TEXAS TECH UNIVERSITY
College *of* Arts & Sciences
Department of Geosciences

**Department of Geosciences**
**Texas Tech University**
**Research Day 2014**
**May 7th**

Welcome to the Department of Geosciences Research Day.

The program this year presents over 40 abstracts from faculty, graduate and undergraduate researchers covering a wide variety of topics that illuminate ongoing research within the Department of Geosciences. I would like to highlight that over 30 abstracts are first authored by geoscience undergraduates which, by my research, is the highest number ever recorded for Research Day. Undergraduate research within the department is a priority reflected in the volume and quality of these abstracts.

We hope to have a significant industry presence this year. Steve Henderson (Halliburton) is returning to help judge the Advanced Petrophysical projects. Steve has become a regular at Research Day and we welcome him again. Additionally, we hope to have representatives from Concho Resources, Columbine Logging, Southwestern Energy, and Denbury Resources. The representative from Columbine Logging (David Henlsey) will be awarding two scholarships to deserving undergraduate students. Please take some time to meet these guests.

New this year, Southwestern Energy is sponsoring Research Day. In the past, the Geoscience Society has provided funding for Rudy's Barbeque and refreshments. However, thanks to Southwestern's generous support, the Society will be able to put those funds to other use, such as providing significant student support for research activities. The Society has also agreed to match all donations (up to $1000 total) given during Research Day to the Sigma Gamma Epsilon Geosciences Society Scholarship Fund.

Lastly, I would like to thank all of the presenters for their hard work and commitment to providing quality research. Plus, a special thank you to all the undergraduate researchers; presenting on Research Day is one of the last hurdles you have to clear before graduation. Be proud of your accomplishments!

Let's have some fun,

Dustin Sweet

Schedule of Events
10:30-12:30 Poster Presentations
12:30-1:15 Rudy's BBQ Lunch
1:15 Award Presentations

## PETROPHYSICAL AND ECONOMICAL ANALYSIS OF THE WOLFCAMP FORMATION

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The early Permian Wolfcamp Formation extends from the Northwestern Shelf to the Val Verde Basin of The Permian Basin. As estimated recoverable resources continue to increase, the Wolfcamp series is currently subject to aggressive development in both the Midland Basin and Delaware Basin. A full log suite from a 900' interval of TTU #1-5399 was used to determine the appropriate depth for a horizontal well and the gross production potential. Compressional and shear wave delay times were used to determine mechanical properties preferable for hydraulic fracturing. Thermal maturity was determined from a combination of vitrinite reflectance data and calculated Maturity Index using the Zhao method. Thermal maturity in the Wolfcamp A and B units indicate that the reservoir is dominated by liquid hydrocarbons and mid-stage gas production is occurring. Original Oil in Place (OOIPstb) was calculated for a 5280' horizontal well at a depth of 8350'. Assuming a conservative total fracture height of 250' from 8150' to 8400', 160 acre drainage, and an interval cutoff of 100 nD, OOIPstb is estimated to be 7.518 MMbbl. With a recovery factor of 3%, the interval is expected to produce 225.5 Mbbl. At $85/bbl, the gross potential for this interval is estimated to be $19.2 million.

## LOG ANALYSIS OF AN "OLD" (PRE 1955) PERMIAN CARBONATE E- LOG [NO CALCULATOR/COMPUTER AND W/ COMPUTER]

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In looking for log examples for the one day course I teach on "OLD" [Pre-1958] E – Logs I came across a Permian Basin Carbonate example in SCHLUMBERGER's publication Document #8. The log suite consists of the following: SP, 10" Short Normal (SN10), 18'8" Lateral (LAT18), 32" Limestone Lateral (LsLat), and a Microlog (ML). I decided to do a log analysis of the "A" Interval (6660 ft to 6700 ft) Pre 1970 using service company charts (no calculator/computer) to first determine formation Temperature (Tf) and correct the mud resistivities (Rm & Rmf) to Tf. Next the SN10 and LAT18 were borehole corrected using logging company Departure Curves. SN10, ML, and LsLat porosities were also determined using appropriate logging company charts. These three porosities were compared to average core porosity ($\phi$core), and it was determined that $\phi$LsLat was the best measure for log derived porosity ($\phi$core = 15%; and $\phi$LsLAT = 13% to 17%) . Last an Archie Water Saturation (Sw) Nomograph chart (F = 1/$\phi$^2) was used to determine Archie Water Saturation (Swarchie) of 18.5%. The well's initial production was 700bopd and No Water.

The log data was then converted to a digital file at depth intervals of 2.5 feet from 6660ft to 6700ft. Based on either known equations or curves fitted to the logging company charts the digital data was used to calculate Tf and correct the Rm and Rmf to Tf. Then $\phi$sn, $\phi$ml, and $\phi$LsLat plus Sw (archie) were calculated. Assuming 80acre spacing and a BOI of 1.2 an OOIPstb of 2.1mmbo was determined.

Next, Moveable Hydrocarbon Index (Sw/Si) and Ratio Water Saturation (Swratio) were determined. Using this data along with a DEW Plot (Rt/Rw versus Sw/Si) the "A" Interval in this Permian Carbonate appears to be a vuggy carbonate.

The last step was to calculate a value for Mobile OOIPstb using Maximum Producible Oil Index (Tixier, 1957):

Mobile OOIPstb = (7758*Y*Area*h)/BOI

Y (Maximum Producible Oil Index) = (Rz/SN)^0.5 – (Rw/Rt)^0.5

Mobile OOIPstb = 691,000bo

In conclusion this poster was designed to illustrate that quanitative log analysis is possible with our older well logging suites.

## PETROPHYSICAL ANALYSIS OF THE WOLFCAMP: IMPLICATIONS FOR FUTURE OIL PRODUCTION

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Petrophysical logs were constructed and analyzed through a sequence of Wolfcampian sedimentary rocks to explore potential for future oil production. In this area, Wolfcampian rocks are composed of tight streaks of sandstone, dolomitized limestone and shale. A potentially productive zone was discovered within the upper portion of the Wolfcampian sequence (8070' – 8370'), assuming a 300' fracture height. This zone contains 3,591,435 OOIP (stb), based on 160 acre lateral drainage area. Recoverable reserves were estimated at 3%. This zone has the potential to produce 107,743 stb. We recommend a well lateral be placed at 8240' and completed with massive hydraulic fractures.

