

BULLETIN

Corpus Christi Geological Society



and

Coastal Bend Geophysical Society



**February
2018
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CORPUS CHRISTI GEOLOGICAL SOCIETY

P.O. BOX 1068* C.C. TX. 78403

2017-2018

www.ccgeo.org

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P.O. BOX 2741*C.C. TX. 78403
2017-2018

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Scholarship Chairman	Ed Egger	361-947-8400	edegger69@gmail.com
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**Visit the geological
web site at
www.ccgeo.org**

CCGS/CBGS JOINT MEETING SCHEDULE 2017-2018

September 2017							October 2017							November 2017						
S	M	T	W	Th	F	S	S	M	T	W	Th	F	S	S	M	T	W	Th	F	S
					1	2	1	2	3	4	5	6	7			1	2	3	4	
3	4	5	6	7	8	9	8	9	10	11	12	13	14	5	6	7	8	9	10	11
10	11	12	13	14	15	16	15	16	17	18	19	20	21	12	13	14	15	16	17	18
17	18	19	20	21	22	23	22	23	24	25	26	27	28	19	20	21	22	23	24	25
24	25	26	27	28	29	30	29	30	31	26	27	28	29	30						

Monday, Oct. 2, 2017 6:00 pm BBQ Kickoff at Hoegemeyers & Presentation by Carl Tape, Ph.D., Associate Professor of Geophysics, Geophysical Institute, University of Alaska Fairbanks “*Seismology in Alaska: Earthquakes, Bears, & High-Performance Computing.*”
 Oct., 18, 2017 11:30am-1:00pm Speaker: David Mittlefehldt, PhD., Planetary scientists, Astromaterials Research & Exploration Science (ARES), Johnson Space Center, National Aeronautics & Space Administration (NASA) “Mars Exploration Rover Opportunity: Exploring the Rim of Endeavour Crater on Mars, Day-4,841+of a 90-Day Mission.”

11:30 am – 1:00 pm
 Speaker: Eugene L. Ames, Jr.
 “The History of Discovery: The Largest Oil Field in the World & Other Musing by a Geologist & Wildcatter.”

December 2017							January 2018							February 2018						
S	M	T	W	Th	F	S	S	M	T	W	Th	F	S	S	M	T	W	Th	F	S
					1	2	1	2	3	4	5	6					1	2	3	
3	4	5	6	7	8	9	7	8	9	10	11	12	13	4	5	6	7	8	9	10
10	11	12	13	14	15	16	14	15	16	17	18	19	20	11	12	13	14	15	16	17
17	18	19	20	21	22	23	21	22	23	24	25	26	27	18	19	20	21	22	23	24
24	25	26	27	28	29	30	28	29	30	31	25	26	27	28						
31																				

Combined
 November/December for the
 Holidays.

11:30 am – 1:00 pm
 Speaker: Lindsay Roe, Core
 Laboratories “South Texas
 Reservoir Geology
 Presentation,” to be
 Determined

11:30 am – 1:00 pm
 Speaker: Peter Wang,
 Geophysical Technical
 Advisor, Paradigm “A New
 Technique of Lithology and
 Fluid Content Prediction from
 Prestack Data: An Application
 to a Carbonate Reservoir”

CCGS/CBGS Joint Meeting Schedule 2017-2018

March 2018							April 2018							May 2018						
S	M	T	W	Th	F	S	S	M	T	W	Th	F	S	S	M	T	W	Th	F	S
				1	2	3	1	2	3	4	5	6	7			1	2	3	4	5
4	5	6	7	8	9	10	8	9	10	11	12	13	14	6	7	8	9	10	11	12
11	12	13	14	15	16	17	15	16	17	18	19	20	21	13	14	15	16	17	18	19
18	19	20	21	22	23	24	22	23	24	25	26	27	28	20	21	22	23	24	25	26
25	26	27	28	29	30	31	29	30						27	28	29	30	31		

11:30 am – 1:00 pm
 Speaker: Collegiate
 Presentations, To be
 determined

11:30 am – 1:00 pm
 Speaker: Phillipe Tissot, Ph.D.,
 Department of Physical &
 Environmental Sciences, TAMUCC
 “Coastal Processes Presentation,”
 to be determined


11:30 am-1:00 pm
 Speaker: To be determined

Calendar of Meetings and Events

Calendar of Area Monthly Meetings

Corpus Christi Geological/Geophysical Society.....	Third Wed.—11:30a.m.
SIPES Corpus Christi Luncheons.....	Last Tues.—11:30a.m.
South Texas Geological Society Luncheons.....	Second Wed—noon San Antonio
San Antonio Geophysical Society Meetings.....	Fourth Tuesday
Austin Geological Society.....	First Monday
Austin Chapter of SIPES.....	First Thursday
Houston Geological Society Luncheons.....	Last Wednesday
Central Texas Section of Society of Mining, Metallurgy & Exp.....	2 nd Tues every other month in San Antonio


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CCGS PRESIDENT'S LETTER

Happy New Year!

We have some new beginnings this year with the move of our luncheon venue from Ortiz Center to Water Street. Oil prices are rebounding, and I hope everyone is getting busy and selling deals.

However, sometimes I wonder how much life our industry has left for us small independents. I remember a quote from the early 2000s by an MA Adelman. "No mineral, including oil, will ever be exhausted." "How much oil is still in the ground when extraction stops, and how much was there before extraction began, are unknown and unknowable." "The amount extracted from first to last depends on the cost and price." I think I had found this quote while searching for reasons to continue down my path towards the oil industry, having some doubt after a group of old timers questioned my decision to study geology for the sake of oil and gas exploration. Then oil skyrocketed. My first check for oil in 2002 was for \$18.32. I remember thinking I would retire before the age of 30 if oil would just stay around \$40. I also remember thinking that surely elephants were left to hunt. Then shale happened, and massive offshore discoveries in quiescent continental shelves one after another worldwide. I remember looking at Google Earth at all the continental shelves and thinking how much oil could be in places like Indonesia. Then in 2009 or 2010 my uncle was the fluid engineer on a well in Papua New Guinea called the Antelope #1, the world's largest gas well. I remember reading the email discussing the pay. We usually discuss pay zones in the tens of feet here in South Texas. Trying to wrap my head around a wellbore with 987 METERS of pay...the subsequent finds justified a multi-billion dollar pipeline and LNG facility in a drilling location that urged workers to stay on location for fear of snakes and cannibals. Yes, cannibals. I remember the description my uncle gave of the rig mobilization: first they helicopter in guys with chainsaws who make way for pieces of bull dozers to be dropped in and put together so the location could be cleared...I cannot imagine the cost to drill an exploratory well in the wilds of Papua New Guinea. Dr. Adelman's quote sounds about right. We all fondly remember commodity prices in the late 2000s.

As the son of a son of an oil man, I went out in the field for exploration at a very young age, and the sights and sounds just stuck with me. Last year we got a handful of wells drilled, and I was thrilled to have the opportunity to share the excitement with my 2 year old. He was actually just 16 months old when I took him to his first location. While our amazing well site consultant educated my wife about mud pits, I was able to walk my son around and show him all the sights and sounds of a rig tripping pipe. A few weeks after his second birthday we were at it again. He exclaimed "strellas" when looking at samples under the black light in the mud logging trailer, and giggled gleefully at the sight

of the tiny little stars on a plate. My hope is that the bits keep going in the ground and I continue to have the opportunity to expose my son and my daughter (arriving this May) so that they might make the decision to grab the torch from my hand much like I have grabbed the torch from my father's hand. Dan Fogelberg's lyrics that "we all become forefathers by and by" sounds a lot different these days. However, three generations later, we are still in business doing what we love.

There is a Geomorphology field trip coming up March 3 that Randy Bissell will be leading. A big thank you to Randy for stepping up to the plate last meeting when weather and flu kept the speaker and many of us from attending. I heard it was a wild success.

The CCGS Golf Tournament is coming up April 13. Please get your sponsorships in and your teams together and let's all cross our fingers for fair weather!

We will be having our Second Annual CC Brewery Pub Crawl the day after the Golf Tournament, April 14, from 2pm-7:15pm. A big thanks to BJ Thompson for his efforts in making this happen two years in a row.

The speaker this month is Peter Wang and he will be discussing his abstract: A New Technique for Lithology and Fluid Content Prediction from Prestack Data: An Application to a Carbonate Reservoir.

Next month is our annual Collegiate Presentation meeting. So be sure to show up and to see how our local Universities are doing.

I'd like to thank our board for their wonderful job in supporting this Society and keeping the momentum in the forward direction.

Here's to a prosperous 2018!

See you guys around.

Austin Nye – President CCGS

CCGS Field Trip: Coastal Geomorphology of the Nueces River System

7-stop field trip over 30 miles of system.

- Nueces River Valley
- Nueces River (fluvial core review)
- Nueces Bayhead Delta
- Lunch at CC Yacht Club with slide presentation on Corpus Christi history
- Corpus Christi Bay Cliff
- Ancestral Padre Island (Flour Bluff)
- Newport Washover Delta & Mustang Island (shoreface core review)



Guided by Dr. Mark Besonen, Mr. Jim Moloney, Mr. Randy Bissell, Ms. Rocky Freund, and Mr. Alan Costello

Saturday, March 3, 2018

Cost: \$95, \$30 students (limit of 10)

**Bus Transportation, Lunch,
& Guidebook**

**Lunch
Included!**

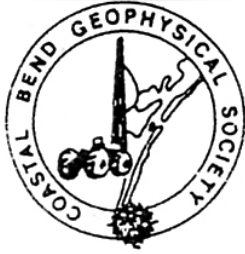
Reserve your spot!

RSVP or information contact

Dawn Bissell, bissells@swbell.net



**Proceeds go to the
Corpus Christi Geological Society Scholarship Fund**



CBGS President's Letter

CBGS Scholarships

The board awarded two scholarships of \$2,000 each to undergraduate geophysics majors from Texas A&M University-College Station, and University of Houston. Another scholarship of similar value will be given to geophysics major from Texas A&M University-Kingsville in Spring 2018.

The following criteria is followed in awarding the scholarships.

1. Must be a citizen of the USA
2. Must have declared Major Geophysics at the main campus of the receiving university
3. Must have GPA 3.0
4. Must be in good standing with the school
5. Must make effort to attend a Coastal Bend Geophysical Society Meeting in Corpus Christi Texas after being awarded a scholarship to be recognized by the society.

Dr. Subbarao Yelisetti- President
Lonnie Blake- Vice President
Matt Hammer- Secretary/ Treasurer
Dr. Robert Schneider- Continuing Education
Lonnie Blake- Golf Chair
Ed Egger- Scholarship Chair

News

- At the time of writing this report, U.S. crude futures have averaged over \$50.85 a barrel in 2017, as opposed to an average of \$43.47 a barrel in 2016. This is expected to rise to \$62 and \$58 a barrel in 2018 and 2019, respectively as reported by Scott DiSavino on reuters.com.

- According to the U.S. Energy Information Administration, U.S. oil output is expected to raise in February to 6.55 million barrels per day (bpd) due to increase in production from shale formations.
- There were 936 oil and natural gas rigs active on Jan. 19. On average, there were 876 rigs available for service in 2017, 509 in 2016 and 978 in 2015 as reported by Scott DiSavino on reuters.com.

CBGS Business

CBGS currently has 56 members.

CBGS offered Basic Seismic Attributes course on 28th April, 2017 in EOG conference center in Corpus Christi and is looking forward to offer many such courses or workshops. Topic/speaker suggestions are welcome. Email your suggestions to Subbarao.Yelisetti@tamuk.edu or Lonnie.Blake@eogresources.com

Golf Tournament

CBGS organized its annual **Golf Tournament** to fund its scholarship program on October 6, 2017 at Northshore Country Club.

