

## Presenters and Judges Breakfasts

Speakers/Judges breakfasts will be held each morning between 7:00 and 7:45 in the Summit restaurant on the 15th floor of the Sheraton.

Speakers, Poster Presenters, Session Chairs and Judges should attend the breakfast on the day of their talk, poster or judging session. You will have the opportunity to meet with your chairs and fellow presenters, get logistical information, and answers to any last minute questions. Please ensure that your talk has been provided to the technician in the Speaker's Preparation Room 4 hours before your session begins..

**Notes:**

# Developments in Onshore Alaska Exploration & Production

*Chairs: Rob Miller*
*Robert Gillis*

**13:45 Introductory Remarks**

13:50 David Houseknecht
*Petroleum systems framework of significant new oil discoveries in Arctic Alaska*

14:10 Richard Lease
*Timing of Cretaceous shelf margins in the Colville Basin, Arctic Alaska*

14:30 Robert Ravn
*Palynological correlation in Cretaceous Brookian strata of the Colville Basin, Alaska North Slope.*

14:50 Robert Gillis
*New insights into the Bruin Bay fault-Moquawkie structural trend, northwestern Cook Inlet basin, Alaska, from subsurface constraints and bedrock geologic mapping*

**15:10 Break (30 minutes)**

15:40 Marwan Wartes
*Preliminary observations on the stratigraphy, tectonics, and petroleum geology of Upper Cretaceous rocks in lower Cook Inlet, southern Alaska*

16:00 David Buthman
*Iniskin Peninsula conventional and unconventional exploration targets, Jurassic Tuxedni Group, Lower Cook Inlet onshore, Alaska*

16:20 Gerry Van Kooten
*Oil and gas exploration in Nenana basin, Interior Alaska: Drilling, stratigraphy and basin analysis*

16:40 John Konkler
*Oil and Gas Exploration in Nenana Basin, Interior Alaska: Improved prospectivity and structural history from new seismic programs*

17:00 End of Afternoon Sessions

## Petroleum systems framework of significant new oil discoveries in Arctic Alaska

*Houseknecht, Dave*

Three discoveries in Arctic Alaska announced since October 2015 each have recoverable oil potential of 300 to >3,000 million barrels (MMBO). The discoveries occur in the distal part of a giant, Lower-middle Cretaceous clinothem comprising bottomset and foreset seismic facies in the Torok Formation and topset seismic facies in the Nanushuk Formation.

The most thoroughly tested discovery (Pikka), in the Nanushuk Formation at 4,100 ft depth on the Colville River delta, is estimated to hold 497 to 3,758 MMBO (30° API). Another Nanushuk discovery (Willow), at similar depth in northeastern National Petroleum Reserve in Alaska, is estimated to hold at least 300 MMBO (44° API). Seismic and nearby well data suggest that both accumulations are stratigraphically trapped in lowstand shelf-margin delta systems. The third discovery is in the Torok Formation at 5,000 ft depth in Smith Bay, about 95 mi west of the Pikka discovery. In-place resources of 6,000 to 10,000 MMBO (40-45° API), with possible recovery factors of 30-40%, are estimated by the operator based on 3-D seismic data and two exploration wells. Operator statements, plus seismic and nearby well data, indicate the accumulation is stratigraphically trapped in lowstand, basin-floor fan deposits.

The three discoveries lie on or near the Barrow Arch, a regional structure that focused oil migration from the south (Colville Basin) and from the north (Canada Basin rifted margin). Fetch areas include high quality, oil-prone source rocks in Triassic, Lower Jurassic, and Lower Cretaceous strata. Source rocks range from thermally immature to mature on the arch to overmature in deep areas north and south of the arch. This favorable potential for multiple sources, local charge, and distant charge from two directions likely accounts for thick oil columns reported in two of the discoveries.

Shelf-margin trajectories with deeply erosional sequence boundaries likely contributed to favorable reservoir quality at the shelf margin (wave winnowing) and toe-of-slope (sand delivery). Basinwide, diagenesis of Nanushuk and Torok sandstones mainly involved compaction of ductile components, and shallow maximum burial along the arch favored the preservation of good reservoir quality. Previously, only minor oil accumulations were discovered in this clinothem. Thus, these discoveries demonstrate the potential for a significant and virtually unexplored play fairway covering at least 8,000 $mi^2$, including onshore and shallow offshore areas.

## Timing of Cretaceous shelf margins in the Colville Basin, Arctic Alaska

*Lease, Richard O; Houseknecht, Dave*

Cretaceous clinothems on the Alaska North Slope hold significant undiscovered oil potential, as attested to by three recent, large oil discoveries in the Torok and Nanushuk Formations clinothem. A quantitative understanding of clinothem timing has been hindered by relatively imprecise biostratigraphy with large uncertainties >5–10 m.y. We integrate new zircon U/Pb geochronology with seismic stratigraphy to illuminate the timing and relationship between the Torok-Nanushuk and Seabee-Tuluvak clinothems. Maximum depositional ages are defined by young detrital zircon U/Pb age populations, likely derived from coeval volcanism in Russian Chukotka or south of the Brooks Range.

The Torok-Nanushuk clinothem stretches from the Chukchi Sea to the Arctic National Wildlife Refuge and represents the world's most voluminous (1.2 million km3) and highest relief (>1 km thick) foreland clinothem. Clinoform dip directions and detrital zircon provenance indicate that sediment was derived primarily from Chukotka during longitudinal, eastward sediment dispersal. Estimated depositional ages (n=13 sites) reveal a progradational surge between ca. 115 and 105 Ma when the shelf margin prograded more than 450 km in a supply-dominated system. Progradation slowed after 105 Ma when seismic stratigraphy shows a shift to aggradational shelf-margin trajectories. The shelf margin prograded only another 125 km eastward to the ultimate shelf margin at 97.9-97.8 Ma (±0.7-1.1 Ma; n=3). We estimate ~400 k.y. periodicity for Torok-Nanushuk depositional sequences, which is equivalent to the Milankovitch long eccentricity cycle.

We detect a curious ~2 m.y. hiatus in deposition on the shelf between the Torok-Nanushuk ultimate shelf margin at 97.9-97.8 Ma and a sequence-bound-

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ing retrogradation at the base of the overlying Seabee-Tuluvak sequence at 95.7-95.4 Ma (±0.4-1.0 Ma; n=3; Ninuluk sandstone). Enigmatic deepwater deposits such as the Juniper sandstone and Arctic Creek unit have been recognized extending >200 km east of the Torok-Nanushuk ultimate shelf margin, but with an uncertain relationship to clinothem sequences west of that ultimate shelf margin. New geochronology indicates that these deepwater deposits young upward from 98.2-97.5 Ma (±0.8-1.3 Ma; n=2) at the base to 96.1-95.5 Ma (±1.1-1.2 Ma; n=2) at the top, suggesting deposition during a lowstand coeval with the hiatus recognized on the shelf. Deposition renewed on the shelf after 95 Ma and includes progradation of the Seabee-Tuluvak clinothem at 93.8-92.1 Ma (±0.3-0.7 Ma; n=3). Notable differences between the Torok-Nanushuk and Seabee-Tuluvak clinothems include a change from Chukotkan to Brooks Range provenance and significant reductions in both sediment flux and clinoform relief.

These new geochronologic data confirm previous interpretations of a Juniper-Arctic Creek-(Gilead?) lowstand systems tract comprising basin-floor fan deposits that post-dates the Torok-Nanushuk ultimate shelf margin, and of the Ninuluk and basal Seabee as a transgressive systems tract that reflects drowning of the relict Torok-Nanushuk shelf during the late Cenomanian. The data also constrain the age of progradation of the Seabee-Tuluvak highstand systems tract across the relict shelf. This study demonstrates the potential to correlate specific lowstand shelf margins with quantitative geochronology, providing improved constraints for understanding hydrocarbon systems in Cretaceous clinothems on the Alaska North Slope.

## Palynological correlation in Cretaceous Brookian strata of the Colville Basin, Alaska North Slope

*Ravn, Robert L; Goodman, David K*

Cretaceous strata of the Brookian Plate Sequence comprise a thick and complex set of dominantly progradational siliciclastic sediments derived from the emergent ancestral Brooks Range, and deposited in the deep foreland Colville Basin. This basin-filling episode commenced in Albian time, and continued without major hiatus throughout the remainder of Cretaceous time. Recently, new attention has been focused on these strata, with the discovery of several significant petroleum reservoirs within strata ascribed to the Nanushuk Formation, of Albian-Cenomanian age. Standard lithostratigraphic nomenclature, derived from surface exposures in the Brooks Range, does not serve adequately to communicate stratigraphic relationships in the subsurface of the basin to the north. Relatively little comprehensive biostratigraphic information has been published from the region, but these strata ubiquitously contain rich and diverse palynological populations of both marine and terrestrial origin, highly valuable for establishment of a robust framework for correlation. The comprehensive presence of abundant palynological populations allows the application of a variety of analytical techniques providing strongly objective evaluations of time-related horizons, by means of correlating reliably repeatable data events, rather than subjective interpretations.

## New insights into the Bruin Bay fault-Moquawkie structural trend, northwestern Cook Inlet basin, Alaska, from subsurface constraints and bedrock geologic mapping

*Gillis, Robert J; Shellenbaum, Diane P; Gregersen, Laura S; Fair, Holly S*

We integrate recent bedrock geologic mapping with new interpretations of privately- and publically-held subsurface data (including 445 line miles of onshore 2D seismic data, and 115 line miles from a recently-released 2D seismic dataset) to more completely understand the framework of producing structures near the northwestern margin of Cook Inlet basin, a major Alaska oil and gas province. Our studies help to delineate, for the first time in the public domain, details related to position, geometry, and linkages of hydrocarbon-trapping structures in the area. Due to predominately offshore occurrences and poor onshore expression of the basin structures, public knowledge of their framework has been based chiefly on derivative proprietary products, limited publically-released industry data, interpretation of gravity and magnetic anomalies, and surface distribution of wells.