## PETROPHYSICAL EVALUATION OF THE UPPER WOLFCAMP SHALE, MIDLAND BASIN, TX

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Petrophysical analysis of digital well logs was applied to Permian Wolfcamp shale log data to determine the optimum

producing interval. This interval was selected with petrophysical calculations that include the following: Maturity Index (MI) [Zhou et al., 2007], Mineral Matrix Porosity (Φom), Organoporosity (Φmm), Original Oil In Place (OOIPstb), Total Organic Content (TOC), permeability (ka), water saturation (Sw), mineral brittleness index (MBI), effective porosity (Φe), bulk density (pb), Poisson's Ratio (μ), and Young's Modulus (E). All calculations were done at half foot intervals and were analyized using the quick log evaluation method to determine producing intervals. Possible producing intervals were determined by excluding depths where petrophysical values did not meet MI (>5 indicates producing zone) or permeability (>100nD) minimums. The primary producing zone in this log was determined to be the Wolfcamp A zone. The MI was calculted to be 6.53 which plots in the wet-gas condensate zone. TOC, photoelectric log, and constituent mineral percentages were used to further determine the interval with optimum kerogen for hydrocarbon production. The optimum producing zone is thought to be from 8050-8300 ft. When fracked with an estimated 250 ft fracture interval, this zone should produce 0.097 MMstb of hydrocarbons and approximately $8.2 million dollars in revenue based on $85 per barrel oil prices.

[1] Zhou et al. (2007) *AAPG* v. 91, no. 4, 535-549.

## WELL ANALYSIS OF WOLFCAMP A AND B ZONES

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The Wolfcamp formation extends across the Permian basin, varying in thickness from ~800 to 1200ft, has a high shale content, and is considered a source rock. The producible oil and depth conducive for placement of a horizontal well, TTU #1-5399, will be examined. Quick analysis of gamma ray, neutron-density, and resistivity confirm the presence of Wolfcamp zones A, B, and C as perspective reservoirs. In order to evaluate each zone, it was essential to first calculate total oil porosity, effective porosity, and effective water saturation. Cut-off values for each zone were selected: effective porosity greater than 4%, effective water saturation less than 45%, and oil porosity greater than 2%. It was found that zones A and B met the cut-offs and had higher total oil porosity than zone C. Next, the total organic content (TOC) and permeability were examined, zones A and B were found to have an average TOC of 5.5% which falls within the producible range of 2% to 10% TOC. Zones A and B were observed to have a higher concentration of permeability greater than 100nD. Young's modulus, Poisson's ratio, and Mineral Brittleness Index (MBI) were calculated to determine the ability of the formation to maintain the integrity of the fractures.

These calculations indicate Zone A and B exhibit the most promising characteristics for fracturing. In light of the data, zones A and B exhibit 7.7 MMstb OOIP and assuming a 3% recovery 232 Mstb of producible oil. Based on the geomechanical properties as well as the cutoffs listed above we recommend placing a horizontal at 8240 ft., assuming a total fracture height of 400 ft., resulting in 5.9 MMstb OOIP and assuming 3% recovery 176 Mstb of producible oil.

## SINGLE-DOPPLER RADAR ANALYSES OF LOW-LEVEL TORNADO STRUCTURE

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To this day, considerable uncertainty exists regarding the low-level wind fields and vertical structure associated with tornado vortices. Unfortunately, ground-clutter contamination and beam blockage make resolving the lowest levels of tornado vortices difficult for many research radars. Higher-frequency radars have proven especially useful in detecting important low-level aspects of tornado vortices. Owing to the higher sensitivity and finer angular resolution, these observations are critical in verifying and expanding upon our current understanding of tornado structure, which prior to now has relied primarily on theory and laboratory simulations.

During the VORTEX2 field campaign, and subsequently in the fall 2011 and spring 2012 seasons, two Texas Tech University Ka-band (TTUKa) mobile Doppler radars deployed to collect high-resolution Plan Position Indicator (PPI) and Range-Height Indicator (RHI) sweeps of tornadoes and the near-tornado environment. The TTUKa was successful in retrieving low-level PPI and RHI data from two simultaneous tornadoes near Cherokee, OK on 14 April 2012, and from a single violent tornado near Rozel, KS on 18 May 2013. These two cases will be the focus of this study. A Doppler on Wheels (DOW) mobile radar, operated by the Center for Severe Weather Research (CSWR), was also successful in capturing low-level PPIs on 18 May 2013 near Rozel, KS. The data from the CSWR DOW are also utilized in this study.

A ground-based velocity track display (GBVTD) method is utilized to obtain tangential and radial components of velocity at concentric rings about each tornado vortex center. Although the GBVTD method was originally designed for larger-scale vortices (e.g., tropical cyclones), recent studies show that this method can be modified and applied to tornado-scale vortices as long as a vortex center can be well defined. From these analyses, radial profiles of tangential and radial velocity, as well as derived parameters such as angular momentum, horizontal divergence, and vertical vorticity have been produced. When coupled with simultaneous or neighboring RHI cross-sections, these GBVTD products prove useful in identifying key low-level dynamical structures associated with tornadoes, such as the corner-flow region, inflow/outflow jets, and secondary circulations.

Results thus far reveal radial profiles of tangential velocity similar to those derived in numerical simulations, as well as in recently published field study work. Analyses of the 18 May 2013 tornado suggest that it transitioned between single- and multi-cellular over the course of its life cycle. RHI cross-sections prove useful in resolving fine-scale vertical structures within tornadoes and the near-tornado environment. Horizontal

misovortices are present in several RHIs, forming as a result of intense shear along the edge of the tornado vortex. Due to the exceptional resolution of the TTUKa radars, the inflow layer for the 18 May 2013 tornado was also resolved in RHIs. This feature is rarely observed and difficult to identify with most Doppler radars, owing to its shallow depth and proximity to the surface.