20 Players, 10 sponsors, 7 contributing cash, 3 contributing golf balls, coolers, etc.....

Raised \$1951 for the scholarship fund.

If you are interested in the Golf Tournament, please contact Lonnie Blake at 361-887-2665 or Lonnie.Blake@eogresources.com

New Degree Tracks

BS degree in Geophysics, Minor in Geophysics and Certification in Geophysics offered at Texas A&M University-Kingsville from Fall 2017.

Please contact Dr. Subbarao Yelisetti (Subbarao.Yelisetti@tamuk.edu) or

Dr. Robert Schneider (Robert.Schneider@tamuk.edu) for additional information.

Seismology class

TAMUK will offer GEOL 4375/PHYS 5385-Seismology grad/undergrad stacked class on Tuesday and Thursday from 3:30-4:15 pm in Spring 2018. This is available for the professional community as well as our students. You can sign up as a “transient” student in order to take classes without actually enrolling in the school. If anyone in the professional community wishes to sign up for this, please contact the instructor, Dr. Subbarao Yelisetti Subbarao.Yelisetti@tamuk.edu

SEG Distinguished Lecture

CBGS and TAMUK SEG student chapter will be organizing 2018 SEG Distinguished Lecture in January, 2018.

Topic: Advanced imaging for practitioners

Speaker: William W. Symes, Rice University, Houston, TX USA

Venues:

Department of Physics and Geosciences, **Texas A&M University-Kingsville**, on **24th January**, Wednesday, **3:00-4:00 pm**

EOG Resources, Corpus Christi on **25th January**, Thursday, at **11:30 am**.

Contact: Subbarao.Yeliseti@tamuk.edu or Lonnie_Blake@eogresources.com

See <https://seg.org/Education/Lectures/Distinguished-Lectures/2018-DL-Symes> for additional details.

Education/Events

-SEG

See <https://seg.org/Education/Lectures/Distinguished-Lectures/2018-DL-Symes> for information about upcoming SEG distinguished lecture in Houston and other locations.

See <http://seg.org/Education/Lectures/Honorary-Lectures/2017-HL-van-der-Baan> for SEG honorary lecture locations in Texas. Topic is human-induced seismicity.

-GSH

Below is a weblink for registration for the January 23-26, 2018 four half-day webinars presented by Mike Graul and Fred Hilterman "**Seismic Amplitude 20/20: An Update and Forecast**" sponsored by the Geophysical Society of Houston and the SEG. Note that CBGS gets 10% of fees that come through CBGS.

https://www.gshtx.org/SharedContent/Events/Event_Display.aspx?EventKey=8906b6ec-a66b-4483-9f16-9eff670aa317

Webinar Pricing	Per Person
Individual Registration	\$390
Company/Group 2-10	\$325
Company/Group 11+	\$295
Individual Student	\$100
Student Group	\$60

SEG and GSH jointly organizing a live webinar on "**Introduction to Applied Depth Imaging**" by **Dr. Ruben Martinez**. It is scheduled from **10 am-2 pm, March 26-29th, 2018** (four half-

days). It covers the basic concepts and practical aspects used in depth velocity model building and depth imaging. See below link for additional information.

https://www.gshtx.org/SharedContent/Events/Event_Display.aspx?EventKey=011cd5de-1f54-4c39-826d-876185a5ea4a&WebsiteKey=955f17e6-46ad-4401-acbd-2af6c393752b

Webinar Pricing	Per Person
Individual Registration	\$390
Company/Group 2-10	\$325
Company/Group 11+	\$295
Individual Student	\$100
Student Group	\$60

Monthly Saying

“Profitable exploration requires wise investment of risk capital in people's ideas” - M.Downey

Monthly Summary

Texas Oil and Gas Info	Current Month	Last Month	Difference	
Texas Production	MMBO/BCF	MMBO/BCF	MMBO/BCF	
Oil	87.2	89.5	-2.3	September
Condensate	8.4	8.6	-0.2	September
Gas	596.6	623.2	-26.6	September
	Current Month	Yr to date - 2017	Yr to date - 2016	
Texas Drilling Permits	885	12600	8113	December
Oil wells	175	3183	2252	December
Gas wells	67	722	429	December
Oil and Gas wells	586	7887	4919	December
Other	9	188	122	December
Total Completions	623	6914	10468	December
Oil Completions	514	5394	7813	December
Gas Completions	80	1022	2129	December
New Field Discoveries	2	29	23	December
Other	3	22	52	December

Subbarao Yelisetti
President, CBGS



CORPUS CHRISTI GEOLOGICAL SOCIETY
COASTAL BEND GEOPHYSICAL SOCIETY



LUNCHEON MEETING ANNOUNCEMENT

FEBRUARY 21, 2018

-
- Location:** Water Street Events (Previously the Seafood Company Restaurant), 300 Block N. Water Street, CC, TX 78401
- Student Sponsor:** Imagine Resources, Nye Exploration, Viper Exploration, Ltd.
- Bar Sponsor:** *SPONSORSHIP OPPORTUNITIES AVAILABLE!!!*
- Time:** 11:30 am Bar, Lunch follows at 11:45 am, Speaker at 12:00 pm
- Cost:** \$25.00 (additional \$10.00 surcharge without reservation; No-shows may be billed and non-RSVP attendees cannot be guaranteed a lunch); **FREE** for students with reservation (discounted by our generous sponsors)!
- Reservations:** Please **RSVP** by 4PM on the FRIDAY before the meeting!
E-Mail: arrangements@ccgeo.org

Please note that luncheon RSVPs are a commitment to the Ortiz Center and must be paid even if you can't attend the luncheon.

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arrangements@ccgeo.org

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A New Technique for Lithology and Fluid Content Prediction from Prestack Data: An Application to a Carbonate Reservoir

Abstract:

Knowledge about the presence and orientation of fractures and stress is fundamental to shale operators. From a seismic point of view, P-wave seismic energy propagating across fractures can be influenced and decelerated because of microscopic opening and closing of fractures as the P-wave propagates. Stress also affects seismic velocities. A phenomenon known as “strain hardening” occurs when applying stress to materials; they strengthen in different directions, and their seismic velocity changes. Therefore, the seismic velocity will be different, depending on the azimuthal orientation of the seismic wave.

We can measure these azimuthal velocity changes using azimuthally diverse prestack seismic data. In this presentation, we show how we develop 3D spatial estimates of horizontal anisotropy caused by fractures and stress on an Eagle Ford example (from Seitel) using AVAZ and VVAZ technology. These estimates enable the engineer to allocate the finite completion budget to the rock mostly likely to develop complex, richly-connected fracture networks. This reduces the costly occurrence of large numbers of stimulated but ultimately non-productive intervals, for significant economic savings. While AVAZ and VVAZ will function on conventional source-receiver sectored azimuthal gathers, optimal results can be expected on full-azimuth reflection angle gathers generated by EarthStudy 360.

Presented by:

Peter Wang, Geophysical Technical Advisor, Paradigm

About our Presenter:



Peter Wang is a Geophysical Technical Advisor at Paradigm. He has a BS Degree in Geosciences from Brown University, and an MS in Geophysics and MBA from the University of Houston. He has a thirty-year history in the geophysical industry, having also served at Schlumberger as a Principal Geophysicist, Product Champion, and Workflow Champion, and Amoco Production Company (now BP) as a Senior Petroleum Geophysicist onshore USA Gulf Coast and Gabon.



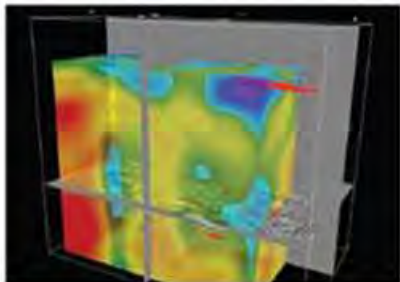


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CORPUS CHRISTI GEOLOGICAL SOCIETY BREWERY CRAWL

SATURDAY – APRIL 14, 2018

SCHEDULE

1:30 PM TO 2:00 PM – Meet at Railroad Seafood Station & Brewing Company,
1214 N. Chaparral, CC, TX 78401



2:00 pm – Depart for Lorelei Brewing Co.



2:15 pm to 3:15 pm – at Lorelei Brewing Co.

3:15 pm– Depart for Lazy Beach Brewing

3:30 to 4:30 pm – at Lazy Beach Brewing

4:30 pm – Depart for B&J's Pizza & Brewpub

4:45 to 5:45 pm – at B&J's Pizza & Brewpub

5:45 pm – Depart for Rebel Toad Brewing Co.



6:00 to 7:00 pm – at Rebel Toad Brewing Co.



7:15 pm – Return to Railroad Seafood Station & Brewing Co.

\$60.00 per person to include transportation and
at least one (1) pint at each venue



NAMES: _____

TELEPHONE: _____

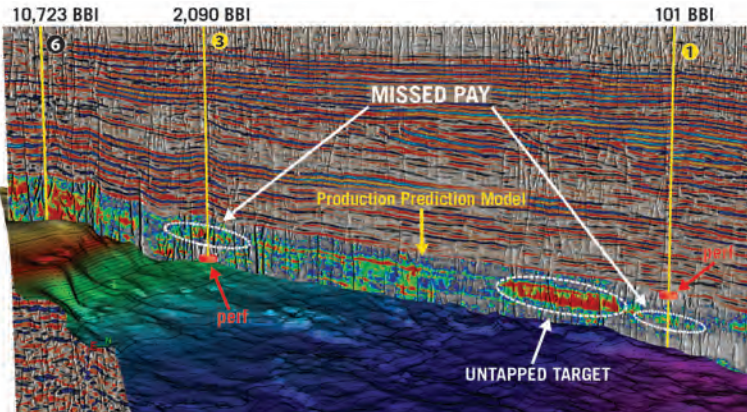
\$ _____ TOTAL _____ CHECK # (Payable to CCGS)

Please send completed form and payment by APRIL 7, 2018!!!

(check payable to CCGS) to:

CCGS BREWERY CRAWL 2018 – P.O. BOX 1068 – CORPUS CHRISTI, TX 78403

SEISMIC-BASED ANALYTICS



An arbitrary line through 3 vertical wells in the West Texas Permian Basin shows the lateral variations of the Production Prediction Model and reveals refrac potential for Wells 1 and 3 where the red disks indicate the actual completion intervals and the white circles highlight the missed pay. Note the untapped target near Well 1.

In today's challenging market, no one can afford a bad well. Global's seismic-based analytics can help you avoid the pitfalls and pinpoint the sweet spots. By integrating seismic, geological, and engineering data, this proprietary workflow identifies the most prospective areas and zones for drilling - down to the stage level! This reduces risk, optimizes spend, and greatly increases the chance for every well and stage to be a winner.

- High-grade prospective drilling areas and zones
- Enhance well planning and geosteering
- Optimize completion placements and frac design
- Predict well performance at stage level
- Boost EUR of individual wells
- Identify candidates for refrac

Global's **SEISMIC-BASED ANALYTICS** approach is field-proven with successful projects in both conventional and unconventional reservoirs. Contact us today to find out how Global can help you make every well a winner.

FIND WHAT YOU'VE BEEN MISSING

For More Information:

www.globalgeophysical.com/ANALYTICS or
Contact ANALYTICS@globalgeophysical.com



Corpus Christi Geological Society

Golf Tournament

4-Person Scramble

April 13, 2018

12:30 p.m. Shotgun Start

At

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NOACHIAN IMPACT BRECCIAS ON THE RIM OF ENDEAVOUR CRATER, MARS: OPPORTUNITY APXS RESULTS. D. W. Mittlefehldt¹, R. Gellert², R. E. Arvidson³, J. F. Bell III⁴, W. H. Farrand⁵, K. E. Herkenhoff⁶, B. L. Jolliff³, D. W. Ming¹, C. Schröder⁷, R. J. Sullivan⁸ and the Athena Science Team ¹NASA/Johnson Space Center, Houston, TX, USA (david.w.mittlefehldt@nasa.gov), ²University of Guelph, Guelph, ON, Canada, ³Washington University, St. Louis, MO, USA, ⁴Arizona State University, Tempe, AZ, USA, ⁵Space Science Institute, Boulder, CO, USA, ⁶U.S. Geological Survey, Astrogeology Science Center, Flagstaff, AZ, USA, ⁷University of Stirling, Stirling, Scotland, UK, ⁸Cornell University, Ithaca, NY, USA.