The new seismic interpretations constrained by wells reveal a complex array of NNE-striking discontinuous contractional faults and folds that decrease in throw and amplitude along strike as a system, potentially partitioning shortening outside of the study area between the Beluga River and Granite Point structures to the NE and SSW, respectively. Two principal faults, the Bruin Bay and the Moquawkie faults, are sub-parallel, closely spaced, and dip steeply away from each other to the WNW and ESE. The faults share a narrow footwall syncline that is best expressed midway along their respective traces, where their fault throws are greatest. Their hanging-wall anticlines decay in amplitude and change in character to the NNE and SSW, tracking fault slip and producing locally complex geometries. Strata adjacent to the Bruin Bay fault may record an early episode of deformation that is not expressed by the Moquawkie structure. Seismic sections constrained by well control (e.g. Stedatna Creek #1 and Chuit River #1) indicate that locally thick (>4,900 ft), Eocene West Foreland and Paleocene? strata occur in the hanging-wall anticline of the Bruin Bay fault, and are thinner (<1,000 ft) in its footwall, consistent with contractional inversion of a Paleogene extensional feature. This interpretation is supported by new bedrock geologic mapping to the NW in the Capps Glacier area, which clearly indicates that ongoing transtension was the principle mechanism for subsidence at the proximal basin margin during West Foreland deposition.

For decades, the Bruin Bay fault has been interpreted as a NE-striking regional transpressional structure continuous for approximately 450 km from the upper Alaska Peninsula to this location, where it either splays into, or is truncated by, the dextral Castle Mountain fault. However subsurface constraints and new bedrock geologic mapping indicate it is neither continuous, of sufficient magnitude to juxtapose Cenozoic units as traditionally mapped, nor connected to the Castle Mountain fault above Jurassic basement. The NNE-striking Bruin Bay-Moquawkie structural complex deviates from the regional trend of the Bruin Bay fault that is well-constrained to the SW. Yet, it is nearly co-axial to the NNE-striking Granite Point and Middle Ground Shoal structures, suggesting that it is not genetically related to the Bruin Bay fault, but rather part of a system of NNE-trending prospective fault-cored anticlines concentrated along the western margin of the basin, which also includes the Trading Bay, McArthur River, Three-Mile Creek, and Beluga River structures.

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**Notes:**

## Preliminary observations on the stratigraphy, tectonics, and petroleum geology of Upper Cretaceous rocks in lower Cook Inlet, southern Alaska

*Wartes, Marwan A; Stanley, Richard G; Lillis, Paul G.; Helmold, Kenneth P; Herriott, Trystan M; Decker, Paul L; Gillis, Robert J*

Upper Cretaceous rocks in Cook Inlet remain only lightly explored, although limited data suggests the interval has petroleum potential. Encouraging evidence includes oil shows reported from at least two wells (Raven No. 1 and Anchor Point No. 1), and significant oil staining documented in outcrops of Upper Cretaceous strata near Saddle Mountain and in the Kamishak Hills. The latter locality is represented by petroliferous sandstone cobbles and boulders in modern stream alluvium that are confidently interpreted to originate from nearby Upper Cretaceous outcrops. Point counts from two samples of these oil-stained clasts indicate a quartzo-feldspathic composition; reservoir quality analyses yielded porosity values of 10% and 14% and permeability values of 0.01 and 0.2 millidarcies. The porosity is notably higher than nearly all existing data for Jurassic rocks in the region, which likely reflects the lack of significant laumontite cement that typically compromises older Mesozoic sandstones. The residual hydrocarbons are currently being extracted for further geochemical characterization (USGS laboratory in Denver, CO).

In order to better understand the Upper Cretaceous stratigraphy, we examined the ~1100m thick upper Campanian to lower Maastrichtian Kaguyak Formation at its type locality at Swikshak Lagoon on the upper Alaska Peninsula. This section is approximately 15 miles south of the Kamishak Hills drainage where we sampled the oil-stained clasts. The lower part of the section is dominantly fine-grained with a diverse and abundant trace fossil assemblage, including Helminthopsis, Phycosiphon, Schaubcylindrichnus, Terebellina, Teichichnus, and Thalassinoides. Primary sedimentary structures are rare, likely reflecting deposition below wave base and thorough disruption of lamination by bioturbation. We interpret this part of the unit as offshore transition to shelfal. In contrast, the upper part of the section is dominated by well-bedded, rhythmic alternations of siltstone and very fine- to medium-grained sandstone. Trace fossils and bioturbation are rare, and the totality of sedimentary facies is consistent with deposition via sediment gravity flows, ranging from high density flows to more dilute, turbulent flows. Based on the sedimentary facies, the lack of wave-generated structures, and the dearth of bioturbation, we interpret the upper half of the Kaguyak as comprising deep-water deposits, likely from a base of slope to basin floor setting.

The origin of this episode of deepening between the lower and upper part of the Kaguyak is unclear. Forearc basins are dynamically linked to subduction zone processes and phases of substantial basin subsidence are generally ascribed to episodes of tectonic erosion of the upper plate. Integration of our data with published information from the Matanuska Valley and lower Alaska Peninsula indicate that abrupt and significant subsidence is widely recorded along the entire length of the forearc basin during the Late Cretaceous, suggesting a common tectonic driver.

## Iniskin Peninsula conventional and unconventional exploration targets, Jurassic Tuxedni Group, Lower Cook Inlet onshore, Alaska

*Buthman, David B*

Since the turn of the century, the Iniskin Peninsula has been the object of several vintages of exploration-from the half a dozen cable-tool oil gushers drilled adjacent to surface oil seeps in the early 1900's, to deeper 8,775 to 11,231' depth wells drilled in the "high camp" area during the 1930's and 1950's, to the first 2D seismic survey conducted on the peninsula during 2013.

Trap at Iniskin prospect consists of a southwest-plunging, 55,000-acre, breached anticline, defined by surface geology, topography, oil seeps, oil shows in seismic shotholes, vintage magnetics, and 2D seismic. Early explorations concentrated on mapping out the surface geologic structure and the locations of oil and gas seeps. The first drilling campaign during the early 1900's concentrated on drilling the oil seeps in the Oil Bay area, and wells flowed oil and gas from 120', 190', 500', and 770' depths. During the early 1930's, and again in the 1950's, exploratory drilling concentrated to the northeast, up-plunge, in "high camp" area. These later wells all flowed oil and gas at noncommercial rates.

Prospective oil and gas reservoirs consist of two radioactive organic mudrocks in the Middle Red Glacier Formation measuring 1292' and 300' thick, located within the oil generative window. In addition to these two unconventional targets, the uppermost Talkeetna volcanic breccia, plus sandstone beds within the Lower Red Glacier Formation, both display secondary dissolution porosity development and are highly prospective conventional targets. The 2D seismic acquired by Hilcorp during 2013 indicates that all of the wells drilled to date have missed the crest of the deeper structure, and that the anticlinal axis at the surface is offset to the west relative to the deeper anticlinal crest. In addition to conventional reservoir targets, numerous low-porosity, low-permeability oil saturated sandstones exist, which might be commercialized given modern lateral and / or hydraulic fracturing technologies.

The remaining risk parameters at Iniskin-source rocks and timing & migration-are mitigated inasmuch as: 1) oil seeps located at N 59 degrees 40.603 minutes latitude, W 153 degrees 19.447 minutes longitude, elevation 65.7', consist of 16 API green-brown, sweet oil, typed to Jurassic Tuxedni source rocks, and 2) live oil was observed in 8 seismic shotholes drilled along the crest of the surface anticline. Additional explorations are planned in the vicinity in the near future.

## Oil and gas exploration in Nenana basin, Interior Alaska: Drilling, stratigraphy and basin analysis

*Van Kooten, Gerry; Richter, Michael; Konkler, Jon; Morahan, G. Thomas*

Recent exploration in Nenana basin of central Alaska has defined a deep basin with excellent source and reservoir rocks for hydrocarbons. Deep wells have numerous shows of thermogenic oil and wet gas, and indicate significant potential for hydrocarbon accumulations.

Three deep wells plus one sidetrack are located in the basin deep, and two older and shallower wells are located on the basin margin. None of the wells found commercial quantities of hydrocarbons. The three deep wells (Nunivak #1, Nunivak #2 and Toghotthele #1) were drilled in 2009, 2013 and 2016 to Tvd depths of 11,136', 8625' and 11,375', respectively. The wells contain variable thickness of Nenana Gravel overlying Usibelli Group non-marine, fluvial

**Notes:**

sediments rich in coal. On the basin flanks, the oldest sediments overlying Late Paleocene basement are Miocene in age, but ~2750' of Oligocene sediment was drilled in the basin center in Tog #1. The Oligocene sediment contains abundant and attractive source and reservoir rocks similar to the overlying Miocene Healy Creek Formation. It is possible rocks of Eocene age are also present in the basin center below drilled horizons. Of the three wells, two had oil shows, sometimes abundant, and one contained abundant wet gas, but at low saturation. Both the oil and wet gas shows are migrated, thermally-generated hydrocarbons.