## DOWNSTREAM GRAIN SIZE DISTRIBUTION OF SANDY BARS IN A PROGLACIAL SYSTEM CHITINA RIVER, ALASKA

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The Chitina River is a 112-mile (180 km) tributary of the Copper River in southeastern Alaska in Wrangell-St. Elias National Park. Originating in the Saint Elias Mountains at the terminus of the Chitina Glacier, the river flows northwest and is fed by the Nizina and Tana rivers. Some rivers reflect a downstream fining in grain size, albeit demonstrated in the full-spectrum of grain size distribution. Less noted is the grain size distribution of the sand fraction only. This study attempts to assess if the sand size fraction fines downstream by sampling active bars every 5 km in midstream from glacial front to ~140 km downstream and obtaining grain size distributions of those samples with a LS13200 Beckman-Coulter laser particle analyzer

In order to accurately assess grain-size trends downstream, contributions from lateral sediment sources must be controlled. Specifically, the influx of sediment and increase in turbulence at river confluences may significantly affect the grain-size distribution. By examining samples taken both prior to and after tributaries with the Chitina River, this analysis will determine if patterns exist in the sand fraction and the impact of tributaries in this proglacial system.

The results show that there is a relationship between sand fraction fining and distance downstream. However, this relationship is only valid between significant sediment inputs. Seventeen individual tributaries are delineated as Strahler numbers ≥ 3rd order, with 1st order streams constituting ≥ 1000 square meter drainages. To define significant sediment inputs mean grain-size is compared spatially in relation to tributaries. Data indicates that several tributaries show little to no input of sediment and the sand fraction fines distally in a relatively linear trend from 200-300 µm. However, immediately downstream from significant sediment inputs the mean grain size increases from 200-300 µm. The resulting data displays a "sawtooth" pattern that correlates with significant tributary confluences. Thus between each individual confluence there appears to be a fining trend and the mean grain-size approaches 50 µm until the following tributary confluence. Although, a fining tend over the entire stretch is not present in the data outliers are most likely due to the natural variability of a braided river system coupled with increasing discharge downstream.

## RARE EARTH ELEMENT CONCENTRATIONS IN METAPELITES ALONG A TEMPERATURE GRADIENT IN THE METAMORPHIC AUREOLE OF THE BALLACHULISH IGNEOUS COMPLEX, SCOTLAND

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The Ballachulish Igneous Complex intrudes a variety of metasedimentary rocks such that samples in a lithology may be collected along a thermal gradient at near constant P and X. This distribution allows the impact of temperature and bulk-rock composition over accessory mineral stability and distribution to be evaluated. Samples from three transects of metapelitic rocks were analyzed for bulk-rock and trace element abundances. The goals were to determine the distribution of important trace elements as a function of T and determine whether abundances are consistent with estimated modal abundances of key accessory minerals.

Bulk rock compositional analysis for major and trace element abundances for samples in three transects was collected using X-ray fluorescence (XRF) spectrometry and laser-ablation inductively coupled plasma mass-spectrometry (LA-ICP-MS). The general trends in major element chemistry are decreasing $SiO_2$ and $Na_2O$ abundances as a function of increasing temperature. This is mirrored by generally increasing abundances of the other oxides (MgO, $Al_2O_3$, $Fe_2O_3$, MnO, CaO, $K_2O$, $TiO_2$). Trace element analyses show much more consistent abundances along the thermal transects, suggesting a lower, to non-existent correlation with temperature. Plots of $P_2O_5$ versus ΣREE and CaO versus ΣREE total there is a positive correlation in the former, but no obvious relationship in the latter. This suggests that P and REE abundances may be mineralogically related to one another, but not necessarily via apatite or allanite. Histogram plots of monazite distribution and ΣREE as a function of temperature are remarkably similar. It is therefore concluded that the abundance of monazite recorded by QEM-SCAN is accurate, but more importantly, that monazite abundances are primarily controlled by REE abundances, and not temperature and the activity of metasomatic and hydrothermal fluids.

## BIAS AND INACCURACIES IN THE TEXAS TECH WRF MODEL

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The Texas Tech University real-time WRF (weather research and forecasting) model has high potential for forecasting wind energy production because of its high resolution capabilities. This research focuses on finding inaccuracies and bias on the Texas Tech WRF model. Bias include, time periods with the most overestimation of wind speeds and errors in front prediction.

This research is valuable in making the WRF effective for wind energy forecasting. Forecasting wind energy production is important because it allows companies to know how much they are able to sell to the grid.

## ANALYSIS OF ONSHORE, OFFSHORE, AND ALONGSHORE TROPICAL CYCLONE WINDS USING WSR-88D DERIVED VELOCITY AZIMUTH DISPLAY WIND PROFILES

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The East and Gulf Coasts of the United States are impacted by tropical cylclones. As is known, tropical cyclones are likely to impact coastal areas at a variety of approach angles. Prior research [1] has observed how offshore winds behave at increasing height; however, the same cannot be said about the understanding of the onshore winds. Velocity Azimuth Display (VAD) [2-3] wind profiles can be utilized to describe how the vertical structure of landfalling tropical cyclones varies at different heights within differing wind flow regimes.

A case study of four landfall events (Katrina, Dolly, Ike, and Irene) is conducted using VAD wind profiles retrieved from a PhD dissertation database. The primary depth of interest lies within the lowest 200 meters of the VAD wind profiles. Matlab wind roses were generated to categorize the VAD layer average wind direction into onshore, offshore, and alongshore flow regimes using images of the United States' coastline obtained from Google Earth. Preliminary results show similar VAD profile trends with a rapid increase in wind speed up to around 600 meters height for all of the regimes. However, the onshore regime's trend contains higher wind speeds than either of the other regimes at all points while the offshore regime contains the weakest winds. It is also indicated that the wind's contained within the onshore regime increase at a more rapid rate than that of the offshore and alongshore regimes.

[1] K. Knupp, J. Walters, and M. Biggerstaff. (2005), Doppler Profiler and Radar Observations of Boundary Layer Variability during the Landfall of Tropical Storm Gabrielle. *Journal of the Atmospheric Sciences* Vol. 63**,** 234-251.

[2] Lhermitte, R.M. and Atlas D. (1961), Precipitation Motion by Pulse Doppler. Proc. 9th Weather Radar Conference, Kansas City, AMS, 218-223.