Introduction: Mars Exploration Rover Opportunity has been investigating the geology of Meridiani Planum since January 2004, and is currently ~3830% into its primary mission. Opportunity reached the rim of 22 km diameter Endeavor crater at Spirit Point on the south end of Cape York on sol 2681 and began exploring the geology of Endeavour rim. She left Cape York on sol 3316 and arrived at the next rim remnant to the south, Solander Point, on sol 3387 to begin geological investigations at the contact and up onto Murray Ridge. The Burns fm. of Meridiani Planum lies near the top of the plains-forming unit of western Sinus Meridiani [1] and onlaps onto the Endeavour rim rocks (hereafter rim rocks). Endeavour crater would have excavated ~4 km into the existing stratigraphy. Thus, the ejecta that form the rim rocks offer windows into the deeper lithologies of Sinus Meridiani.

Endeavour Rim Stratigraphy and Targets: The rim rocks on Cape York are informally divided into two formations: the lower Matijevec fm. and the upper Shoemaker fm. [2, 3]. The Matijevec fm. is composed of fine-grained deposits containing variable concentrations of mm-sized spherules, and is thought to represent a pre-Endeavour-impact lithology [3]. The Shoemaker fm. is composed of impact ejecta from Endeavour crater [2, 3]. It is subdivided into three members, from the bottom up: (i) Copper Cliff mbr.; (ii) Chester Lake mbr.; (iii) Greeley Haven mbr. We have not yet defined stratigraphic units for Murray Ridge. Here we discuss the polymict breccias of the Shoemaker fm. on Cape York and the breccias from Murray Ridge, with a focus on compositions determined by the Alpha Particle X-Ray Spectrometer (APXS). For the most part, APXS targets were not brushed or abraded. This adds some uncertainty to interpretations of rock compositions owing to the presence of dust, soil, pebbles, and possibly alteration rinds on rock surfaces.

Textures of Impact Breccias: Rocks of the Shoemaker fm. on Cape York are breccias containing cm-sized and larger dark, angular clasts set in the lighter-toned, fine-grained matrix [2, 3]. Rocks with identical textures are found on Murray Ridge (Fig. 1a). There is a linear fabric to the outcrops, possibly due to differential wind erosion. Microscopic views of the rocks show dark, angular to sub-rounded clasts of variable sizes (Fig. 1b). Clasts are fine-grained, although

the internal texture of some suggests they may in turn be breccias (Fig. 1b).

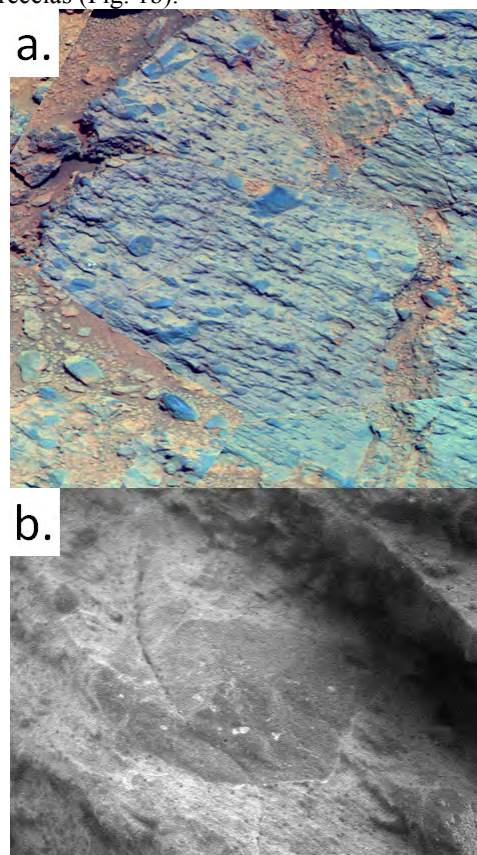


Figure 1. a. Portion of sols 3494-3496 Pancam false-color mosaic of the Moreton Island breccia outcrop on Murray Ridge containing APXS targets Tangalooma and Mount Tempest. b. Portion of sol 3502 Microscopic Imager view of APXS target Mount Tempest showing a 1.6×1 cm angular clast in matrix.

Compositions of Cape York and Murray Ridge Breccias: In general, the breccias of the Endeavour rim are mafic in composition. They follow compositional trends shown by martian basaltic and lherzolithic shergottites, and MER igneous targets Bounce Rock and Backstay, including the $\text{Cr}_2\text{O}_3'$ vs. mg# (100*molar $\text{MgO}/(\text{MgO}+\text{FeO})$) trend shown in Fig. 2a. (The “prime” on the oxides indicates bulk compositions renormalized to a SO_3 - and Cl-free basis.) However, the breccias are distinct from Adirondack class basalts from Gusev crater [4]. The protoliths for the

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breccias were plausibly a sequence of mafic extrusive and intrusive igneous rocks. However, the compositions are not pristine. All have 4-10 wt% SO_3+Cl , significantly higher than for martian meteorites (<0.5 wt%).

Evidence for Aqueous Alteration: Most of the breccias have FeO'/MnO' ratios like those of martian meteorites (Fig. 2b). Ferrous iron and Mn^{2+} are homologous species during igneous processes and do not significantly fractionate. Aqueous processes can fractionate Fe from Mn and this is likely the cause for low Mn in one Chester Lake mbr. target, and high Mn in some Greeley Haven mbr. breccias and the one Murray Ridge target. Dark clast targets in the Greeley Haven and Chester Lake mbrs. have higher Mn than nearby matrix-rich targets. This suggests the Fe/Mn fractionation was accomplished in the protoliths, before assembly of the breccias. CIPW normative mineralogies contain lower diopside than do the abraded targets of Adirondack class basalts [4]. Empirically, altered rocks on the Columbia Hills in Gusev crater contain lower normative diopside than do Adirondack class basalts.

Alteration processes on Mars differ from those on Earth. The latter typically occur under moderate pH, high water/rock, leading to Al- and Fe^{3+} -rich residues (arrow E in Fig. 2c), while on Mars alteration occurred under low pH and low water/rock resulting in dissolution of olivine in mafic protoliths (arrow M) [5]. The Shoemaker fm. and Murray Ridge rocks plot on the field of martian mafic meteorites and Adirondack class basalts indicating minimal transport of cations by alteration solutions in the protoliths.

While the data suggest much of the alteration likely occurred in the protoliths before impact excavation, there was nevertheless additional localized alteration after emplacement on the rim. Veins rich in Ca-sulfate crosscut the Copper Cliff mbr. and the underlying Matijevec fm. [3, 6], and highly mobile elements such as Zn show extreme variations between different members of the Shoemaker fm. [2]. Boxwork veins on Matijevec Hills in particular indicate strong alteration resulting in localized enrichments in Al and Si [6].

Variations between different rim segments: The breccias on Murray Ridge are generally similar to Shoemaker fm. breccias for many elements (cf., Fig. 2a) but there are differences (cf., Fig. 2b). Thus, while the Murray Ridge breccias were formed from protoliths generally similar to those of the Shoemaker fm., the two breccia groups represent distinct areal or stratigraphic packages in the pre-impact terrain. Correspondence analysis of the APXS data shows subtle differences between the Murray Ridge breccias and Shoemaker fm. breccias further indicating compositional differences between rim segments [7].

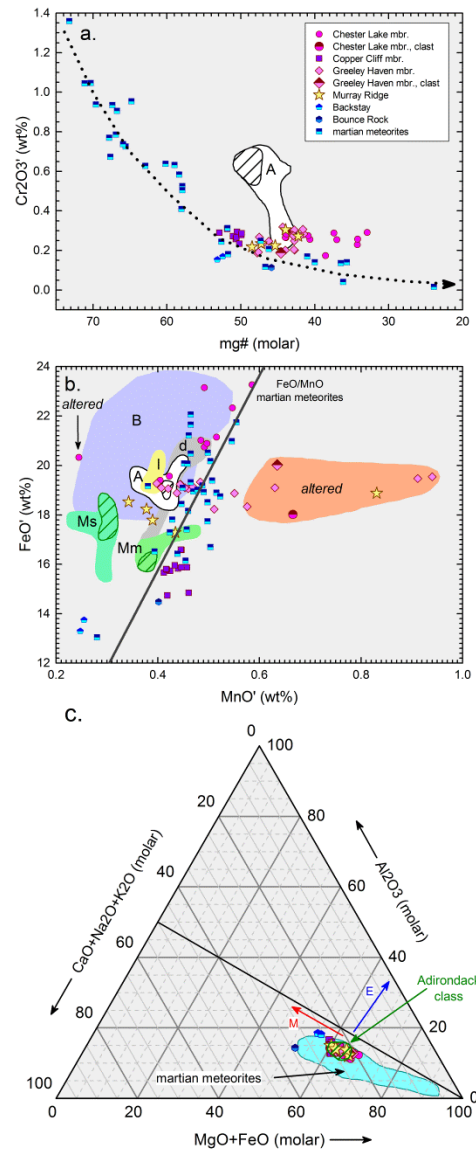


Figure 2. Compositions of Cape York and Murray Ridge rocks compared to martian basalts. Labeled fields are: B - Burns fm.; A - Adirondack class basalts; Mm - matrix-rich Matijevec fm.; Ms - spherule-rich Matijevec fm.; d - dark soils; l - light-toned soils. Crosshatched sub-fields in fields labeled A, Mm and Ms enclose abraded targets.

References: [1] Edgett K. S. (2005) *Mars*, 1, 5-58. [2] Squyres S. W. et al. (2012) *Science*, 336, 570-576. [3] Arvidson R. E. (2014) *Science*, XXX, in press. [4] Ming D. W. et al. (2006) *J. Geophys. Res. Planets* 111, E02S12. [5] Hurowitz J. A. and McLennan S. M. (2007) *Earth Planet. Sci. Lett.* 260, 432-443. [6] Clark B. C. et al. (2014) *LPS*, XLV, this conference. [7] Arvidson R. E. et al. (2014) *LPS*, XLV, this conference.