Potential source rocks include coal and coaly shale while shale itself has very low source potential. The source rocks show variable hydrocarbon potential depending on TOC content and samples were concentrated for analysis by hand picking and density separation. Shale with 0-4% TOC is lean and gas-prone with average HI values ~155 (RockEval). Coaly shale with TOC from 4-12% is an excellent source rock with average HI values ~350. Coal with TOC from 20-70% is very good source material with average HI values ~255. Both coaly shale and coal from Nenana have higher HI values than comparable rocks from the analog Gippsland Basin, Australia, where ~5 BBO sourced from coaly rocks has been discovered. Nenana coaly shale and coal routinely generate high gravity oil in the lab during dry pyrolysis . Although the literature suggests uncertainty whether coal can efficiently expel oil, coaly shale could have better expulsion dynamics than coal.

Healy Creek Formation (Usibelli Group) sediments of Miocene and Oligocene age contain thick, porous sandstone reservoir beds and are probably amalgamated fluvial channel sands. Sand beds reach a maximum of 120' thick and are quartz-rich in composition. Healy Creek sands above ~8500' are friable and SWC's disaggregate when spun to extract formation fluids. Deeper sand from 9000 to 11,375' Tvd in the Tog 1 well range from 15-18% porosity and 20-125md permeability, considerably better than Cook Inlet sands at comparable depth.

Vitrinite reflectance (Ro) in Tog #1 reaches 0.91 at 11,350' Tvd, and Ro depth trends from Tog #1 imply about 3000' of recent uplift in the central basin. Uplift increases to the south, but is minimized northward where the Nenana basin is deepest.

A recent basin-wide geohistory and hydrocarbon endowment analysis concludes coal and coaly shale in the Nenana basin can generate and expel billions of barrels of oil and many Tcf of gas. While issues remain, such as efficiency of hydrocarbon expulsion from coal and identification of structurally intact traps, potential remains high for oil and gas discoveries in the Nenana basin.

## Oil and Gas Exploration in Nenana Basin, Interior Alaska: Improved prospectivity and structural history from new seismic programs

*Konkler, Jonathan L; Morahan, G. Thomas; Van Kooten, Gerry; Richter, Michael*

Gravity/magnetics, earthquake studies and historical seismic data outline the general geometry of the Nenana. As additional new data (seismic and wells) become available, the basin geometry is further refined, leading to more focused oil and gas exploration. For the past 14 years, Doyon, Limited has promoted and financially supported an exploration program that has led to new data and a better understanding of the basin geology. During 2016, Doyon, Limited completed drilling the Toghotthele #1, the third well in this current program. The well penetrated a 2750 foot interval of previously undrilled Oligocene sedimentary units containing excellent reservoir and source rocks, thus adding to the known potential of the overlying Miocene Healy Creek Formation. Doyon, Limited also acquired 172 miles of new 2D seismic data, infilling the pre-existing seismic grid in the northern Nenana basin. Integration of new and existing seismic and well data has resulted in the identification of new exploration targets, a more specific understanding of source rock maturation and migration pathways, and a better comparison of exploration risks between the north and south portions of the basin.

The new seismic infill program has allowed a more comprehensive mapping of the thick Nenana gravel, which overlies prospective units within the basin. Several continuous seismic horizons were identified and mapped within this stratigraphic unit. The new mapping work has led to a better understanding of the areal extent and timing of late subsidence in the north Nenana basin. The structural interpretation was used to update the basin-wide geohistory and hydrocarbon endowment analysis by Platte River Associates (Van Kooten, 2017). Results of the study suggest that the deep north Nenana basin should have produced and expelled prolific quantities of oil and gas. The Nenana basin is filled by east-dipping Paleocene to Miocene non-marine units deposited within an actively subsiding half-graben, and more recently overprinted by a transtension/transpression structural style (Tape, et al, 2015; Dixit, 2015; Morahan, 2016). The geometric elements of the half graben are a NNE-SSW trending basement ridge on the west, sedimentary fill onlapping the ridge and gently dipping to the east, and a large-displacement basin-bounding fault along the eastern margin. This deep seated normal fault exhibits gradual subsidence from Paleocene to Miocene time. Paleocene-Miocene sedimentary units are overlain by the rapidly deposited late Miocene to Pliocene Nenana Gravel.

Mapping the thickness changes of the Nenana Gravel has helped to outline major structural style differences between the north and south Nenana Basin. The Nenana Gravels appear to have experienced significant uplift and erosion (up to 3000 feet) in the south Nenana basin. The north Nenana basin has experienced significant late stage subsidence, with the Nenana Gravel formation to the north reaching thicknesses up to 7000 feet, dropping the Paleocene - Early Miocene succession to depths of 12000-24000 feet, well within the hydrocarbon maturation zone. Continuous structural evolution, accompanied by source rock subsidence into the hydrocarbon kitchen puts the north Nenana basin into a better setting than areas to the south with respect to risk in an exploration program.

## Speakers Preparation Room

DATES: Sunday, Monday, Tuesday and Wednesday, May 21-24.
HOURS: Sunday 1-6 pm; all day Monday and Tuesday, until noon on Wednesday
LOCATION: Susitna Room, Second Floor

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**Notes:**

# PSAAPG and SEPM: Sequence Stratigraphy and Sedimentology: Fluvial to Deep-Water Reservoirs

*Chairs:* *Jennifer Aschoff*
*Mark Scheihing*

**8:00 Introductory Remarks**

8:05 Gregory Gordon
*Paleogeographic controls on reservoir quality in the Carneros turbidite systems, San Joaquin basin, California*

8:25 Dolores van der Kolk
*Sedimentology and stratigraphy of the lower Schrader Bluff and Prince Creek formations at Shivugak Bluffs, National Petroleum Reserve-Alaska*

8:45 Peter Flaig
*Combined autogenic and allogenic driven facies and stratal architecture change at the transition between the Schrader Bluff and Prince Creek fms, Shivugak Bluffs, North Slope, Alaska*

9:05 Christopher Kremer
*Sedimentology, early stratigraphic evolution, and sediment provenance of a submarine axial channel system: lower Puchkirchen Formation, Molasse Basin, Austria*

**9:25 Break (30 minutes)**

9:55 Graham Emerson
*Stratigraphic and depositional controls on field production. Challenges and future opportunities in the Borealis field, northern Alaska.*

10:15 Shuvajit Bhattacharya
*Machine Learning-assisted Vuggy Carbonate Reservoir Characterization: Application to Mature Oil Fields*

10:35 Kehinde Oyeyemi
*Hydrocarbon resource evaluation of an offshore field, western Niger Delta*

## Paleogeographic controls on reservoir quality in the Carneros turbidite systems, San Joaquin basin, California

*Gordon, Gregory; Fisher, Emily; Myers, Gary; Boles, James*

The Carneros sandstone member of the Temblor Formation is a petroleum reservoir in California that has been the focus of increased exploration and production activities in recent years. The Carneros sandstone was originally deposited in the early Miocene as a group of turbidite systems located along the structurally complex western and southwestern margins of the San Joaquin basin, which was in a stage of extensional/transtensional tectonics and volcanism at that time. Regional petrologic studies, petrographic analyses from outcrop and core samples, and new subsurface mapping efforts confirm the presence of multiple, discrete Carneros depositional systems with differing reservoir-quality properties due in part to different provenance areas. This study will focus on two of these systems, the Westside system and the Belridge system.

Syndepositional normal faulting adjacent to the San Andreas fault along the western margin of the basin is interpreted to have created local accommodation into which the Westside system was deposited. This localized accommodation was the main control on development of a channel fairway in the Westside system. The fairway contains the greatest thicknesses of Carneros sandstone in the basin; the thickness trends suggest abrupt changes in paleotopography. Several prolific Carneros-productive oil fields are located along this fairway, and the Westside system sandstones generally exhibit favorable reservoir quality. Subsurface map trends and paleocurrent data from outcrop suggest that the general sediment transport direction for the Westside system was from northwest to the southeast, toward the deepest part of the basin.

The Belridge system was deposited east of the Westside system, closer to the synclinal axis of the greater basin. The two systems, and possibly their source terranes, were separated by a seafloor high that was located near the current McDonald Anticline and Antelope Hills oil fields. From subsurface map patterns, it is interpreted that the general sediment transport direction for the Belridge system was from northwest to southeast, and the Belridge system source terrane might have been located farther to the north than the Westside source terrane. Petrographic analyses show that the Belridge system contains a distinctive petrofacies marked by >50% volcanic rock fragments and zoned feldspar grains. The volcanic detritus appears to be first-cycle reworked, suggesting that these rock fragments were derived from contemporaneous or recently deposited lower Miocene volcanics. As a result of the presence of this volcanic petrofacies and other factors, the Carneros sandstone in the Belridge system tends to exhibit poorer reservoir quality than the Westside system.

This example of contemporaneous turbidite systems deposited in a tectonically active, topographically complex basin has exploration implications for other deepwater depositional systems/reservoirs deposited in structurally segmented basins. This study has particular relevance to syn-rift reservoirs deposited during phases of localized volcanism.