[3] Browning, K.A. and Wexler, R. (1968), The Determination of Kinematic Properties of a Windfield Using Doppler Radar. *Journal of Applied Meteorology* Vol. 7, 105-113.

## HIGH TEMPERATURE STRUCTURAL RELATIONSHIPS IN RE-ORIENTED CORES FROM THE ATLANTIS BANK, SOUTHWEST INDIAN RIDGE AND THE ATLANTIS MASSIF, MID-ATLANTIC RIDGE

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An untested assumption in models of oceanic core complex formation is the orientation of magmatic and crystal plastic fabrics in the lower crust reflect the kinematics of extensional deformation and strain localization during detachment initiaion. In order to determine the geometric and/or kinematic link between the orientation of high temperature fabrics, the ridge, and the detachment shear zone, high temperature planar fabrics were oriented in the ridge reference frame by correlating structural measurements of fractures in the core and fractures identified in the borehole wall. The results demonstrate there is no simple kinematic and/or geometric relationship between magmatic and/or crystal plastic fabrics at any depth. This suggests that high temperature deformation must have been occurring before detachment initiation.

## PETROPHYSICAL ANALYSIS OF THE WOLFCAMP FORMATION

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The Wolfcamp Formation is located within the Permian Basin and encompasses parts of southeast New Mexico and the west Texas panhandle. The Wolfcamp Formation is classified as a tight oil reservoir, with permeability usually in nanodarcies, and porosities ranging from 0.01 to 0.15 p.u. Though the formation is divided into four layers, designated as Wolfcamp A, B, C, and D, our study only examines the top three layers A, B, and C. Mineralogical data reveals that layer A is carbonate rich, while B, and C are quartz dominant with thin interbedded layers of sand and shale. Wolfcamp A and B have significant clay content, averaging 18% and 27% respectively, with the dominate clay type being Illite [1].

This study includes a petrophysical analysis of a vertical well within the Wolfcamp Formation in order to determine the best depth to place a horizontal well, which will be hydraulically fractured. Analysis of Wolfcamp layers A and B yeilds an average Maturity Index (MI) of 6.6 and 6.8 respectively, indicative of wet gas and gas condensate. Vitrinite reflectance averages 0.84 and 0.80, respectively, representing oil. It was determined that both layers are located within the oil maturity window, based on vitrinite reflectance, which is a more proven maturity measurement.

The horizontal well will be placed in the lower Wolfcamp A at a depth of 8245 ft, due to high local porosity and permeability, low water saturation, high kerogen volume, and high percent TOC. This depth is also a good candidate for hydraulic fracturing due to the low Poisson's ratio (averaging 0.22), and acceptable Young's modulus (averaging $6*10^6$ psi). Due to Young's modulus remaining at approximately the same value above the chosen depth, we can conclude that the fractures will propagate upward into shallower oil bearing zones. The OOIP in Wolfcamp A is estimated to be 4.01 MMSTB.

[1] Malik, M., Schmidt, C., Stockhausen, E. J., Vrubel, N. K., & Schwartz, K. (2013, September 30). Integrated Petrophysical Evaluation of Unconventional Reservoirs in the Delaware Basin. Society of Petroleum Engineers. doi:10.2118/166264-MS

## QUALITATIVE URANIUM ANALYSIS OF HIGH-GAMMA MISSISSIPPIAN CARBONATE, BEND ARCH REGION, TEXAS

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A Mississippian carbonate core from the Bend-Arch region of Texas has higher than expected gamma ray values. Interpretation of the full spectrum gamma-ray log suggests that peaks in the gamma-ray values are largely a result of unexpectedly high uranium radioactivity as opposed to gamma-ray values dominated by potassium and thorium radioactivity. High and low gamma-ray intervals were identified, and ten core plugs were taken from depths corresponding to the high and low values. Samples of the core-plugs were prepared for a sequential extraction procedure [1] that is designed to leach metals from various mineralogical hosts [2] with the goal of identifying the mineralogical host of uranium.

Each extraction in the procedure targets a different host, including the exchangeable metals hosted by soluble minerals, metals bound to carbonates, metals associated with iron and manganese oxides, and metals that were bound to organic matter [2]. Concentrations of uranium in the leachates from each step were measured by ICP-AES analysis. Analyses from the first set of extraction leachates showed uranium fractions from greatest to least as: bound to carbonates (stage 2); bound to Fe-Mn oxides (stage 3); exchangeable (stage 1) and bound to organics (stage 4). Conversely, results from the second procedure showed uranium fractions from greatest to least to be: bound to Fe-Mn oxides; bound to carbonates; bound to organic matter and exchangeable.

The ICP-AES results are complex because there was a qualitative discrepancy in the uranium fractions between the two separate extraction procedures employed. One cause of the discrepancy may be the excessively concentrated acetic acid used in stage 2 of the first leaching experiment. The acetic acid may have been so strong that it stripped uranium from another host depleting the uranium available to be leached in subsequent stages. A second cause of experimental complexity may be un-quantified peak overlaps of Fe on the measured U. The presence of even very low abundances of Fe in the solutions may artificially elevate the measured U concentrations.

To test this hypothesis bulk-rock U abundances were measured by LA-ICP-MS on fused glass discs. Bulk-rock uranium concentrations qualitatively coincide with the gamma-ray log values, and bulk-rock measurements broadly mirror total U abundances recorded by leaching experiments indicating a degree of consistency between the techniques. If the leaching experiments are considered representative, they suggest that the highest uranium fractions leached from carbonates and Fe-Mn oxides. The implications of these experiments may be improved mineralogically-based correlation techniques for use in lateral well placement.

[1] Tessier, A. Campbell, P. G. C. and Bisson, M. (1985). Sequential Extraction Procedure for the Speciation of Particulate Trace Metals, Analytical Chemistry, v. 51, no. 7, p. 844-851.

[2] Crass, B. (2013). Qualitative Uranium Analysis of Mississippian-Age High Gamma Carbonate, Bend Arch Region, Texas.