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Noachian Impact Breccias on the Rim of Endeavour Crater, Mars: Opportunity APXS Results

D. W. Mittlefehldt¹, R. Gellert², R. E. Arvidson³, J. F. Bell III⁴, W. H. Farrand⁵, K. E. Herkenhoff⁶, B. L. Jolliff³, D. W. Ming¹, C. Schröder⁷ and the Athena Science Team

¹*NASA/Johnson Space Center, Houston, TX, USA*

²*University of Guelph, Guelph, ON, Canada*

³*Washington University, St. Louis, MO, USA*

⁴*Arizona State University, Tempe, AZ, USA*

⁵*Space Science Institute, Boulder, CO, USA*

⁶*U.S. Geological Survey, Astrogeology Science Center, Flagstaff, AZ, USA*

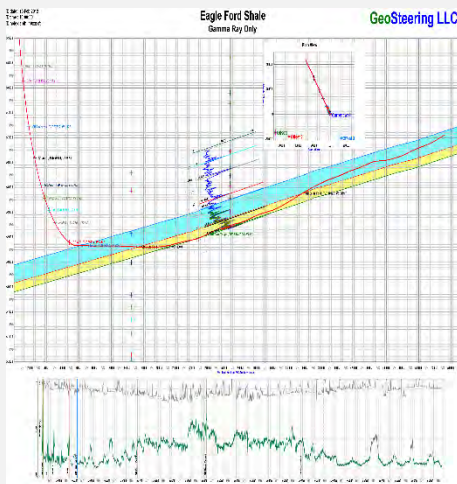
⁷*University of Stirling, Stirling, Scotland, UK*

synopsis

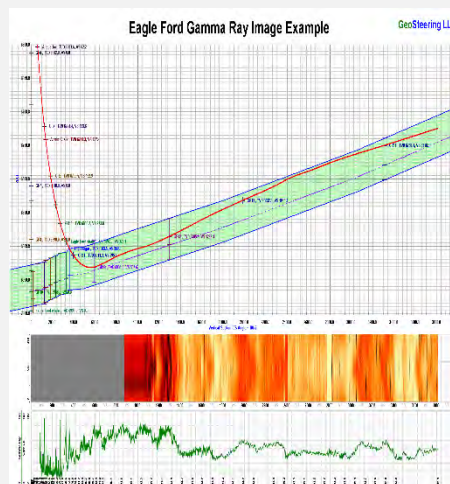
- Summarize impact breccia stratigraphy
- Show their textural and spectral character
- Present rock compositions
- Discuss alteration
- Interpret the nature of the target lithologies that sourced the breccias

Geosteering in the USA and Internationally since 2002

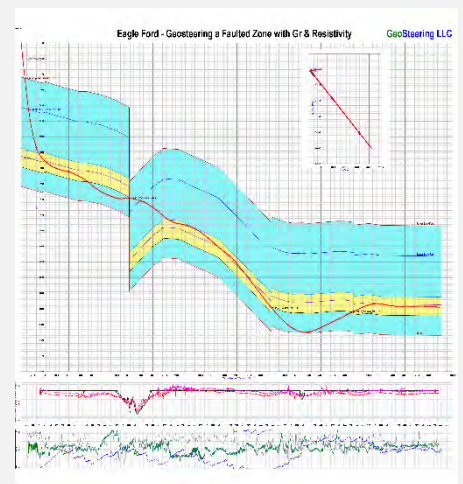
Steering with GR



Steering with Images



Steering with Resistivity



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Endeavour crater

Cape York

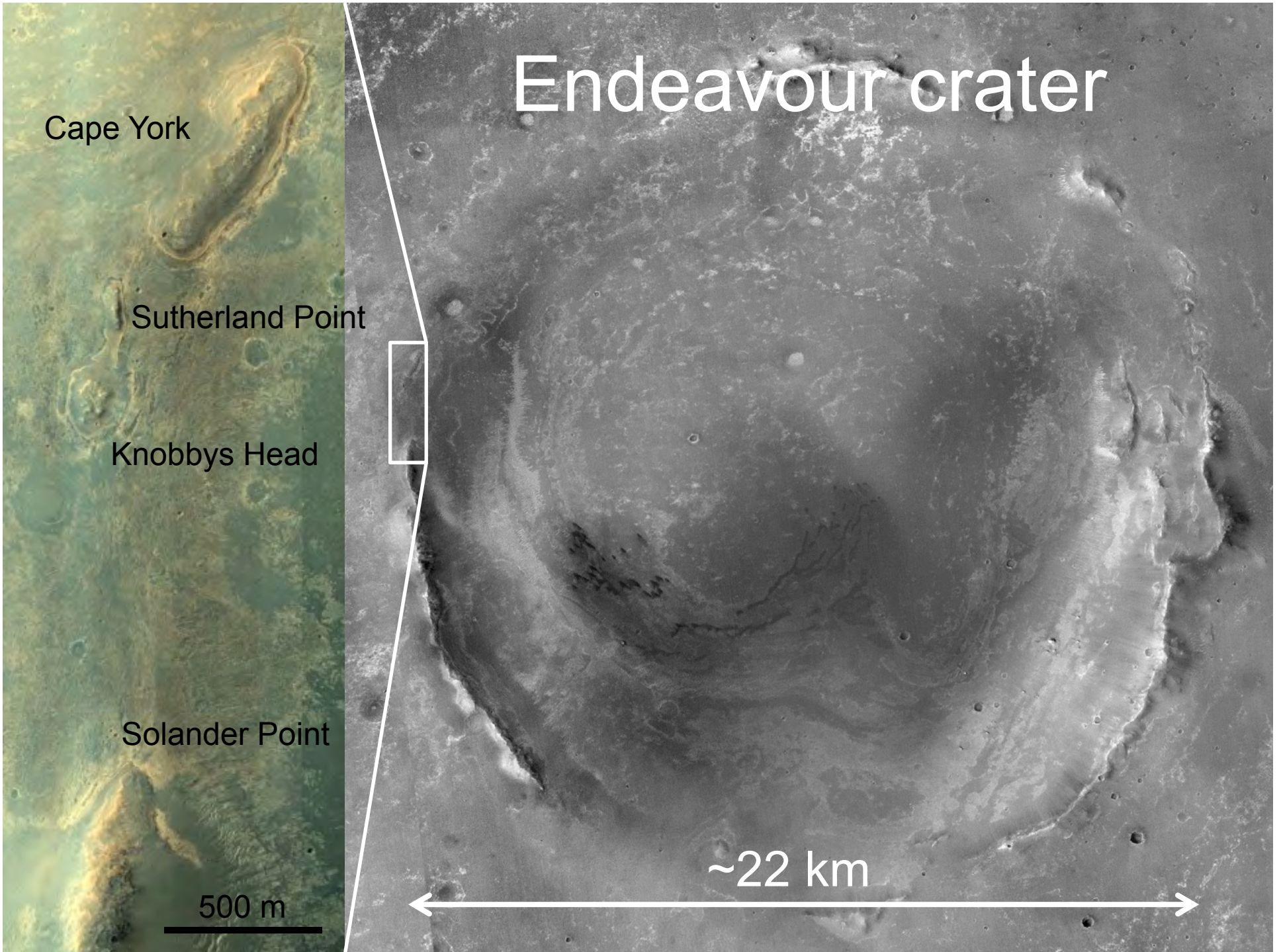
Sutherland Point

Knobbys Head

Solander Point

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Endeavour Rim Breccia Stratigraphy

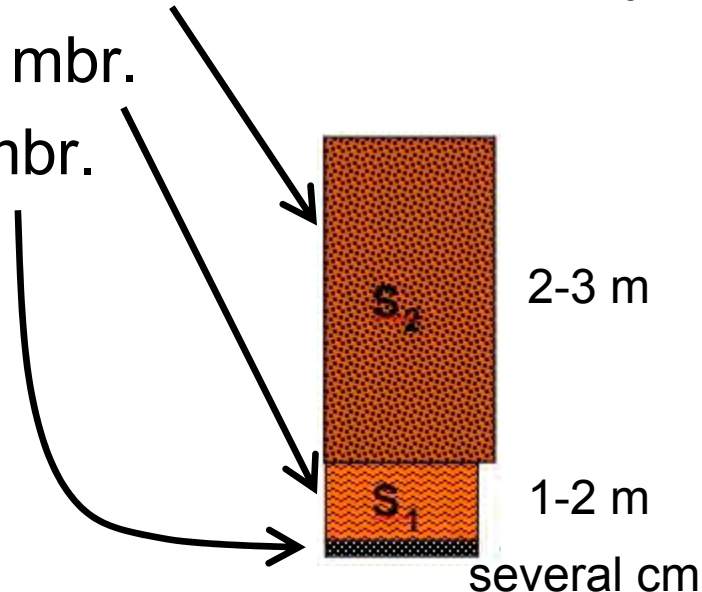
(after Crumpler et al. (2015))

Cape York

- Shoemaker fm., three members, top down:
 1. Greeley Haven mbr.
 2. Chester Lake mbr.
 3. Copper Cliff mbr.

Solander Point, Murray Ridge

- Shoemaker fm., currently undivided



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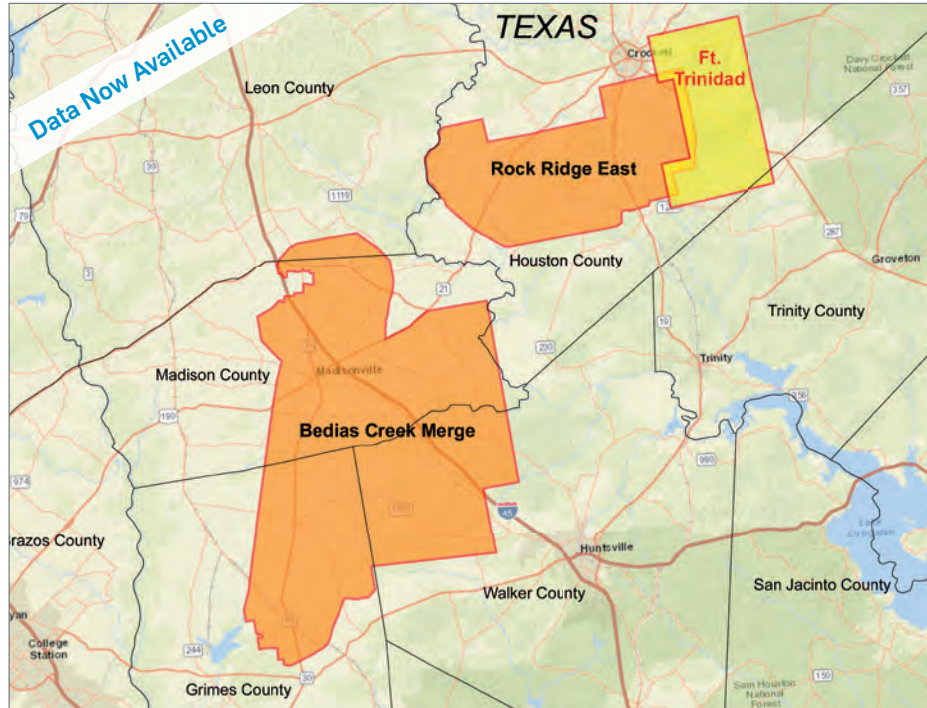
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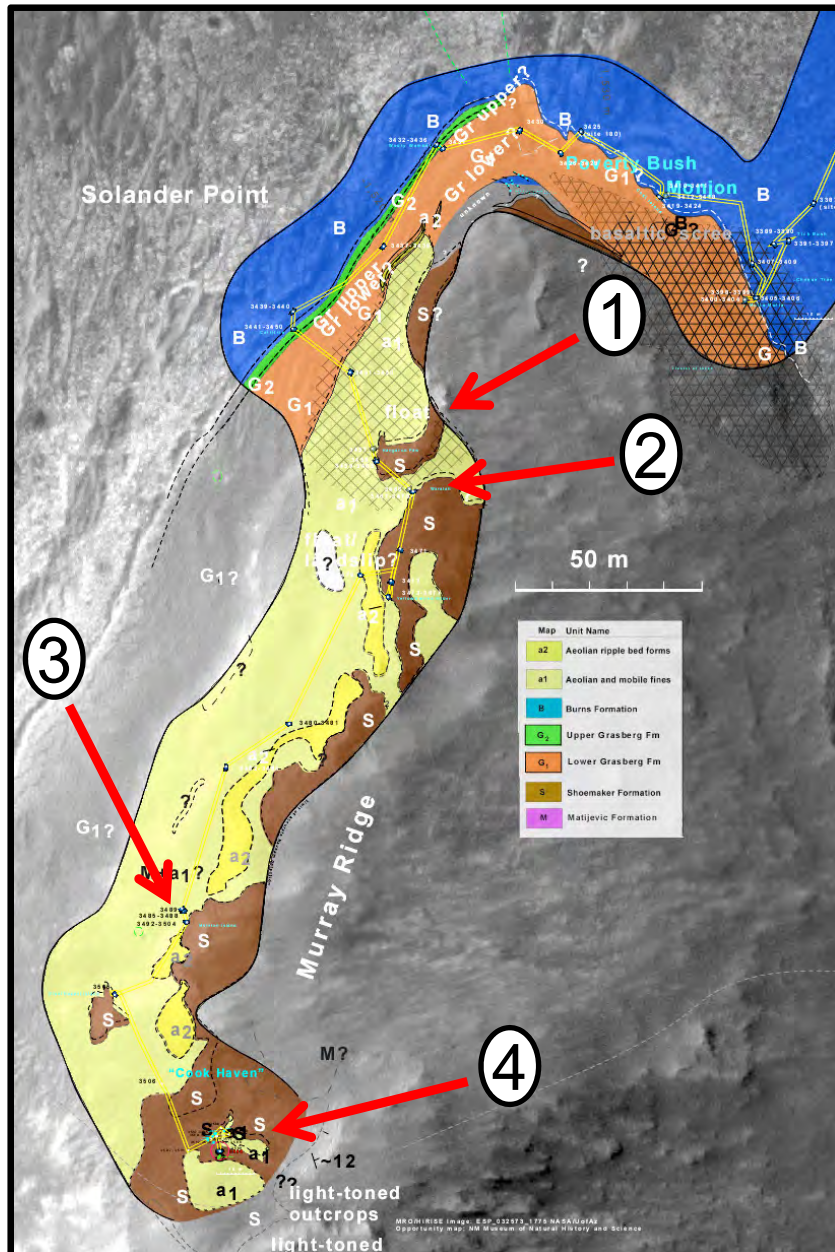
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Solander Point Geological Traverse Map (Crumpler et al., 2014)



Shoemaker fm.