## Sedimentology and stratigraphy of the lower Schrader Bluff and Prince Creek formations at Shivugak Bluffs, National Petroleum Reserve–Alaska

*van der Kolk, Dolores A; Flaig, Peter P.; Hasiotis, Stephen T.*

Near horizontal (6° dipping) outcrop exposures of Upper Cretaceous (Santonian-Campanian) strata at Shivugak Bluffs in northern Alaska preserve an extensive record of a clinoform-topset system. These strata are subdivided lithostratigraphically into proximal shelf, deltaic, and shallow marine deposits of the Schrader Bluff Formation (Fm) and lower delta plain, coastal plain, and fluvial deposits of the continental Prince Creek Fm. Shivugak Bluffs includes 400 m of continuous marine deposits overlain by 140 m of strata containing the marine–continental transition between the lower Schrader Bluff and Prince Creek Fms. The lowermost 400 m of the lower Schrader Bluff Fm is divided into the Rogers Creek, Barrow Trail, and Sentinel Hill members interpreted as recurring deposits of river-dominated deltas comprising distributary mouth bars (DMBs), subaqueous terminal distributary channels (TDCs), interdistributary bays, medial delta front deposits, distal delta front deposits, and prodelta deposits interbedded with proximal shelf deposits. The marine-continental transition is one of the few outcrop expressions of an ancient, mud-

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dy, prograding river-dominated deltaic system that contains interdistributary bays that shoal upward into floodbasins with pedogenic modification. An isolated interval of hummocky cross-stratification within the Rogers Creek Member at Shivigak Bluffs is interpreted as wave-reworked DMB-TDC complexes or storm sheets. This investigation focuses on the sedimentology, ichnology, and stratal heterogeneity within a sequence stratigraphic framework to ascertain large-scale cyclical trends in these river-dominated deltaic systems. The Schrader Bluff (West Sak and Tabasco equivalent in the subsurface) and Prince Creek (Ugnu equivalent in the subsurface) Fms are relevant to industry as outcrop analogs for numerous shallow, viscous- to heavy-oil reservoirs on the central North Slope of Alaska.

## Combined autogenic and allogenic driven facies and stratal architecture change at the transition between the Schrader Bluff and Prince Creek fms, Shivugak Bluffs, North Slope, Alaska

*Flaig, Peter; van der Kolk, Dolores A*

Although the Prince Creek and Schrader Bluff fms (Campanian-Maastrichtian) together comprise a topset of a Brookian-age giant clinoform deposited in the Colville Basin on the North Slope of Alaska, the two formations are typically divided lithostratigraphically into shallow marine deposits (Schrader Bluff Fm) and continental distributive deposits (Prince Creek Fm). In outcrops at Shivugak Bluffs along the Colville River on Alaska's North Slope the transition from shallow marine deposits to continental deposits contains highly complex surfaces and fluctuating stratigraphic geometries likely driven by a combination of autogenic and allogenic processes.

Employing the lithostratigraphic terminology, the uppermost Schrader Bluff Fm at Shivugak Bluffs comprises delta front deposits dominated by mouth bars and subaqueous terminal distributary channels. Sandbody geometries and sedimentary structures combined with marine to brackish water trace fossils are evidence for marine deposition. The initial deposits of the Prince Creek Fm overlying the Schrader Bluff Fm contain no marine trace fossils and instead record deposits of highly sinuous distal distributaries (4-6 m thick) with common inclined heterolithic stratification that overlie and incise into the mouth bars. This progression of paleoenvironments reflects normal, autogenic deltaic processes found during delta progradation; however, the overlying stratigraphy and surfaces become much more complex.

In portions of the outcrop belt, the basal sinuous distributary channel of the Prince Creek Fm is "beheaded" so that the top of the fining-upward succession typical of Prince Creek Fm sinuous meandering channels is removed by an incision 2-4 m deep. A sandbody does not overly the incision, instead a coaly interval and an ~ 10 m thick succession of interbedded coals, carbonaceous shales, organic-rich paleosols, and relatively thin (1-2 m-thick) channel deposits that typically lack evidence of sinuosity (e.g. lateral accretion surfaces) overly the incision. A second, major incision surface, that is most likely the outcrop expression what has been termed the mid-Campanian unconformity, incises into the top of these interbedded sands and coals. Overlying this unconformity are anomalously coarse-grained channel systems 6-10 m thick that may contain basal conglomeratic lags with boulder-size clasts and additional conglomeratic lags on scours. Based on the abundance of downstream accretion and the outcrop geometries of these sandbodies the channel system is best classified as straight to braided. Although the overlying strata is lost to the modern erosion surface at Shivugak Bluffs the system is seen to transition stratigraphically upward into meandering channels and associated floodplain 5 km to the northeast at Uluksrak Bluffs.

The incisions within the Prince Creek Fm are interpreted to reflect valley cutting during a significant basinward shift in facies, bypass of coarse grained material to the shelf, and subsequent valley filling, sometimes with relatively fine-grained material. The incisions are interpreted to reflect a compound unconformity, likely driven by allogenic forcings (e.g. tectonics, relative sea level fall) near the mid Campanian unconformity. The fill overlying these unconformities suggest that there may have been significant bypass of sand to the shelf, providing potential reservoirs down-dip of valley systems.

## Sedimentology, early stratigraphic evolution, and sediment provenance of a submarine axial channel system: lower Puchkirchen Formation, Molasse Basin, Austria

*Kremer, Christopher H; Graham, Stephan A*

The Molasse Basin of Austria is an asymmetric foreland basin that contains Oligocene to lower Miocene deep-water strata, including the Puchkirchen Formation. Based on the deposition of the extensively studied upper Puchkirchen Formation in and proximal to a large east-west, meandering axial channel belt, it has been preliminarily proposed that such a channel belt may have been active during the deposition of the lower Puchkirchen Formation. This study focuses on the ongoing sedimentological and stratigraphic architectural work from a study of the lower Puchkirchen Formation that integrates a suite of sub-surface data to investigate the early evolution of the Molasse Basin axial channel belt. We identified the deposits of low-density turbidity currents, high-density turbidity currents, debris flows, and slurry flows in approximately 250 m of drill core from the lower Puchkirchen Formation, which were acquired from 13 wells and graphically logged at the centimeter scale. Using a 3D seismic volume of the study area, we have identified stratigraphic architectural elements associated with main channel belt deposits, overbank wedges, overbank lobes, mass transport complexes, slide blocks, and tributary channels. Our work confirms the hypothesis that a deep-water channel system was active in the Molasse Basin during the deposition of the lower Puchkirchen Formation. Furthermore, our work suggests that topography created by the emplacement of mass transport complexes influenced the distribution of sediment gravity flow deposits in the main channel belt, as well as the overall migration direction of the channel system.

## Stratigraphic and depositional controls on field production. Challenges and future opportunities in the Borealis field, northern Alaska

*Emerson, Graham*

The Borealis oil field produces from Kuparuk shoreface sands of early Cretaceous age. The field began

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production in 2001 and is anticipated to achieve a recovery factor of approximately 35%. The field is a waterflood development; water injection began in 2002 and miscible gas injection in 2004, into a combination of vertical and horizontal wells. Faulting is pervasive at Borealis. There are two main fault set trends; an older northwest to southeast and a younger trending north south. Production data demonstrates faults do not generally seal where there is sand on sand juxtaposition. The depositional stacking patterns of the shoreface sands have a significant impact on production and several techniques are being considered to maximize recovery.

The Kuparak C sands contain more than 95% of total field pay. Located in the Kuparuk Trough, the C sands were deposited immediately above the Lower Cretaceous Unconformity. Shoreface transgression and regression within the C sands impacted the spatial distribution of reservoir quality sands. There is a clear relationship between good reservoir quality, field segment recovery factor and wellbore injectivity. The good quality sections are focused in L pad and northern V pad where the thickest, proximal prograding sands within the C3 and C2 are found and recovery factors are up to 40%. The lower quality sections are located in northern L pad where the shoreface sands consist of distal deposits and in Z pad where the progradational C2 and C3 packages are not deposited and there is abundant Siderite cementation. Recovery factors can be as low as 10%. A recent multi-stage frac well in Kuparuk sands in the neighboring Aurora field (S-42A) has demonstrated excellent productivity from these poorer quality, uncemented distal sands, where permeabilities are 15-20mD.

The depositional history has impacted the distribution of horizontal permeability by layer. High permeability is found in the shallowest portions of the reservoir in the C4 and Upper C3 and the deeper C1 interval. The high permeability contrasts have caused a significant amount of the lower quality C2 and Lower C3 sands in L pad and V pad to be poorly swept, as observed by recent logging in a 2015 well (L-01A). Developing these low permeability sands is technically and economically challenging and options for this are being considered.

Post depositional Siderite cementation has dramatically reduced wellbore productivity in some southern V pad and northern Z pad wells. The distribution of Siderite cemented sands is highly uncertain and the nature and concentration can vary quite rapidly between wellbores. This leads to additional risk when drilling infill wells.

## Machine Learning-assisted Vuggy Carbonate Reservoir Characterization: Application to Mature Oil Fields

*Bhattacharya, Shuvajit; Haagsma, Autumn; Howat, Erica; Schuetter, Jared; Conner, Amber; Mishra, Srikanta*

Reservoir characterization of carbonate formations is challenging due to heterogeneities and diagenesis. Vugs in carbonate formations hold the potential for fluid storage, and enhanced oil recovery from mature fields. In general, vugs can be identified from core samples and high-resolution image logs, which are limited and expensive. The goal of this work is to develop novel methods to detect vugular porosity in wells without core samples and image logs. The Cambrian Copper Ridge Formation in the Appalachian basin is selected for this study. This carbonate formation produces hydrocarbon from remnant fields.

First, vugs are identified from a limited number of wells with relevant core samples and image logs. Next, an ensemble of various machine learning algorithms, such as Support Vector Machine, Artificial Neural Network, and Random Forest etc., are used to train the model using conventional well log suites, such as gamma ray, bulk density, neutron porosity, and photo-electric index. Model performance is assessed by using 5-fold cross-validation method.