## SAND AND GRAVEL PETROLOGY OF THE OGALLALA FORMATION AT MATADOR, TEXAS

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The composition of sand and gravel in the Ogallala Formation near Matador, Texas is similar to that found elsewhere in Ogallala samples. Lithic grains are dominant in the coarser grain-size fraction, and of the lithic grains, limestone is most abundant, particularly in the very coarse sand fraction. In the fine grain-size fraction, quartz is the dominant constituent, and the abundance of limestone fragments is much lower. Sedimentary rock fragments are the dominant lithic grain in all size fractions. The average values reported in the Ogallala Petrology Project database are similar to those found at Matador, but there are notably higher amounts of quartz in both the coarsest and finest grain-size fractions at Matador. Also, in the Matador sample volcanic lithic grains are much less common than in previously reported samples of the Ogallala Formation. This may reflect the fact that the Matador locality is near the easternmost extent of Ogallala exposures, and most distant from presumed sediment source areas in New Mexico. The greater transport distance could have reduced the number of volcanic lithic grains, and increased the relative abundance of quartz.

## A QUANTITATIVE ANALYSIS OF XENOLITH FRAGMENTATION AND INCORPORATION IN MAGMA

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We report results of statistical analyses that aim to quantify the effect of composition and the resultant size-distribution of blocks on xenolith incorporation and fragmentation in magma. Datasets comprise xenoliths from three granodioritic plutons: 1) Jackass Lakes, CA, (n=104 metavolcanic and metasedimentary xenoliths, 0.001-1.0 km2); 2) Andalshatten batholith, Norway (n=103 meta-calcareous xenoliths, 0.001-1.0 km2); and 3) Vega intrusive complex (VIC), Norway (n=1159 metasedimentary xenoliths, 0.001-1.0 m2). Many natural fragmentation processes produce a linear size-distribution when the normalized radius of each block is compared to the number of blocks greater than that radius on a logarithmic scale. Results of measured xenoliths produce a non-linear or log-normal relationship between sizes when plotted in this manner. This deviation from size-distribution studies of naturally fragmented materials is due to the scarcity of small block sizes.

Analysis of block shape was accomplished by comparing axes measurements (short/long) of each block as a function of lithology. Detailed study of xenolith populations from the VIC indicate no dominant block shape, with values ranging from <0.1 (pencil-like) to 1.0 (equidimensional); ~18% have an axial ratio

of 0.5. Additionally, sorting xenoliths from the VIC into compositional classes found no strong preference to either block shape or size. A more significant role in block fragmentation and incorporation in magma may then be anisotropy, thermal disequilibrium, and fluid pressure rather than host rock lithology.

The departure of our size-distributions from those of presumably similar fragmentation processes that yield power-law and fractal dimensions suggests that processes other than catastrophic fragmentation might control the formation and subsequent incorporation of xenoliths in plutons. Preferential removal of small sizes by assimilation or change in fracture mechanism (or sampling bias) could also skew studies of size and shape distributions and minimize the potential for observable population trends in xenolith shape and size. Therefore, resultant log-normal trends and quantitative conclusions based on these trends may not offer a definitive means of evaluating mechanisms of xenolith fragmentation and incorporation in magma.

## COMPARING THICKNESS VARIATIONS OF EARLY PERMIAN AND PENNSYLVANIAN STRATIGRAPHY IN THE DENVER BASIN

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The Ancestral Rocky Mountains (ARM) are Precambrian-cored uplifts with intervening sedimentary basins filled with arkosic material shed from adjacent uplifts. As of now, two different models have been proposed for the demise of the ARM. The first model proposes that the ARM rose in early Pennsylvanian through mid-Permian time. After tectonic forces ceased continuous erosional beveling continued into the late Permian to early Triassic i.e. the mountains persisted as topographic highs for nearly 100 M.Y. The second model proposes that the ARM also rose in the early Pennsylvanian and tectonic activity ceased by late Pennsylvanian to early Permian. However, it differs in that directly following tectonic uplift isostatic adjustment of a high–density crustal root (termed here the IAHR model) created regional subsidence that allowed for sediment accommodation to continue within basins as well as atop ARM uplifts.

Over 450 wells have been analyzed to test the two models; the wells contained thickness data of a variety of formations, but only two stratigraphic intervals were recorded, early Permian and Pennsylvannian. After collecting the well data, isopach maps were produced at 500m contour intervals. In general, the data sets show gross similarities between Pennsylvanian and early Permian deposition patterns. Specifically, that in both time periods depostional packages thin to the northwest and exhibit spatially coincident depositonal thicks in the northwest and southeast of the study area. However, a subtle difference exists in the Pennsylvanian map such that material appears to have specific migration channels that may be representative of deep water fans. Whereas, in the early Permain map, the northwestern depositional thick is linear and may be the result of local faulting.

The results of this study are inconclusive as a test for either model. Yet, the Pennsylvanian map does strongly indicate that material was derived from the southwest as would be expected in either model during the Pennsylvanian. However, the early Permian isopach pattern doesn't exhibit a reversal in sediment transport direction as potentially suggested by the IAHR model, but it does show a reduction in focused sediment delivery as predicted by the same model.

## TWO-DIMENSIONAL FRACTAL MODELING AND ANALYSIS OF INTRACLOUD BRANCHED LIGHTNING DISCHARGE UTILIZING LIGHTNING MAPPING ARRAY DATA

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A calculation is made of the electric potential and electric field of lightning discharge as a chan- nel propagates through a cloud. The lightning model replicates the macroscopic propagation of discharges as a step-by-step process. The data points come from a winter storm recorded on the 26th of January, 2011 by the Washington DC lightning mapping array (DCLMA). These points are plotted on a uniform grid, one at a time. After each point is plotted, the electric potential at that point is set to a constant value. The electric potential and electric fields are then calculated for every point on the grid via the Poisson's equation utilizing the successive over relaxation (SOR) method. With these calculations, one expects to be able to determine if the lightning track follows a statistically probable path. This research follows a similar approach to Mansell (2002), Riousset (2007), and Petrov and Petrova (1992). However, as their approaches are probabilistic simulations with comparisons to observations from real lightning data, this research attempts to determine the physical structures of the cloud starting with the real lightning data and then judging whether or not these calculated physical structures are convincing.