1. Kangaroo Paw region:
Spinifex and Paper Bark (MI only) targets
2. Waratah region:
Baobab* target
3. Moreton Island region:
Tangalooma and Mount Tempest targets
4. Cook Haven region:
Cape Darby*, Cape Elizabeth, Green Island and Turnagain Arm targets

*Debris-littered surfaces;
not discussed here



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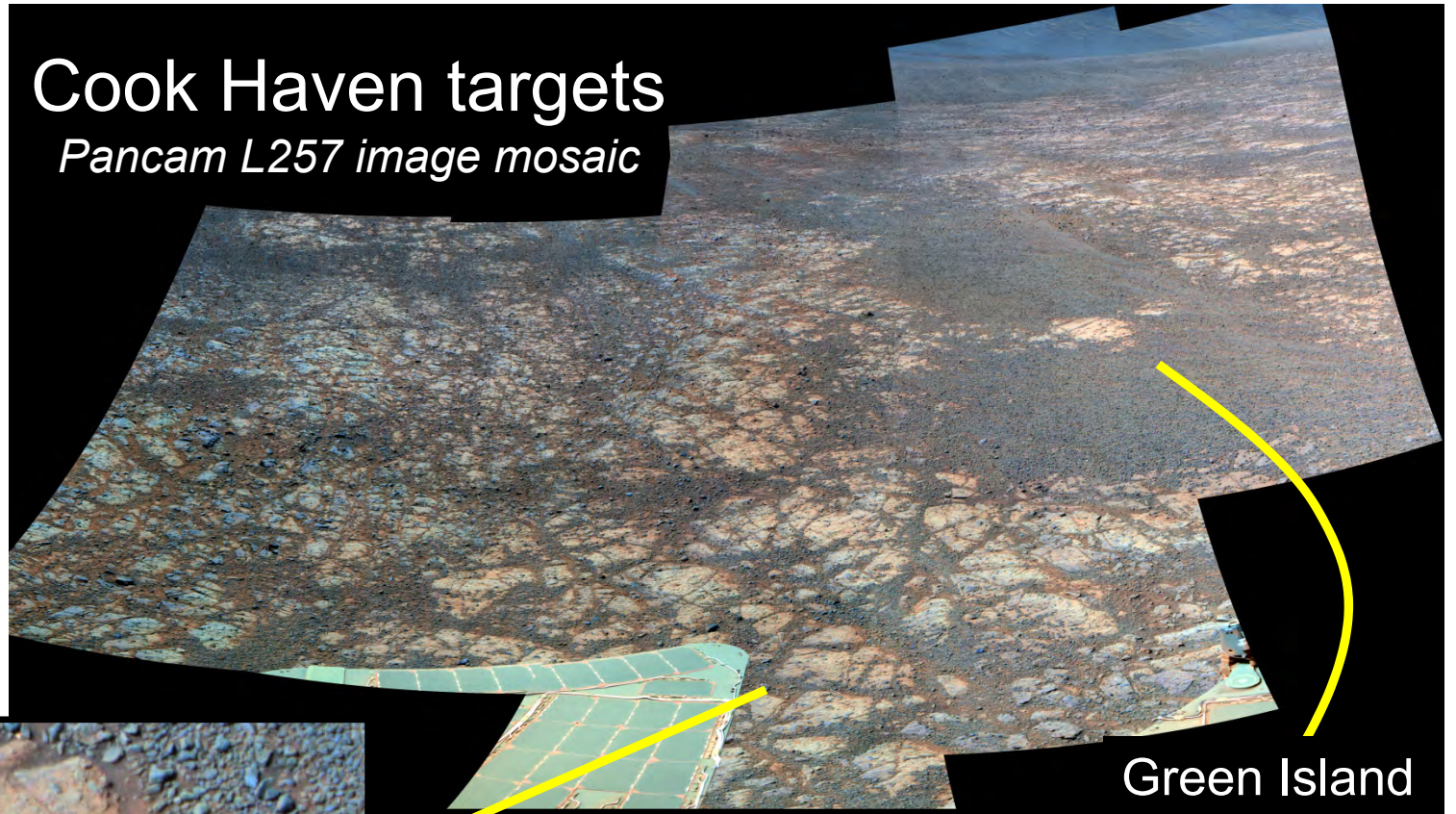
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Cook Haven targets

Pancam L257 image mosaic



Cape Elizabeth

Green Island

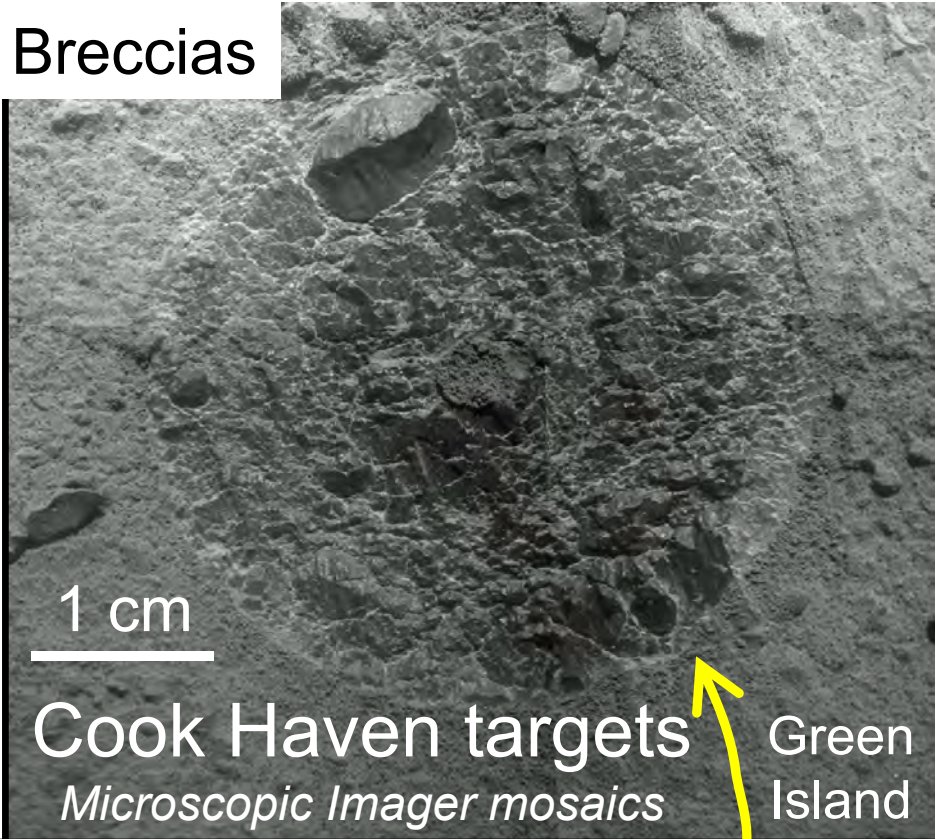
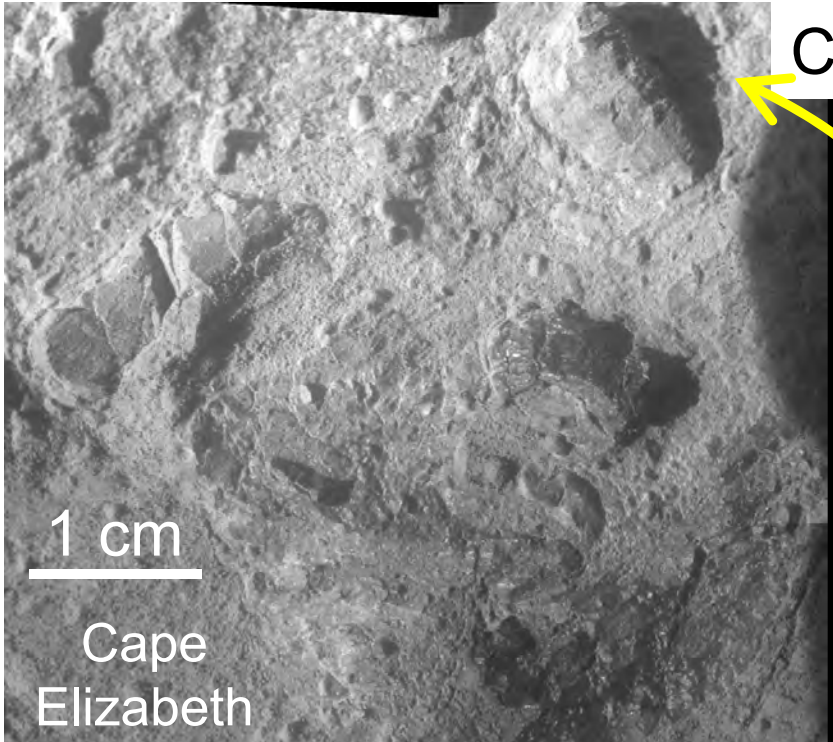