The results show that Support Vector Machine is the best performer for vug prediction among all other machine learning algorithms. Higher proportion of model-predicted vugs correlated to hydrocarbon production data. Furthermore, a new well was drilled inside the study area with whole core collection. The predicted vugs correlated to presence of actual vugs and distribution of oil in the core. Such techniques can be useful for local and regional-scale reservoir characterization of other carbonate formations.

## Hydrocarbon resource evaluation of an offshore field, western Niger Delta

*Oyeyemi, Kehinde David; Olowookere, Mary T; Aizebeokhai, Ahzegbobor P.*

Integrated structural and seismic attributes analyses of 3D seismic data covering about 50 square kilometer in western Niger Delta have been carried for prospect mapping and play fairway analysis. The seismic data provided the framework of the subsurface geometries to examine the lateral extent of the reservoirs and there corresponding trapping mechanisms. Four reservoir sand units code named H1, H2, H3 and H4 were interpreted and mapped across the field within the Agbada formation sequence. Amplitudes extractions based on the reservoirs of interest were generated with depth maps for interpretation. Seismic structural analyses and attributes enhancement were applied on the entire seismic volume and reservoir sand units in the field with a view to delineate bright spots, sweet spots and fault zones□ the faults zones were identified based on distinct displacements and amplitude distortions The depth structure maps shows crestal faults and rollover structure assisted by faults□ these are the principal structure responsible for the hydrocarbon entrapment in the field. Distinctive fault closures represents the mappable structural plays in the field. Structural highs, fault assisted closures comprising two way closure and four-way dip closed structures are evident structural traps. Different stratigraphic traps such as channel bodies were also revealed by amplitude and frequency attributes. The study has contributed to of hydrocarbon exploration activity within the western Niger Delta through evaluation of various amplitude anomalies and the analysis of subsurface structures that constitute traps for hydrocarbon accumulation.

***Directly following the meeting....***

**Annual GSA/AGS Spring Picnic**

A GSA Scholarship Fund Benefit Event

Wednesday, May 24th
5:00 - 8:30 PM
Abbott Loop Community
Park Pavilion
8101 Elmore Road

**Notes:**

# Posters

*Chair:* *Steve Wright*

Poster authors are requested to be present at their posters during the Monday and Tuesday intra-session coffee breaks. Their presence during the Icebreaker and MiniBreaker is suggested.

POSTER 01
*Stratigraphy and sedimentology of the Chinitna Formation, Iniskin–Tuxedni Bays area, south-central Alaska—Late Middle Jurassic depositional systems and petroleum prospectivity in Cook Inlet forearc basin*

POSTER 02
*Remaining hydrocarbon habitat in the Tango Member (Zone 2B) of the Ivishak Formation*

POSTER 03
*Petroleum exploration history and subsurface geology of the Castle Mountain fault anticline near Houston, south-central Alaska*

POSTER 04
*Results of 1:63,360-scale geologic mapping and related field studies in the south-central Tyonek Quadrangle, Alaska: Late Paleocene?-middle Eocene transtension and post-Oligocene inversion on the northwest periphery of the Cook Inlet forearc basin*

POSTER 05
*Characterization and remediation of sites contaminated by historical fuel spills in Arctic Alaska.*

POSTER 06
*Detrital zircon LA-ICPMS geochronology of western Arctic Alaska Basin sedimentary rocks*

POSTER 07
*Outcrop Characterization of a Turbidite Deposit: The Pigeon Point Formation, California*

POSTER 08
*Brookian Sequence Stratigraphic Framework of the Northern Colville Foreland Basin, Central North Slope, Alaska*

POSTER 09
*Overview of Late Cretaceous depositional systems of the Colville foreland basin, east-central North Slope, Alaska*

POSTER 10
*Microfacies and Trace Element Variation Across the Frasnian punctata Event Within the Bear Biltmore Drill Core (Alberta, Canada)*

POSTER 11
*Reservoir Characterization of Oligocene Vedder and Miocene Stevens Sandstones of the Southern San Joaquin Basin, California, for Robust Estimation of Their Simultaneous CO2-EOR and Storage Potentials.*

POSTER 12
*Mineralogical and geochemical characterization of the Santos shale, San Joaquin Basin, California*

POSTER 13
*Depositional setting and potential reservoir facies in the Nanushuk Formation (Albian-Cenomanian), Brookian topset play, North Slope, Alaska*

POSTER 14
*Preliminary ichnology, sedimentology, and stratigraphy of Maastrichtian Prince Creek and upper Schrader Bluff formations at Ocean Point, National Petroleum Reserve - Alaska*

POSTER 15
*Surveillance: minding our P's and Q's - production, pressure, quantity and quality (steam)*

POSTER 01

## Stratigraphy and sedimentology of the Chinitna Formation, Iniskin–Tuxedni Bays area, south-central Alaska—Late Middle Jurassic depositional systems and petroleum prospectivity in Cook Inlet forearc basin

*Herriott, Trystan M; Wartes, Marwan A; Stanley, Richard G; Decker, Paul L; Helmold, Kenneth P; Harun, Nina T*

The Chinitna Formation of lower Cook Inlet is a ~700-m-thick marine unit that crops out near the arc-proximal forearc basin margin. Two members of comparable thickness are mapped as Tonnie Siltstone (Bathonian–Callovian) and Paveloff Siltstone (Callovian). Geologic mapping, stratigraphic reconnaissance, and sedimentologic work provide new insights into the Chinitna.

A ~70-m-thick channelized conglomerate package at Chisik Island is reportedly associated with Tonnie, but field relations indicate these beds may be younger than Tonnie. Nevertheless, lower Tonnie exposures near Tonnie Peak do host channelized, cross-stratified sandstone. At Iniskin Bay, part of lower Tonnie exhibits thin, sharp-based sandstone intercalated with bioturbated siltstone; hummocky cross-stratified sandstone is also present. Reconnaissance of upper Tonnie reveals a finer-grained interval with local gully-scale channel-forms and mainly fine-grained fills. A generally comparable stratigraphic stacking motif is documented in Paveloff. A ~100-m-thick succession of tabular and channelized sandstone and conglomerate commonly occurs at this member's base, and hummocky cross stratification is also noted. Regionally, overlying finer-grained deposits are observed. Upper Paveloff at Chinitna Bay comprises more than 160 m of bioturbated, very fine-grained sandstone with subordinate coarser, sharp-based sandstone; slump scars and channels with m-scale relief are principally filled with fine-grained detritus. Mountain-scale exposures exhibit even larger channel-forms in upper Paveloff, including a slump-associated feature with ~140 m of stratigraphic relief.

Tonnie and Paveloff each record third-order sedimentation cycles. Regressive, lowstand depositional systems with probable delta associations supplied coarse sediment during onset of each cycle. The conglomerate at Chisik Island highlights marked base-lev-

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el fall (10s of m of incision), probably represents shelf-valley fill, and is tentatively associated with Paveloff rather than Tonnie. Overlying finer-grained successions in both members may reflect waning deltaic influences as near-shore environments were transgressed during rising base level, diminishing sediment supply to prodelta settings in shelfal water depths ranging down to–and perhaps below–storm wave base. Continued transgressions likely terminated direct deltaic inputs into outer shelf settings. The lithologically monotonous, gullied upper parts of each member may record highstand normal regressions–rather than continued transgressions–when muddy clinoforms(?) of delta- to slope-scale relief prograded into the basin during later periods of base-level rise; the strongest evidence for this scenario occurs in Paveloff, where the largest channel-form approaches submarine-canyon-scale.

Rock-Eval pyrolysis results from 44 samples (12 from Tonnie, 32 from Paveloff) indicate poor petroleum source potential, with total organic carbon values of 0.14–0.69 weight percent and S2 values of 0.00–0.57 milligrams hydrocarbon per gram of rock. Thermal maturity of the samples ranges from ~0.7% Ro at Oil Bay to 0.85–1.20% Ro at Iniskin Bay based on Rock-Eval Tmax, spore color, and vitrinite reflectance analyses. Sampled Chinitna sandstones are mainly feldspathic and generally have less than 6% porosity and less than 0.2 millidarcies permeability. Nevertheless, migrated oil is documented in a lower Paveloff outcrop, and viable scenarios exist for Chinitna-hosted oil accumulations.

POSTER 02

## Remaining hydrocarbon habitat in the Tango Member (Zone 2B) of the Ivishak Formation

*McFarland, Joshua C; Phillips, Sandra; Miller, Robert*

Characterizing the remaining hydrocarbon habitat in stratigraphically complex, fluvially-dominated zones within the Ivishak Formation is a key challenge for Area Development Planning in Prudhoe Bay Field. A target interval (Lower Tango) still remains based on the complex nature of the stratigraphy. The re-development of this zone is currently targeted with horizontal wells via coil and to a lesser extent rotary side-tracks to exploit un-swept oil. Sediments of the Tango were deposited in a multi-point sourced, braided river-dominated, coastal plain environment with variable marine influences (Eckelman et al., 1976; Lawton et al., 1987; Atkinson, 1988; Paris, 1988). Lithologically, the Tango is composed of a broad range of clastic sediments, from pure mudstones to coarse pebble conglomerates (Atkinson, 1988). Five genetic depositional elements were interpreted based off of core data in 200 wells from 5 drill sites in Prudhoe Bay using gamma-ray signature, porosity/permeability data, and petrophysical sand flags. Manual interpretation of depositional elements in the Tango from a vertical well results in a one-dimensional subdivision of a fluvial sequence. Multiple geological elements exist interchangeably within a field-wide, non-genetic, layering scheme currently utilized in Greater Prudhoe Bay. Each element interpreted in the Tango represents a unique fluvial process, and exists variably in three dimensions. Furthermore, the lateral extent of the element intersected by the wellbore (i.e. channel margin vs. channel axis) is difficult to constrain spatially, and makes predictability of inter-well depositional architecture difficult to map in detail. Increasing the resolution of mapping by utilizing a stand-alone, vertical sequence of fluvial deposits increases the correlative uncertainty of its predicted subsurface position. To reconcile these problems, base maps with pie-diagrams at well locations displaying the relative percentage of the interpreted element were combined with 3D geometrical dimensions of elements from field outcrop analogues (Ye, Burns, & Levinson, 2000). This methodology helped establish a predictive model showing the fabric of fluvial element on RDE maps for the respective Tango interval. The maps represent a genetically-influenced, quantitative bias using a 'contouring' methodology utilizing the relative percentage of an element within the base map 'pies' in order to reduce uncertainty. The multi-input mapping schema helped to: 1) construct a 3D architectural framework of the Lower Tango from a combination of both surface and subsurface data; 2) develop high resolution RDE maps (< 1,500 feet); 3) improve the understanding of injector-producer interaction in enhanced oil recovery areas; and 4) improve the overall understanding of the depositional behavior of the Lower Tango in the Eastern portion of Prudhoe Bay.