## APPLICATION OF MESOSCALE ENSEMBLE-BASED SENSITIVITY ANALYSIS TO OBSERVATION TARGETING

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Observation targeting techniques based on ensemble statistics utilize covariance relationships between a chosen forecast aspect and initial condition variables to identify locations where the atmosphere can be observed to reduce errors in the forecast. From Ensemble Kalman Filter (EnKF) theory it can be shown that assimilating additional observations will always reduce the variance in a chosen forecast metric, by a value that is calculated from ensemble-based sensitivity. Both

localization and inflation within the ensemble data assimilation procedure can act to modify this expected value. Furthermore, in a convective environment, the non-linear nature of convective forecasts makes targeting difficult, as ensemble sensitivity analysis (ESA) and associated targeting techniques assume a linear relationship between the two variables. This problem can be exacerbated by the binary nature of convection, with only some of the ensemble members producing convection for certain cases. Thus, this study aims to develop useful adaptive observing techniques toward improving forecasts of convection.

In order to determine whether real-time targeting techniques on small scales hold value for a forecast, a set of experiments will be presented for a specific case study to assess the impacts of non-linear relationships between initial conditions and the forecast metric and more specifically, the binary nature of convective ensemble forecasts. The 4 April 2012 dryline-initiated convective outbreak over Northern Texas will be used to determine impacts that assimilated surface observations from the West Texas Mesonet (WTM) have on forecast error and to validate the usefulness of targeted observing on convective scales. Impacts are determined by running a control simulation that withholds WTM observations, determining which station would have the greatest impact on the forecast metric via variance reduction formulations, and then assimilating that station's surface observations into the model through the EnKF. Expected impacts and actual impacts can then be compared to determine if variance reduction can be accurately predicted under the various assumptions listed above. It is observed that actual reduction in variance does not follow theoretical expected impacts and reasons for these results are presented including differences in initial conditions between convecting and non-convecting ensemble members.

## SURFACE ADSORPTION OF $Fe^{3+}$ ON SILICA DIOXIDE AS A FUNCTION OF pH AND TIME

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Silica-dioxide can absorb and remove heavy metals from multiple systems, and previous studies have shown that rates of silica dissolution and accumulation of other ions on the surface boundary depend on a variety of factors [1,2,3]. This study characterized and investigated the $Fe^{3+}$ absorption behavior on the surface of three different silica samples, Baker Silica gel, used as-received and washed in 18MΩ nanopure water, and Sigma Aldrich Nanopowder, at low controlled pH strengths over time.

The samples were characterized using a Hitachi transmission election microscope (TEM), a Hitachi scanning election microscope (SEM), and a Rigaku Miniflex II powder X-ray diffractometer (XRD).

The mass of each silica-dioxide sample used in the experiments was scaled using their surface areas to be held consistent at 30 $m^2$. The pH 2.0 stock solution included $FeCl_3$. The silica powders were combined into three solutions of pH 2.5, 3.3, and 3.5 prepared by adjusting the amounts of NaOH, and NaCl. The experiments held ionic strength constant at 0.02 M by NaCl in the solutions.

The silica-$Fe^{3+}$ solutions were agitated throughout the experiments on an oscillator, and sampled at preset times. The withdrawn samples were filtered to remove the silica, and acidified with $HNO_3$. The amount of remaining $Fe^{3+}$ in each sample was determined via Inductively Coupled Plasma Emission Spectroscopy.

Of the three silica samples, the nanopowder absorbed more $Fe^{3+}$ at all pH levels tested. There was no significant difference between as-received and washed silica gel.

[1] Brady, et al. (1990) Chemical Geology. 82: 253-264.
[2] Dove, et al. (1992) Geochimica et Cosmochimica Acta 56: 4147-4156.
[3] Yantasee, et al. (2010) American Chemical Society 2, 2749-2758.

## EXAMINING AIR QULAITY AND SYNOPTIC METEORLOGY FROM 2003-2013, IN HOUSTON, TEXAS

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Addressing the relationships between synoptic weather patterns and atmospheric pollution is important in highly-populated cities. This study derives relationships between ozone, air quality, and synoptic-scale air mass presence within the city of Houston, Texas. This study also address the current state of how air quality and ozone are presented to the public and how more effective communication can be attained.

Synoptic air mass data is downloaded from the Spatial Synoptic Classification website. Daily ozone concentrations and air quality index values are collected from the Texas Commission on Environmental Quality. Charts categorizing synoptic air mass type, air quality index, and ozone concentration are produced and important relationships determined. A discussion with meteorologist Tim Heller on the public reporting of air quality is also included. In this study, the discussion is presented in conjunction with the ambient data acquired in order to determine if there is a more accurate way to present air quality information to the public. We produce results that allow for a deeper understanding of Houston's environment with the overarching objective of providing improved guidelines of air pollution for protecting human health based on incoming air mass.

## CHARACTERIZING THE HANGINGWALL DAMAGE ZONE ALONG THE CENTRAL PORTION OF THE MONTOSA FAULT, CENTRAL NEW MEXICO

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We investigate fracture density as a function of distance from the Montosa Fault to characterize the distribution of hangingwall damage zone structures in the Priest Pluton,

southern Manzano Mountains, New Mexico. The pluton hosts: (1) two sets of Tabular Fracture Clusters (TFCs) that predate the initiation of the Montosa Fault; and (2) variably oriented fault-related fractures that rapidly decay in abundance away from the Montosa Fault. The damage zone associated with the Montosa Fault is characterized by elevated fracture density that extends approximately 300 m. We suggest that the density of fault-related fractures is related to proximity to the Montosa Fault while their orientation is controlled by stress perturbations around TFCs.

## DETERMINING EXCESSIVE "RAINFALL POTENTIAL" IN PRE-LANDFALL TROPICAL CYCLONES

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Tropical cyclones bring a vaiety of life-endangering, landscape-changing, and economy affecting impacts to coastal regions of the United States. However, excessive rainfall associated with these tropical cyclones can occur thousands of miles inland; also producing widespread damage and loss of life.

The purpose of this study is to identify, examine, and use a tropical cyclone's pre-landfall characteristics to determine excessive rainfall potential over North America, using formula ( Dd/v ) as a guide. Tropical cyclones of similar strengths that made landfall between 1981 and 2005 were selected. Characteristics such as size, speed of movement, and landfall location were then examined to determine each storm's rainfall efficiency and subsequent inland flooding potential. An excessive rainfall-ranking system was developed and implemented, then checked against actual maximun rainfall reports associated with each cyclone. Finally, inconsistencies in the ranking system were examined to determine why certain tropical cyclones produced extreme amounts of rainfall and further examine factors - leading up to landfall - that city managers, first responders, and others, can use to properly prepare for a tropical cyclone.