Sol 3540 p2594 L257



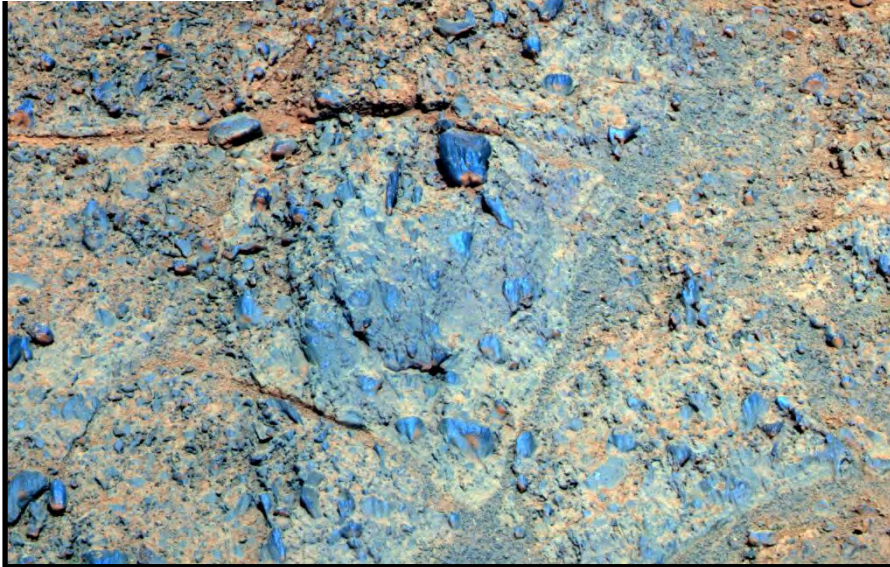
Sol 3552 p2530 L257

Clastic Breccias

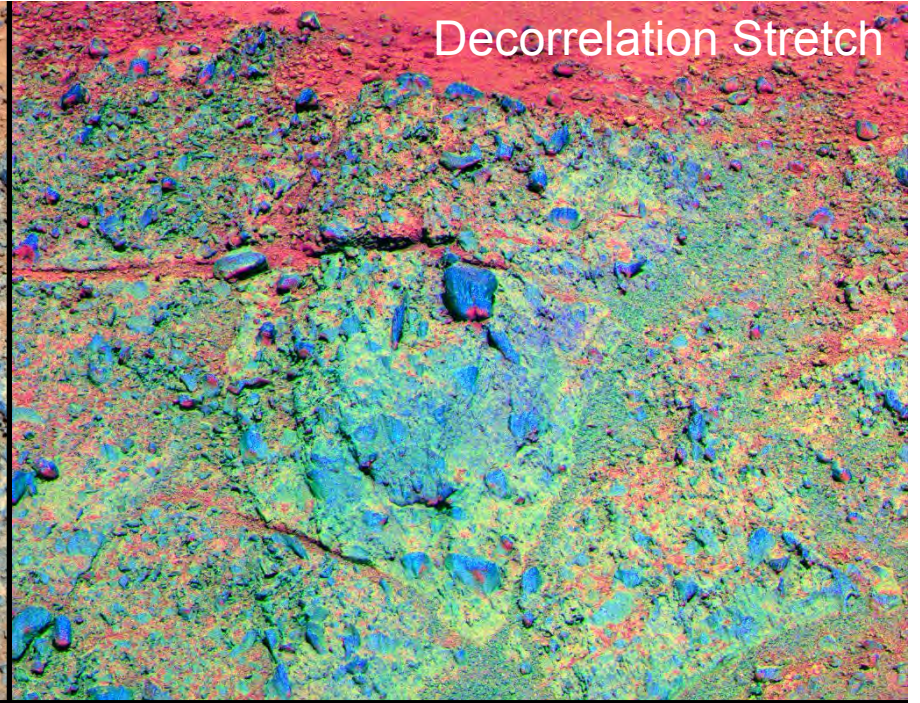


Greeley Haven,
Cape York

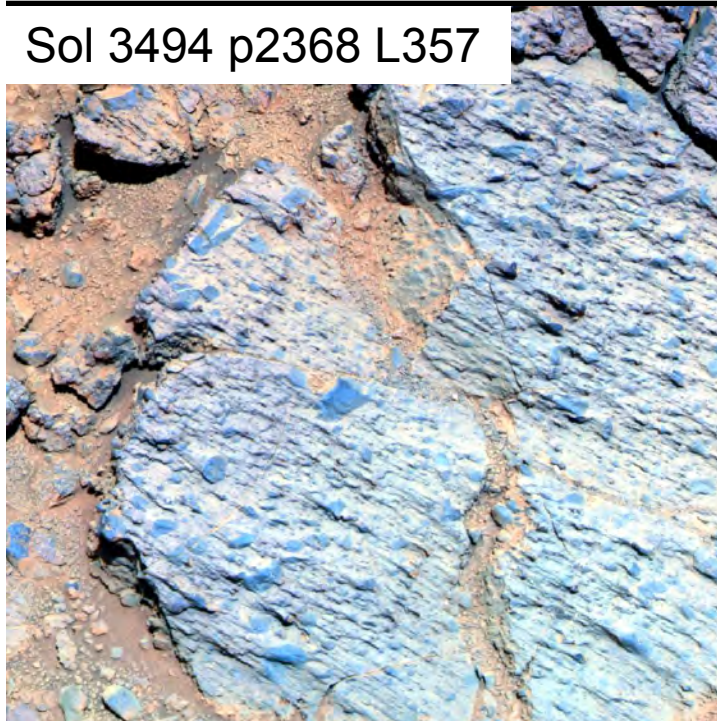
Sol 2795 p2588 L357



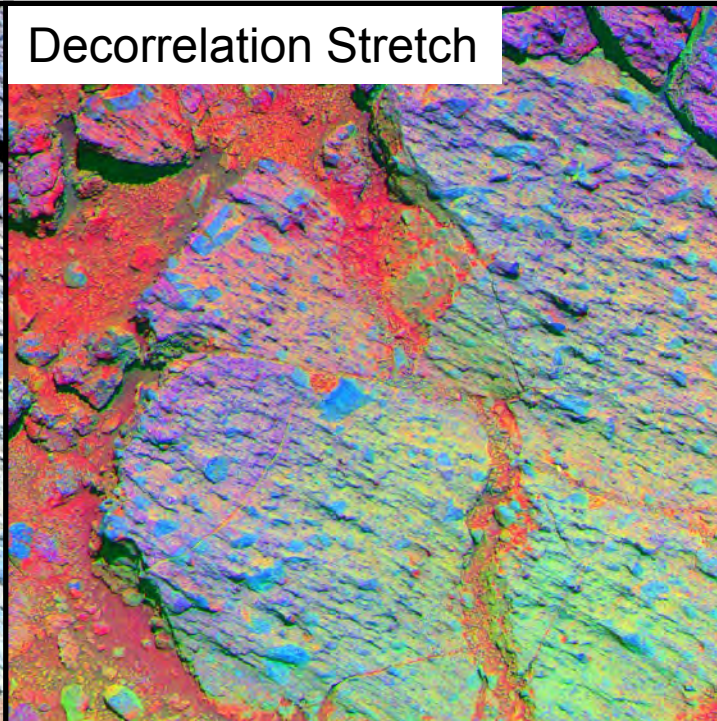
Decorrelation Stretch



Sol 3494 p2368 L357



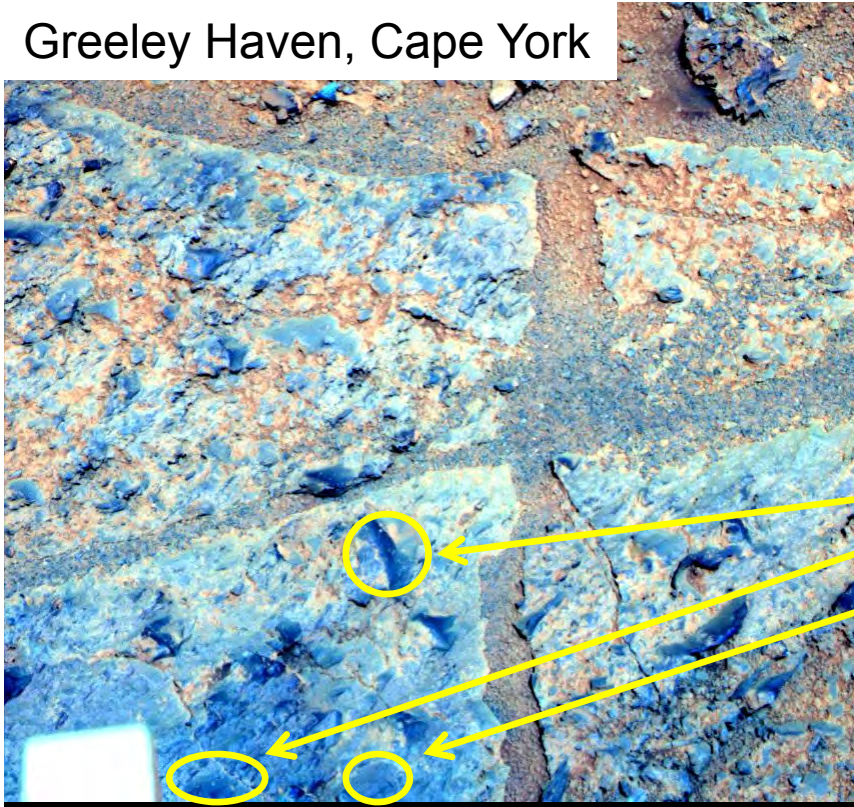
Decorrelation Stretch



- Clasts are subangular to subrounded.
- Some are more resistant to wind erosion.

Moreton Island,
Solander Point

Greeley Haven, Cape York

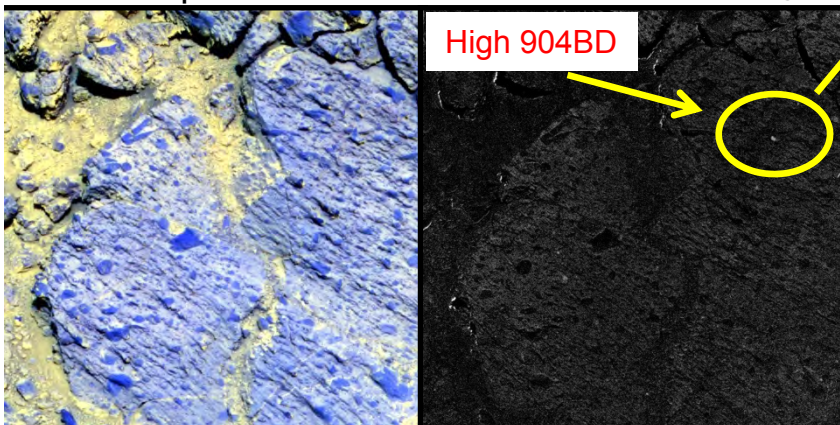


Sol 2817 p2597 L357

Moreton Island, Solander Point

Sol 3494 p2368 R731

RMS error image



High 904BD

Clasts vs. Matrix

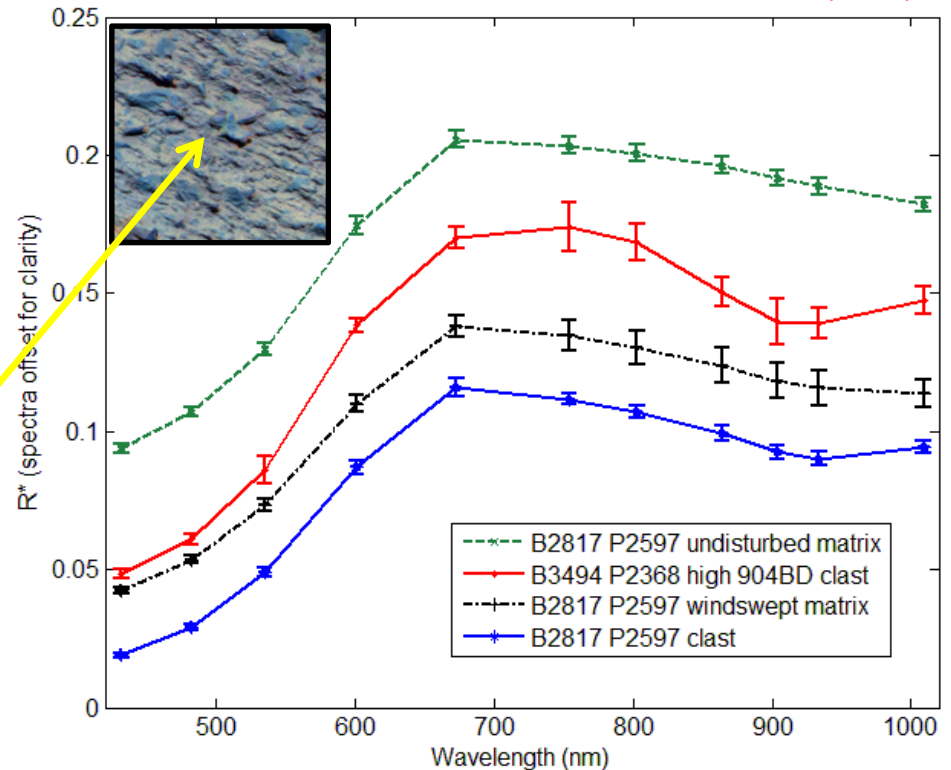
- Some clasts have distinct spectral properties.
 - Matrix: Generally decreasing reflectance from 673 to 1009 nm.
 - Clasts: Absorptions at ~900-930 nm.