## Petroleum exploration history and subsurface geology of the Castle Mountain fault anticline near Houston, south-central Alaska

*Stanley, Richard G; Haeussler, Peter J; Potter, Christopher J; Gregersen, Laura S; Shellenbaum, Diane P; Decker, Paul L; Benowitz, Jeffrey A; Goodman, David K; Ravn, Robert L; Blodgett, Robert B*

The Castle Mountain fault anticline is located on the north side of the seismogenic Castle Mountain fault near Houston, about 30 miles north of Anchorage. Previous work, including a published seismic-reflection profile, showed that the anticline is cored by several steeply-dipping faults and that the crest of the anticline is coincident with an aeromagnetic high that parallels the surface trace of the Castle Mountain fault. Here we provide a short history of petroleum exploration on the anticline and report new isotopic and biostratigraphic results that yield further insights into its subsurface stratigraphy and structure. Coal was discovered near the crest of the anticline in Houston in 1917 during excavation for a cut along the Alaska Railroad. A mine was established and produced subbituminous coal from the Tyonek Formation, which yielded plant fossils of the Seldovian floristic stage indicating an age of early to middle Miocene. During 1951-1952, the U.S. Bureau of Mines drilled three core holes to subsea depths of -137 to -812 feet near Houston and found sandstone intervals in the Tyonek Formation that flowed methane gas and brackish water. During 1954-1963, five wells named for Rosetta, wife of one of the operators, were drilled as oil and gas exploration wells to subsea depths of -887 to -5,774 feet. All five Rosetta wells were dry holes with confirmed shows of gas and unconfirmed reports of minor oil stains. During 1998-2004, four wells were drilled on the anticline in search of coalbed methane. No commercial production was established but the Houston 3 well reportedly flowed gas at 2-3 mcf/day from perforations in five coal beds in the Tyonek Formation at subsea depths of -1,027 to -1,545 feet. The Houston Pit 1 well, drilled in 2004 as a coalbed methane test near the crest of the anticline, spudded in the Tyonek Formation. At a subsea depth of -1,042 feet, this well found the top of the Arkose Ridge Formation, consisting of nonmarine conglomerate, sandstone, and basalt. Two core samples of basalt from depths of -1,247 and -1,279.5 feet yielded whole-rock $^{40}Ar/^{39}Ar$ ages of 58.6±1.6 Ma and 58.8±2.4 Ma, respectively,

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indicating a late Paleocene age for these rocks. We hypothesize that basalt in the Arkose Ridge Formation may be the source of the aeromagnetic high associated with the Castle Mountain fault anticline. The Rosetta 3 well spudded in the Tyonek Formation on the south flank of the Castle Mountain fault anticline and found the top of the Arkose Ridge Formation at a subsea depth of -1,655 feet. At -2,165 feet the well apparently penetrated a fault and entered an interval of sandstone, siltstone, shale, and coal that persists to the total depth of the well at -5,774 feet. Core samples from this interval contain fossil leaf impressions and a freshwater clam, and palynomorphs indicate a probable Miocene age and terrestrial depositional setting. These results suggest that the interval from -2,165 to -5,774 feet is correlative with the Tyonek Formation. If this interpretation is correct, then there is likely an unnamed contractional fault at -2,165 feet in the Rosetta 3 well that places Paleocene Arkose Ridge Formation above Miocene Tyonek Formation. The geometry of this unnamed fault is unclear; it may be a north-dipping synthetic reverse fault that parallels the Castle Mountain fault, or it may connect at depth with the surface trace of the Castle Mountain fault in a positive flower structure.

POSTER 04

## Results of 1:63,360-scale geologic mapping and related field studies in the south-central Tyonek Quadrangle, Alaska: Late Paleocene?-middle Eocene transtension and post-Oligocene inversion on the northwest periphery of the Cook Inlet forearc basin

*Gillis, Robert J; LePain, David L.; Herriott, Trystan M; Wartes, Marwan A; Decker, Paul L; Shellenbaum, Diane P; Benowitz, Jeffrey A; O'Sullivan, Paul B.*

Cenozoic nonmarine strata in upper Cook Inlet are up to 25,000 feet (7,620 m) thick and host significant commercial accumulations of oil and gas. These strata are discontinuously exposed around the basin margins, but the largest area with the most complete exposures of the Cenozoic succession occurs between the mouth of the Beluga River and Mount Spurr Volcano. However, difficult access and often sparsely-distributed outcrops in this area of the northwest basin margin have hindered understanding of the margin-proximal stratigraphy and structures that deform it. New inch-to-mile geologic mapping of approximately 875 sq. mi. along this extent of the basin margin includes parts of the exhumed Late Cretaceous and Paleocene magmatic arcs and the principal structures that define the Cenozoic arc-forearc basin boundary, providing new insights into subsidence mechanisms during Paleogene deposition. Major results include division of the earliest exposed Cenozoic basin strata (West Foreland Formation) into three mappable subunits based on distinct lithofacies, identification of stratigraphic units previously thought to be absent from the area (Hemlock and Sterling formations), and corroboration of a largely overlooked extensional structural model for the northwest basin margin proposed in the mid-1970s. A more nuanced depositional model and better constraints on the timing of arc magmatism and deformation were guided by 37 detailed measured stratigraphic sections, 102 U-Pb and $^{40}Ar/^{39}Ar$ geochronologic analyses of intrusive, extrusive, and sedimentary rocks, and 143 palynologic analyses from throughout the Cenozoic succession. Often well-expressed meso- to macro-scale cross-cutting relations and over 1000 shear plane measurements constrain the structural style, sense of fault slip, and relative timing of deformation during early basin formation. Stratal thickening and a prominent overlap succession associated with structures within the West Foreland Formation indicate syntectonic deposition during middle Eocene time. In regions approaching the Cook Inlet coast where outcrops are relatively rare due to a glacial deposits and dense vegetation, publicly- and privately-held subsurface data informed the mapping of stratigraphic contacts and major structures. These subsurface data also permit redefining what has classically been called the Bruin Bay fault as a complex system of en echelon faults referred to here as the Beluga River-Moquawkie fault system (BR-MFS). Collectively, the new mapping, field observations, and supplemental data define the northwestern margin of the Cook Inlet forearc basin as a dextral, right-stepping transtensional pull-apart system that initiated as early as 57 Ma, linking the Capps Glacier fault to the northwest with the Castle Mountain fault to the southeast. Deposition of proximal West Foreland Formation strata was syntectonic from <47.9 to <38.7 Ma during margin-oblique, northeast-directed extension. Seismic and well log interpretations suggest initial normal slip locally along the BR-MFS during Paleocene(?) through Eocene time prior to regional structural inversion that likely began after the Oligocene. However, dextral transtension after middle Miocene time might have occurred locally in the Chuitna River area and certainly occurred on a Lake Clark fault splay, which places Tyonek Formation strata against Late Cretaceous granodiorite along a well-exposed south-dipping plane.

POSTER 05

## Characterization and remediation of sites contaminated by historical fuel spills in Arctic Alaska.

*Torrance, Keith W*

The Naval Arctic Research Laboratory (NARL) was operational from 1947 until 1980 occupying a 350 acre site north of the city of Barrow. At a latitude of 71 degrees north Barrow is the most northerly city in North America and is located at the strategic junction of the Chukchi and Beaufort Seas. Most of the original structures at NARL are still intact and have been put to other uses. However, complete utilization of the facility is limited by soil contamination dating back to its former use. Most of the contamination relates to fuel spills but metals, PCBs and chlorinated solvents are also present at some locations above action levels. Characterization and remediation efforts have been ongoing since the Navy left NARL and are expected to continue for another decade or more. Sub-surface movement of contaminants is complicated by the presence of permafrost which limits vertical migration of contaminants and restricts lateral migration to the unfrozen zone, which is active during the summer months. As extreme low temperatures in Barrow during the Arctic winter greatly reduce the effectiveness of natural degradation contaminant concentrations can remain elevated for an extended period. Other remediation options are limited by the high cost of transporting contaminated soil by barge during the short window when ocean transportation is possible; there are no road connections to Barrow. This poster provides an overview of efforts to characterize sub-surface contamination at the former NARL site and the effectiveness of previous attempts to remediate specific sites. Observations on the future direction of clean-up activities will be presented in light of the growing importance of the Arctic as an economic and strategic resource and the environmental concerns of local inhabitants.