[1] Jiang et al. (2007) Journal of Applied Meteorology and Climatology 47, 944-959

## EXAMINATION OF CARBON ISOTOPE RATIOS OF NATURAL GASES FROM AVALON BASIN SHALE CORE SAMPLES (LEA COUNTY, NEW MEXICO)

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Stable carbon isotope ratios ($^{13}C/^{12}C$ or $\delta^{13}C$) were measured on natural gas fractions ($C_1$ to $C_5$) of shale gas that were derived from Lea County, New Mexico, shale core samples located in the Delaware Basin Avalon Shale play. These core samples were donated by SCAL, Inc. The depth of the cores ranges from 8,868 feet to 10,009 feet. As soon as they were recovered from drilling cores, the four shale core samples were then transferred to glass cutting jars that were filled to two-thirds volume with KCl solution. It took a couple weeks for the natural gases to be totally degassed from the shale core samples. The gas accumulated in the head space of the jars and was then transferred to small serum bottles with thick butyl stoppers for storage. The gas composition and $\delta^{13}C$ values of $C_1$ to $C_5$ fractions were determined using trace gas-chromatography (GC) attached to the ThermoFisher Delta V isotope-ration mass spectrometer (IRMS) at the TTU Stable Isotope Laboratory. Using a microliter syringe, the gas was then transferred from the serum bottles and injected into the GC. The shale gas was then separated into $C_1$ to $C_5$ fractions by the GC column, combusted to $CO_2$ gases, and then analyzed for $\delta^{13}C$ values by Delta V IRMS. Numerous test samples were ran for each natural gas sample in order to test the accuracy and precision of the analysis. This information was then compared to the depth and total organic carbon content in order to establish relationships and maturity of the hydrocarbons present.

The purpose of this research is to establish a relationship between the different carbon ratios and the variation in depth. Certain observations can then be made about shale gas maturation in this area. The general trend of the stable carbon isotope ratios in this area increased from 8,868 feet to 9,364 feet, and then hit a sudden decline at 9,964 feet. An interesting phenomenon occurs at high maturity where isotope values begin to reverse and become lighter, thus indicating higher maturity levels of the wells.

## DYNAMICS OF NITROGEN AND ALGAE BIOMASS IN THE JIM BERTRAM LAKE SYSTEM

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The Jim Bertram Lake System is a series of six man-made lakes that runs northwest to southeast through Lubbock, Texas. The lakes were created during the 1970s by constructing dams along the Yellow House Canyon of the North Fork Double Mountain Fork Brazos River. The lakes were created to provide a recreational aquatic environment for the city of Lubbock along the ephemeral streams of the Yellow House Canyon. Irrigation water accumulated underneath the Lubbock Land Application Site in Lubbock, Texas, was pumped into the headwaters of the Jim Bertram Lake System. The irrigation water is secondary water from the Southeast Water Reclamation Plant in Lubbock. The previous study [1] showed that high levels of nitrates were found at the headwaters of the lakes which show an overall rapid decrease with distance from the outflow pipe at lake one though lake six. However, the cause of this decrease has not been identified. This study was conducted to quantify the decreasing trends in the concentration of dissolved nitrate throughout the Jim Bertram Lake System. This was achieved by testing the algae recovered from water filters to obtain the amount of nitrogen and carbon in the algae. Then, the nitrate levels in the water were compared to the nitrogen content of algae to determine if the algal blooms in the lake have an effect on the nitrate composition within the water, and if nitrogen by algal blooms can balance the nitrogen budget within the lake system.

The results showed that decreasing levels of nitrate in the lake water generally coincides with increasing amount of nitrogen in the algae, but not totally balanced by the levels of algae found in the water. This study shows that the observed trends of nitrate concentrations were not fully dependent on algal blooms, and nitrate levels were affected by other sources in the lake system.

[1] Quintanilla. (2013) *Hydro-Geochemical Study of Urban Man-made Lakes in Lubbock, Texas.(32).*

## THE STUDY OF CLOUD-TO-GROUND LIGHTNING FORMATION AND LOCATION AND THE EFFECT OF THE CAPROCK ESCARPMENT IN WEST TEXAS

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The following study explored the effect of terrain on the formation and location of cloud-to-ground lightning strikes formed from thunderstorms in West Texas in 2013. The main focus of the study was the Caprock Escarpment, which stretches across the Eastern Texas Panhandle. The data was collected with the West Texas Lightning Mapping Array system and analyzed with numerous methods of computer processing. A few previous studies agree that terrain affects cloud-to-ground lightning formation. Other studies disagree and state that terrain impacts formation based on influencing the meteorological conditions only. The goals of this study were to relate topography to the formation and location of cloud-to-ground lightning strikes and determine whether or not this effect is seen in West Texas due to the Caprock Escarpment. The results suggest that the Caprock Escarpment does not directly affect the formation or location of strikes in West Texas. The topography appears to merely influence the set up of the meteorological conditions, such as moisture access. The set up of these conditions are what causes storm creation and electrification.

## SAND AND GRAVEL PETROLOGY OF THE BRIDWELL AND COUCH FORMATIONS (OGALLALA GROUP), LUBBOCK COUNTY, TEXAS

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The Bridwell and Couch Formations of the Ogallala Group are exposed along the north side of Yellowhouse Canyon in eastern Lubbock County near Slaton, Texas. Both units include fluvial channel-fill facies with unconsolidated sand and gravel. Sediment samples were collected, sieved and separated into grain-size fractions, embedded in epoxy, and cut into thin-sections for point-counting (300 counts of framework grains per slide). Carbonate rock fragments dominate the coarsest size fraction in both formations, while the finer size fraction is predominantly quartz. Both formations have more sedimentary lithic grains than in the nearby Slaton channel-fill or in average Ogallala sand and gravel. The Couch has a higher abundance of lithic grains, particularly limestone compared to the Bridwell, which has a higher percentage of quartz in all grain-size fractions. The composition of Bridwell sand and gravel is closest to that in the Slaton channel-fill, and the two may be correlative. The high abundance of limestone lithic grains in both units suggests a nearby source area, most likely Lower Cretaceous limestone outcrops. A significant trend within the Ogallala Group along a north to south transect is a steady increase in sedimentary lithic grains in the -1 and 0 phi grain size fractions.