Clast

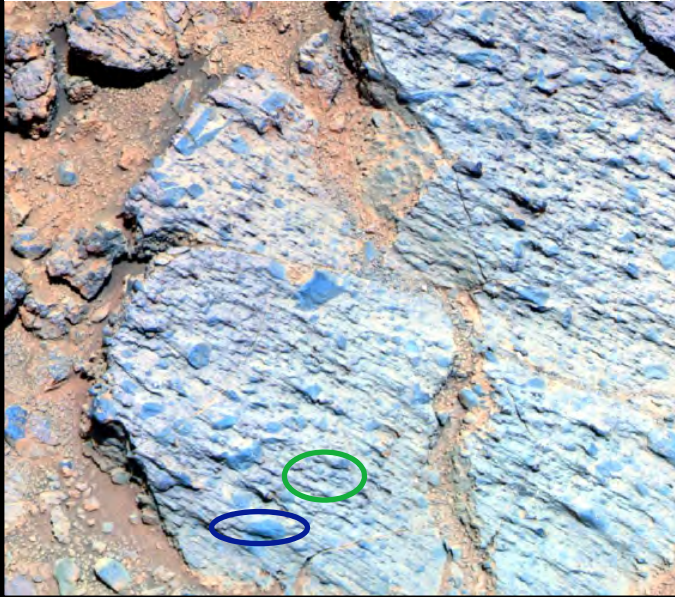
Windswept matrix

Undisturbed matrix

after Farrand et al. (2014)



Sol 3494 Moreton Island L357



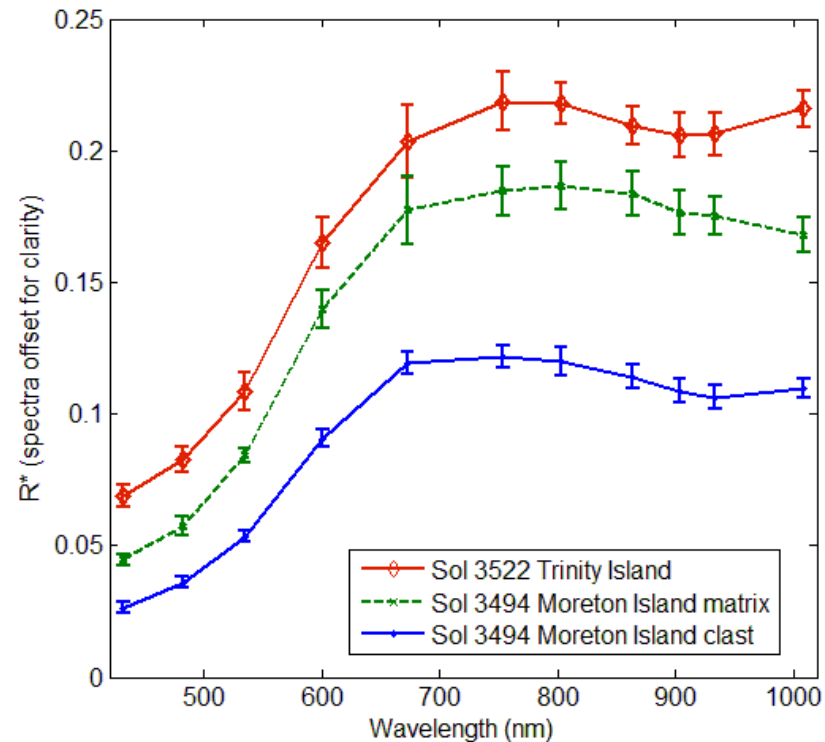
Sol 3522 Trinity Island L357



Spectral Variations on Murray Ridge

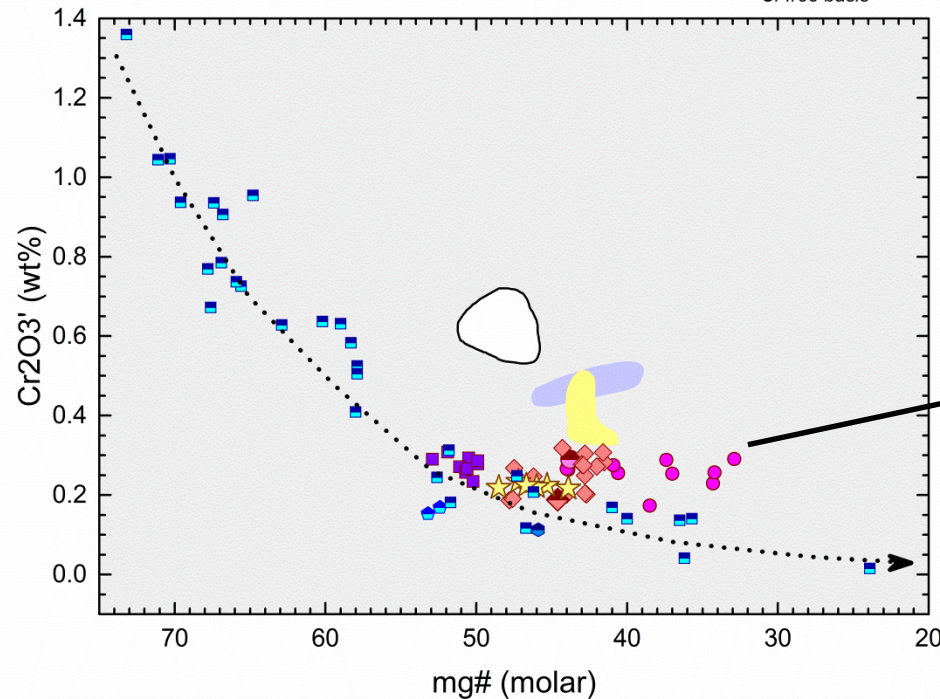
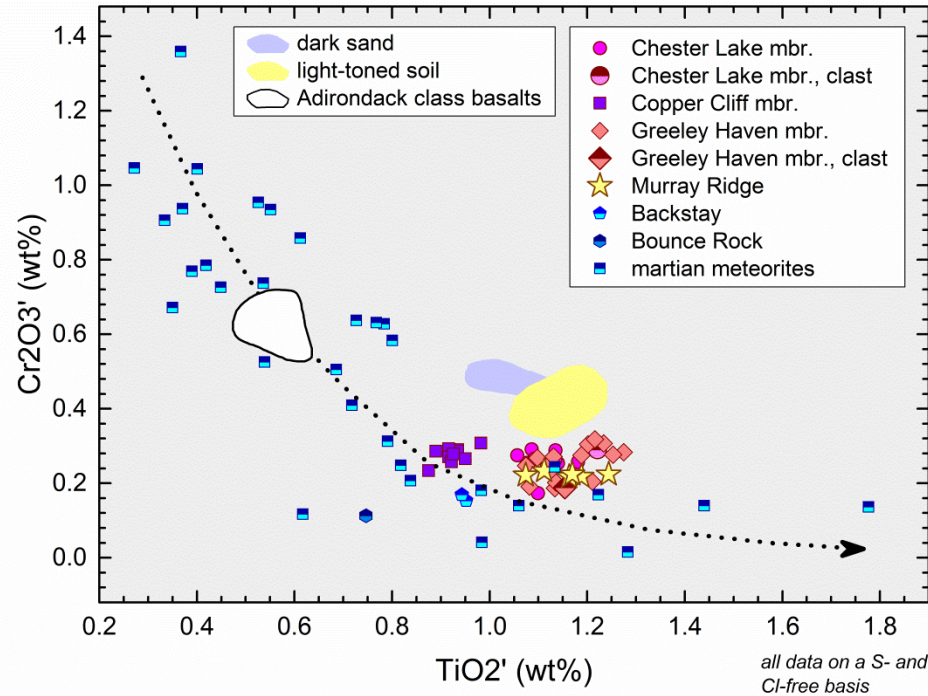
Cook Haven (Trinity Island) compared to Moreton Island:

- Greater 904 nm band depth
- Steeper blue-to-red slope
- Spectrum consistent with more oxidized rock

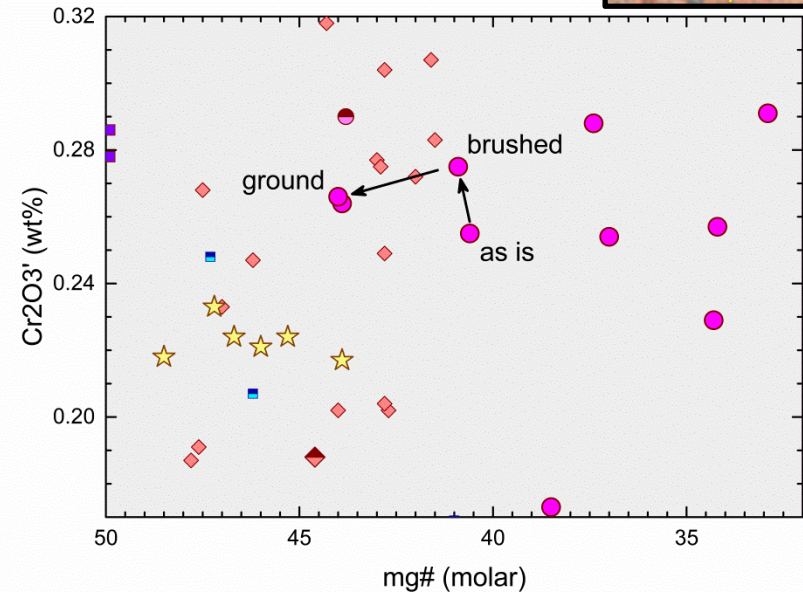


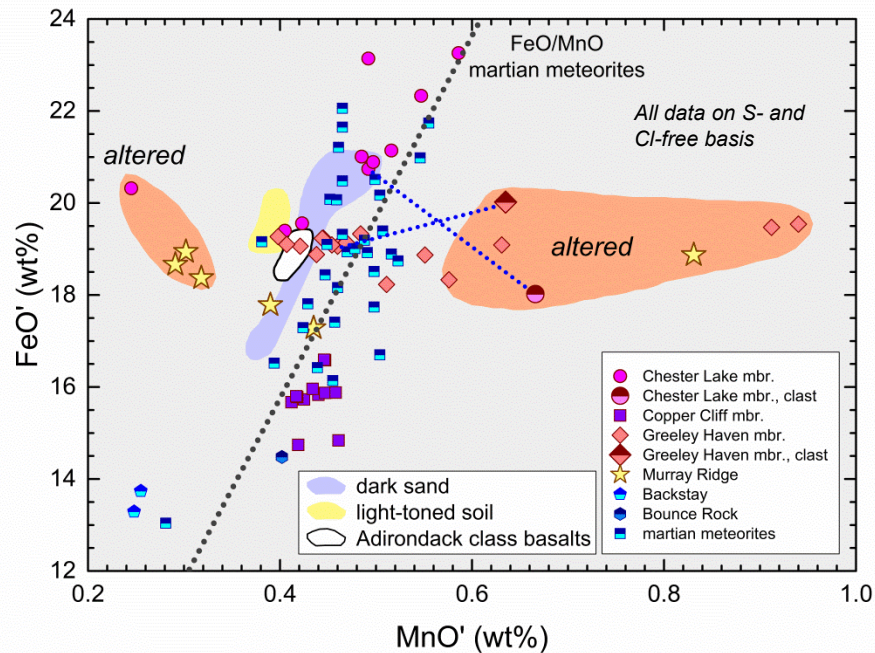
after Farrand et al. (2014)

Breccia Compositions; Mafic Parentage



- Breccias follow martian mafic igneous trend (martian meteorites; Gusev crater rocks).
- For many elements, Murray Ridge breccias closest in composition to Greeley Haven mbr.
- Caveat:** Most targets are “as is”; few brushed, only one ground.