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POSTER 06

## Detrital zircon LA-ICPMS geochronology of western Arctic Alaska Basin sedimentary rocks

*Holm-Denoma, Christopher; Niglio, Louis C; Strong, Thomas*

New U-Pb detrital zircon ages were determined by laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) for several quartz-rich horizons from cores and cuttings from boreholes in western Arctic Alaska. Preliminary results are presented here for reservoir rocks in the Chukchi Sea (Klondike well) and western National Petroleum Reserve Alaska. The samples are from middle Paleozoic basement and the Middle Mississippian to Upper Jurassic-Lower Cretaceous Ellesmerian and Beaufortian mega-sequences. Detrital zircon U-Pb age populations from several samples, including the borehole in the Chukchi Sea, are remarkably similar and span the Mesoarchean to Devonian. Age populations include major peaks between ~500-390 Ma, a broad spread of ages between ~1900-950 Ma, and a minor peak between ~2800-2400 Ma. The observed western Arctic Alaska Precambrian zircon age population patterns are largely consistent with detrital zircon lineages from Neoproterozoic to early Paleozoic sedimentary rocks of the northwestern Laurentian passive margin; specifically these detrital zircon age spectra are similar to hybrid or mixed populations of cratonal and marginal sequences (e.g., Adams argillite, Lane and Gehrels, 2014). In addition, the overall detrital zircon age population signatures of Arctic Alaska samples are remarkably similar to rocks of the Devonian clastic wedge in Arctic Canada and the Yukon (Gottlieb et al., 2014 and references therein). Our preliminary results imply a consistent Laurentian and Ellesmerian/Caledonian sourcing of zircons and widespread, well mixed, sedimentary dispersal in post-Mississippian Ellesmerian and Rift (Beaufortian) Sequence marine rocks. Similarity between detrital zircon age populations from the Late Permian(?) Kavik Sandstone in the Klondike well to other Laurentia-sourced Arctic Alaska samples suggests that areas west of the Hanna Trough axis in the Chukchi Sea contain Laurentia-derived sediments of the Devonian clastic wedge, and the part of the Chukchi basin may have similar reservoir rocks to those in the North Slope of Alaska. Triassic strata in westernmost Arctic Alaska contain <300 Ma zircon which is postulated to have been derived syndepositionally from eastern Arctic Russia (e.g. Miller et al., 2006, 2010). The absence of zircon younger than ~380 Ma in the Kavik Sandstone samples has implications on the reconstruction of the Arctic Alaska-Chukotka microplate. Western Arctic Alaska and the Hanna Basin trough axis palinspastically restores to the Sverdrup basin using a simple rotation model during the opening of the Amerasia basin. The Klondike borehole is opposite to the North Slope subterrane along the Hanna Basin trough axis but apparently doesn't contain <380 Ma zircon; it shows that the Hanna Trough axis may not have been the physical barrier to sediment derived from eastern Arctic Russia during the Triassic. Gottlieb et al., 2014, Geosphere, v. 10, p. 1366-1384. Lane and Gehrels, 2014, GSA Bulletin, v. 126, p. 398-414. Miller et al., 2006, Tectonic, v. 25, TC3013. Miller et al., 2010, AAPG Bulletin, v. 94, p. 665-692.

POSTER 07

## Outcrop Characterization of a Turbidite Deposit: The Pigeon Point Formation, California

*Jaikla, Chayawan; Lowe, Donald*

The Upper Cretaceous Pigeon Point Formation, outcrops along the Pacific Coast south of San Francisco, California, contains a full spectrum of coarse-grained deep-water deposits that are well exposed despite being heavily faulted and structurally deformed. Although the outcrops are widely visited by geologists, the stratigraphy, sedimentology and tectonic implications of the formation are still poorly resolved. The goal of this study is to develop a depositional model for the Pigeon Point Formation and infer the depositional processes of the depositing turbidity currents and debris flows. The lithofacies of low-density turbidity currents are generally thin-bedded sandstone interbedded with mudstone with occasional sandstone beds that are 1-2 meters thick. The thick massive sandstone deposited by high-density turbidity currents would be considered prime targets for petroleum exploration elsewhere. Although hydrocarbon is not present in the area, the findings from this study will contribute to petroleum exploration in deep-water deposits. The preparation of a detailed geologic map records features at the sedimentation unit scale, and stratigraphic measured sections are constructed in order to understand the stratigraphy. This study reconstructs the formation before faulting to determine the geometries of deposits and their dimensions in different environments. Major and trace element analysis and petrography are used to determine the composition and provenance of the rocks and the tectonic evolution of the formation.

POSTER 08

## Brookian Sequence Stratigraphic Framework of the Northern Colville Foreland Basin, Central North Slope, Alaska

*Decker, Paul L*

This study presents detailed regional well and seismic correlations through the Brookian sequence of the northern Colville basin - Barrow Arch province just south of the major producing oil fields of the central North Slope, Alaska. The well log cross transect extends 261.4 km (162.4 mi) from the Clover 1 well in the northeastern National Petroleum Reserve - Alaska (NPRA) on the west to the Stinson 1 well in Beaufort Sea state waters near the Arctic National Wildlife Refuge (ANWR) on the east. The section traverses a zig-zag path from west to east, from proximal to more distal settings along depositional dip. At least seven horizons (A-G) are recognized as recording regionally significant changes in relative sea level (transgressive flooding surfaces, lowstand sequence boundaries, or surfaces of composite origin) that exerted fundamental control on distribution of lithofacies through time. These surfaces subdivide the Lower Cretaceous through Neogene foreland basin succession into primary genetic units (I-VII) made up of time-equivalent topset, foreset, and bottomset facies that typically span across formation boundaries as defined on the basis of lithostratigraphic criteria (e.g., Mull and others, 2003; Molenaar and others, 1987). Most of the rock volume within these cycles was deposited during phases of pronounced east- and northeast-directed progradation or vertical aggradation; major retrogradational (transgressive flooding) episodes are represented mainly by condensed sections. Three of the key lowstand sequence boundaries are interpreted from seismic and well data to exhibit significant submarine scour, attributable to mass failure events initiated on the upper slope, traction currents on the basin-floor, and perhaps other processes. Seismic records across the modern Beaufort Sea shelf margin exhibit a variety of recent and modern features clearly linked to analogous mass transport and seafloor erosion, attesting to its probable significance in Brookian sequence architecture through time. Striking differences between transient submarine geomorphologic elements and their more muted appearance in the subsurface are important reminders that the vagaries of geologic preservation may mask

**Notes:**

locally important controls on the deposition and distribution of reservoir sandstones and other facies.

POSTER 09

## Overview of Late Cretaceous depositional systems of the Colville foreland basin, east-central North Slope, Alaska

*Wartes, Marwan A; Decker, Paul L; LePain, David L.; Gillis, Robert J; Herriott, Trystan M*

Recent field and subsurface studies of Upper Cretaceous strata of Alaska's east-central North Slope have resulted in a revised formation nomenclature that emphasizes regional sequence stratigraphic relationships. These strata record the time-transgressive northeastward progradation of genetically related shelf, slope and deep water facies. In these rocks, we have found that the stratigraphic record of major rises in relative sea level (e.g. condensed sections) can be readily recognized and provide a useful criteria for subdividing depositional cycles and correlating across widely disparate parts of the basin. We recognize flooding surfaces and episodes of sediment starvation associated with significant landward shifts in the paleoshoreline in the Cenomanian-Turonian, Santonian, and middle Campanian. In an effort to improve stratigraphic correlations, we have utilized a number of tools including megafossil biostratigraphy, palynology, chemostratigraphy, and sandstone composition, each with varying degrees of success. Most recently, we successfully generated U-Pb zircon ages from several airfall volcanic units using the LA-ICP-MS technique. Upper Cretaceous condensed intervals are typically shale-prone and preserve abundant and thick silicified tuff and bentonite zones, suggesting U-Pb geochronology has the potential to guide high resolution stratigraphic correlations, and improved basin models.

POSTER 10

## Microfacies and Trace Element Variation Across the Frasnian punctata Event Within the Bear Biltmore Drill Core (Alberta, Canada)

*LaBounty, Deirdre; Whalen, Michael T*

Late Devonian oxygen isotope records show an increase in global sea surface temperature by as much as 9°C over the Frasnian stage (382.7-372.7 Ma), coincident with deposition of regional black shale horizons and global perturbation of the carbon isotope record. Previous studies of Devonian strata within the Western Canadian Sedimentary Basin have shown that pulses of terrestrial input during the mid-Frasnian punctata event are associated with increases in primary productivity and suboxic to anoxic marine conditions. Microfacies investigation and major and trace element measurement by XRF focused on understanding changes in sedimentation over 150ft of a single Frasnian section from northeastern Alberta. Unlike previously-studied Frasnian sections from western Canada, samples from the Bear Biltmore core (7-11-87-17W4) provide insight into more proximal reef to lower slope environments. Samples cover the middle to upper Frasnian within the Duvernay and Cooking Lake formations, including the globally recognized punctata carbon isotope excursion. Results show a transition from high reef influence to low reef influence, an increase in terrigenous input, and a deepening trend. In the lower part of the section, rounded to subangular, unlaminated reef-derived bioclastic wackestones to floatstones were deposited in a chaotic ramp environment. The section grades into a calm microbially-dominated ramp environment, concurrent with an increases in terrigenous input, primary productivity, and bottom water anoxia. After a brief change to primarily argillaceous sedimentation, the top of the section consists of largely unlaminated calcareous mudstone. While terrigenous input decreases, it does not return to the same low as at the start of the section.

POSTER 11

## Reservoir Characterization of Oligocene Vedder and Miocene Stevens Sandstones of the Southern San Joaquin Basin, California, for Robust Estimation of Their Simultaneous CO2-EOR and Storage Potentials.

*Gomes, Charles J; Saini, Dayanand*

With advances in CO2 capture, transport, and injection technologies the process of simultaneous CO2-EOR and storage becomes more efficient and economically viable for smaller projects. The Vedder and Stevens Sandstones in the Southern San Joaquin Valley have been extensively produced with many fields reaching the residual oil saturation via conventional production practices. These sands have already been identified as top candidates for future CO2-EOR and storage projects. However, more robust reservoir characterization is needed for more reliable estimations of their simultaneous CO2-EOR and storage potentials and optimal injection strategies. The arkosic to subarkosic marine shelf deposits of the Vedder Sandstone occur in widespread and thick intervals which varies with the Stevens Sands which have been interpreted as marine turbidite deposits and occur in stacked channelized deposits. The two selected fields have >90% of cumulative production from either the Vedder or Stevens sands with stacked pay intervals providing additional CO2 storage options. By using petrophysical logs and side wall core data to constrain the heterogeneous reservoir characteristics of the modeled areas a more accurate geological model can be produced to further refine future dynamic simulation based estimations of their simultaneous CO2 -EOR and storage potentials under various injection scenarios.

POSTER 12

## Mineralogical and geochemical characterization of the Santos shale, San Joaquin Basin, California

*Mitchell, Nicholas; Guo, Junhua*

The Santos shale is an underdeveloped and understudied formation that had very limited oil and gas development. However, with modern technical applications it could prove to be economical. This study aims to better understand its mineralogical and geochemical characteristics by utilizing 40 samples from 5 different wells with ranging depths from 1061 to 14,970 ft. Analyses conducted include X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF), Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) and Loss-On-Ignition (LOI). Depositional conditions were constrained by geochemical indices such as detrital influx proxies, redox-sensitive element evaluation and paleoproductivity. XRD semi-quantitative analyses results indicate that the average bulk composition of the Santos shale is composed of 77.5 wt-% quartz, 13.4 wt-% clays and 9.1 wt-% carbonate with TOC of 7.7 wt-%. The high quartz and TOC values are likely the main contributors to the highly fractured nature of the Santos noted in conventional and sidewall cores. Relationships between iron, TOC and total sulfur suggest the Santos was deposited in an oxic environment with a well circulated ocean. Diage-

**Notes:**

netic effects can be seen at different burial depths. The shallow burial depths are dominated by sulfate reduction. The intermediate burial depths are characterized by smectite to illite transformation and the deep burial depths by late stage compaction. The implications of this study will help evaluate the Santos shale as a potential source rock or as a fractured shale reservoir.

POSTER 13

## Depositional setting and potential reservoir facies in the Nanushuk Formation (Albian-Cenomanian), Brookian topset play, North Slope, Alaska

*LePain, David L; Helmold, Kenneth P.; Wartes, Marwan A; Decker, Paul L*

The Nanushuk Formation is a thick fluvial-deltaic-shelf succession that crops out in the foothills north of the Brooks Range and is present in the subsurface throughout the NPRA and state lands immediately to the east, up to a maximum progradational shelf edge approximately 30 miles east of the Colville River. Nanushuk strata comprise prominent topsets visible on seismic lines that pass basinward (east) to clinoform reflectors in slope strata of the Torok Formation. Large rivers with headwaters west of the present-day North Slope flowed eastward, down the axis of a foreland basin, and built an extensive delta complex and shelf. Smaller, steeper gradient rivers, with headwaters in the ancestral Brooks Range, flowed north and northeastward and built deltas on the south side of the basin. Six facies associations are recognized in Nanushuk cores from wells in the eastern NPRA and in outcrops to the south, including: 1. offshore mudstones with minor interbedded fine-grained sandstones; 2. shoreface-delta-front sandstones with minor interbedded mudstones; 3. distributary channel-fill sandstones; 4. bayfill-estuarine mudstones that envelop a variety of fine-grained sandy facies; 5. fluvial channel-fill sandstones; and 6. alluvial floodbasin mudstones. In the eastern NPRA and in outcrops to the south, the offshore and shoreface-delta-front associations are most common. Shoreface-delta-front deposits stack to form coarsening-upward parasequences from 30 feet to over 100 feet thick that are typically bounded by flooding surfaces; amalgamated parasequences with sand-on-sand contacts are common in shoreline proximal settings. Hummocky and swaley cross-stratification, wave ripple cross-lamination (and symmetrical ripple bedforms), mudstone rip-up clasts, and pebble-lined scours are abundant in this association. In the most proximal settings, some shoreface successions are overlain by bayfill-estuarine mudstones. Distributary channel-fill sandstones and bayfill-estuarine mudstones are present locally in the subsurface. The fluvial channel-fill and alluvial floodbasin associations are common in outcrop, but have not been recognized in cores from the eastern NPRA. The abundance of storm wave-generated structures in the shoreface-delta-front and offshore associations indicates powerful storm waves routinely affected Nanushuk deltas and the adjacent shelf in this part of the basin. Stacked shoreface-delta-front parasequences overlain by flooding surfaces and offshore mudstones, and in proximal settings, parasequences that pinch out updip in mudstones of the bayfill association, represent attractive reservoir targets. Sandstones of this association commonly display visible porosity in core. Toplap relations visible on seismic and sharp-based shoreface successions recognized in Nanushuk outcrops along the Colville River suggest the likely presence of shelf-edge deltas associated with forced regressions, adding to stratigraphic trap potential. Distributary channels encased in bayfill-estuarine mudstones are potentially attractive reservoir targets if effectively sealed updip.

POSTER 14

## Preliminary ichnology, sedimentology, and stratigraphy of Maastrichtian Prince Creek and upper Schrader Bluff formations at Ocean Point, National Petroleum Reserve - Alaska

*van der Kolk, Dolores A; Flaig, Peter P.; Hasiotis, Stephen T.*

Previous studies of Santonian-Paleocene successions in the Colville Basin have documented fluvial, lower-delta-plain, and coastal-plain deposits of the Prince Creek Formation (Fm) and deltaic, shallow marine, and proximal shelf deposits of the Schrader Bluff Fm. During reconnaissance along the Colville River in 2012, several high-resolution stratigraphic sections of the Maastrichtian Prince Creek and upper Schrader Bluff fms were measured at Ocean Point. This study summarizes the ichnology, sedimentology, and stratigraphy of 79 m of stratigraphic section across a 21 km (13-mile long) fence diagram for Ocean Point. Past field investigations indicate that

Ocean Point strata record an overall transgression, with storm-dominated shallow bay deposits of the upper Schrader Bluff Fm overlying the coastal plain deposits of the Prince Creek Fm (Phillips 2003; Flaig et al. 2011, 2013, 2014). This study compares previously interpreted storm-dominated shallow bay deposits at Ocean Point to the interdistributary bay deposits that were recently described at Shivugak Bluffs (van der Kolk et al. 2015), and makes a case for storm-influenced, estuarine deposits at Ocean Point.

POSTER 15

## Surveillance: minding our P's and Q's - production, pressure, quantity and quality (steam)

*Schempp, Rebecca*

In a thermal field, surveillance is key. A considerable amount of time is spent working across disciplines to monitor field performance. Lost Hills is one of the shallowest steam floods in the world, with the average depth of a Tulare well at 250' MD. Every week the Reservoir Management Team (RMT) consisting of an engineering tech, geologist, operations engineer, reservoir engineer, and team lead reviews pre-selected patterns which include: steam injectors, producers, and temperature observation wells. The RMT relies on a plethora of surveys collected by knowledgeable field personnel. These surveys include steam injection, temperature (at the well head, flowline, and within the reservoir), steam ID, and steam separator surveys. These surveys, combined with Petrophysical data from openhole logs, side wall and conventional core and a 3-D model, all aid in the interpretation of the reservoir, and are critical to understanding steam flood performance and ensuring safety, efficiency and profitability. Managing steam, monitoring pressure and understanding steam chest growth help maintain safe operations, ensure compliance with State permits and regulations, and control costs. Steam is one of the largest operating expenses in a thermal field, approximately 30-50% of the total operating cost. Heat management is essential to keeping costs low. Knowing where steam quality is the highest and lowest can help explain why some areas have higher production. Monitoring steam generators, injection wells, temperature observation wells, and producers helps the team understand both subsurface and surface operational efficiency. Confidence in the geology and reservoir geometry can help explain steam chest development. This can also be seen at the producers with the help of flowline, casing, and reservoir temperatures. Annual steam ID logs identify depletion and de-saturation within the productive interval. Lost Hills has a vast network of Temperature Observation wells within patterns. The surveys are used to ensure that heat from injectors is contained within the targeted interval and to track growth of the steam chest. Anomalies may indicate heat loss to thief zones or problems with the injector and facilitate appropriate intervention. Each week well notes are captured and action items are assigned to team members to ensure that work is completed. The RMT has a goal to evaluate each pattern in detail twice a year. Documenting well performance, proposed and completed work, downtime, lessons learned, and general observations creates a robust history for each well. This process promotes knowledge sharing so future petrotech staff will have the necessary information to maintain and grow the field. Surveillance sessions are opportunities to find work-over candidates and identify replacement and new wells. Surveillance is crucial to thermal operations to ensure project safety, efficiency and profitability. The interactions, discussions, and knowledge shared each week empower each team member to see the reservoir through the eyes of their team, not just with their own discipline.

**Notes:**

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