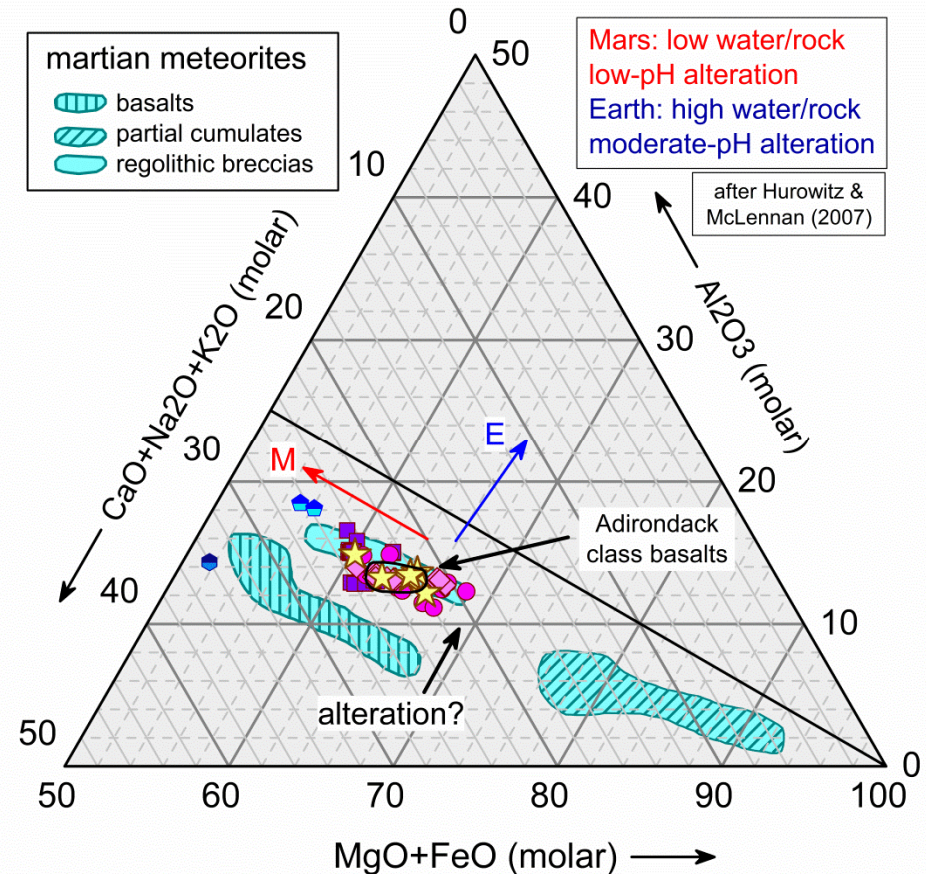




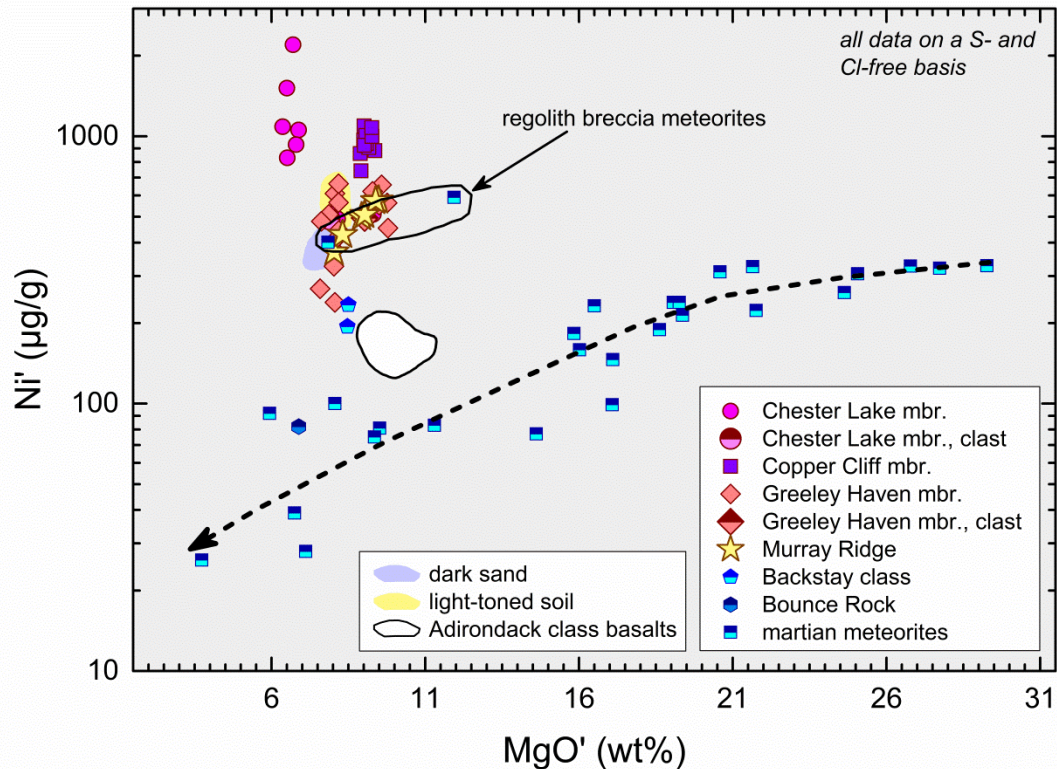
- Clasts can be different from host matrix (blue dotted tie-lines).
- Least altered Murray Ridge breccias have lower FeO' than Greeley Haven mbr. breccias.
- Breccias more Al_2O_3 -rich than little-altered martian basaltic meteorites; like mildly altered regolith breccias.
- High water/rock moderate-pH alteration of protolith (*cf.*, Hurowitz & McLennan, 2007)?

Breccia Compositions; Mild Alteration

- Most breccias follow martian FeO/MnO trend.
- Some show gain or loss of MnO by alteration; oxidation state control?



Breccia Ni Contents; Alteration or Regolith?



- Ni high compared to martian mafic igneous trend.
- Overlap fields for soils (but other elements distinct).
- Ni enhanced by alteration of the protolith?
- Ni contents like those of martian regolith breccia meteorites.
- Alternative: Protolith deep regolith contaminated by impactor debris?

summary

- Shoemaker fm.: Impact breccias engendered by the Endeavour impact (Squyres *et al.*, 2012; Arvidson *et al.*, 2014).
- Shoemaker fm. breccias are consistent with mildly altered mafic rock parentage.
- Some clasts in Shoemaker fm. have distinct alteration signatures from breccia matrix (*e.g.*, Mn-Fe separation):
Alteration prior to assembly of breccias.
- Alteration may have been higher water/rock and more moderate pH than the acidic alteration of Burns fm. (*cf.*, Hurowitz & McLennan, 2007).
- Murray Ridge breccias most similar to Greeley Haven mbr., but nevertheless, distinct from Shoemaker Ridge breccias.
- Murray Ridge and Shoemaker Ridge breccias formed from different (areal or stratigraphic) portions of the protolith.

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<http://www.geographynetwork.com/> Go here and try their top 5 map services. My favorite is 'USGS Elevation Date.' Zoom in on your favorite places and see great shaded relief images. One of my favorites is the Great Sand Dunes National Park in south central Colorado. Nice Dunes.

<http://antwrp.gsfc.nasa.gov/apod/asropix.html> Astronomy picture of the day--awesome. I click this page everyday.

<http://www.spacimaging.com/gallery/ioweek/iow.htm> Amazing satellite images. Check out the gallery.

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www.ccgeo.org Don't forget we have our own we page.

<http://terra.nasa.gov/gallery/> Great satellite images of Earth.

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Goose Island
Half Moon Reef
Nine Mile Point
Rockport, West
St. Charles
Tally Island
Tract 831-G.O.M. (offshore)
Virginia

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Mosca
Nomanna
Orangedale(2)
Ray-Wilcox
San Domingo
Tulsita Wilcox

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Boedecker
Cage Ranch
Encintas
ERF
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Gyp Hill West
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Mills Bennett
Pita
Tio Ayola
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Long Mott
Magnolia Beach
Mosquito Point
Olivia
Panther Reef
Powderhorn
Seadrift, N.W.
Steamboat Pass
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S.E. Zoller

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Luttes
San Martin (2)
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Shary
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Weslaco, North
Weslaco, South
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StewartSwan Lake

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889S(offshore)
Nueces Bay/Nueces Bay
West

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Hiberia
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Taft
Taft, East

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Garcia
Hinde
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Rincon
Rincon, North
Ross
San Roman
Sun
Yturria

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Carr Lobo
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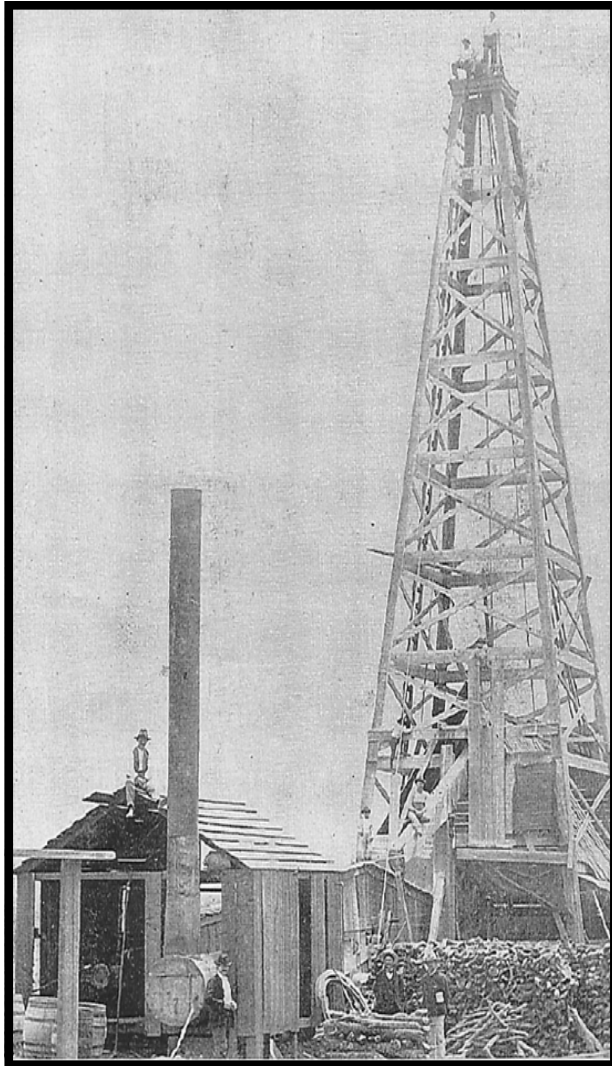
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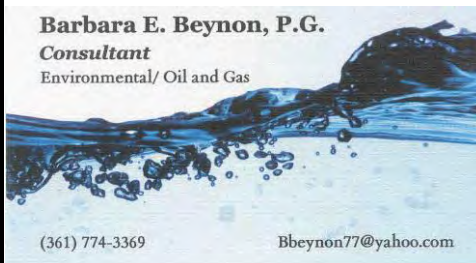
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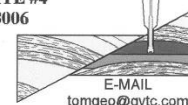
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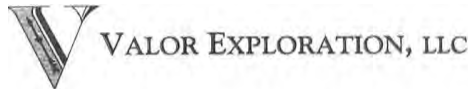
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