## PASSIVE SENSOR AND ARRAY COMPARISON FROM RECEIVER FUNCTION PRODUCTION

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The Muleshoe National Wildlife Refuge hosts MSTX, a permanent broadband seismic station in the USArray Transportable Array network. Five stations of high frequency, three component sensors were deployed in an array on the refuge surrounding MSTX. Array processing was applied to the small network of high frequency sensors to produce a single stacked receiver function [RF]. A RF was also produced for the permanent broadband station, MSTX. These receiver functions were used to estimate the depth of the Moho and comparatively determine the efficiency of a short term, high frequency array versus a permanent broadband station.

## THE HOMERIAN (SILURIAN) MULDE EVENT IN THE BAINBRIDGE GROUP IN THE ILLINOIS BASIN

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During the Silurian Period three significant extinction events took place, the Sheinwoodian Ireviken Event, the Homerian Mulde Event, and the Gorstian Lau Event. Alternations between primo and secundo conditions, the former characterized by cold, nutrient rich bottom water and the latter by saline, nutrient poor bottom water, have been used to model these events. In addition to extinctions, the events are characterized by major positive $^{13}C$ excursions.

The Homerian Mulde Event differs as it is a secundo-secundo event and represents a cessation of vertical circulation of oceanic waters. In the Baltic it is recorded by a dramatic die off of conodonts and benthic taxa and by a distinct double peaked positive $^{13}C$ excursion. In the Bainbridge Group (St. Clair Formation) at the Lindsey section near Thebes, southern Illinois, the Mulde Event is incompletely preserved in deeper water, offshore trilobite/ostracod carbonate mudstone. It lies at an oxidized layer, probably a disconformity, that marks the

extinction level of the Sheinwoodian conodont fauna and preserves just a remnant of the Mulde $^{13}C$ excursion. The Bainbridge record is slightly more complete than the Mulde record in West Texas and Oklahoma, where most of the Mulde is missing at an offshore disconformity. It resembles the Mulde Event in western Tennessee, where a disconformity occurs, but more of the Mulde Event is preserved as the Waldron Shale.

## IMPACT AND VERIFICATION OF MICROPHYSICAL PARAMETERIZATIONS ON SUPERCELL THUNDERSTORM COLD POOLS USING WRF/DART ENKF DATA ASSIMILATION EXPERIMENTS

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An ongoing study is considering the ability of numerical weather prediction microphysical parameterizations to properly simulate supercell cold pools. Inaccuracies in these parameterizations have led typically to an overestimation of high-level clouds, precipitation amounts, and magnitude of evaporative cooling, which impact the evolution and strength of the supercell cold pool. Real data simulations using WRF/DART and assimilating WSR-88D and mobile radar radial velocity data onto a 1 km domain every two minutes were conducted. The EnKF technique was used in order to minimize the initial condition error and otherwise best produce the observed atmospheric state, allowing for a focus on errors attributed to bulk microphysical parameterizations.

This study investigates two cases from the Verification of the Origins of Rotation in Tornadoes Experiment 2 (VORTEX2) using two different microphysical parameterizations (Milbrandt-Yau and Morrison) to determine which of these sophisticated two moment bulk parameterizations produce the most realistic cold pools. Using in-situ observations collected during these cases it is possible to verify the supercell cold pool at a high temporal and spatial scale, allowing for detailed investigation as to why one parameterization is producing a better cold pool in a portion of the supercell. Droplet breakup and fall speed of particles seems to be a major contributor to the differences in the cold pools from the simulations.

## MINERALOGICAL COMPOSITION OF FLUVIAL AND EOLIAN FACIES IN THE OGALLALA FORMATION AT RAGLAND, NEW MEXICO

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The Ogallala Formation near Ragland, New Mexico consists of fluvial and eolian facies. The basal interval here consists of coarse fluvial sand and gravel channel-fill. The upper interval consists of massive fine sand deposited in eolian sand sheets. The mineralogical compositions of the two facies are very similar. Possible differences are found in two compositional aspects. In the fine to medium sand grain size fraction, fluvial facies have volcanic lithic grains that comprise an average of 9% of framework grains; whereas, no volcanic rock fragments were found in the same grain size fraction for the eolian samples. The same is true for the coarse to very coarse grain size fraction; the fluvial samples have an average volcanic lithic grain content of 12%, but the eolian samples have none. Another possible compositional difference observed between the eolian and fluvial facies is in the relative abundance of feldspars. In eolian samples, feldspar comprises 19% of framework grains in the fine fraction; whereas, the fluvial samples have feldspar content of 8%. The lower volcanic lithic content of eolian facies could indicate that these grains were less durable when transported by wind, or selectively excluded if their density was greater than quartz and feldspar grains of similar size. The greater feldspar content of the eolian sand may indicate that these grains resisted destruction by hydrolysis longer in eolian environments. The overall similarity in composition between fluvial and eolian facies suggests that the eolian sediments could have been derived directly by reworking of the fluvial sediments that they overlie.

## ELECTRICAL STRUCTURE OF AN MCS TRANSITION ZONE DETERMINED WITH LMA DATA

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LMA (Lightning Mapping Array) data collected from an MCS (Mesoscale Convective System) that moved across the city of Lubbock, TX on 5-6 June 2013 was used to determine the type of electrical charge structure within the transition zone between the convective and the trailing stratiform regions of the MCS. The polarity of the net storm charge was inferred from lightning propagation characteristics seen in the LMA data. The data were analyzed for a 50-minute interval with an emphasis only on lightning flashes that initiated behind the convective line and extended into the transition zone and/or into the stratiform region. The type of charge structure was indicative of the intensity of the thunderstorm [1], where a Type A [1,2] structure of mid-level negative and upper positive charge regions, at 5km and 8km respectively, were observed. LMA data were then overlaid onto Ka-band radar (radial velocity, reflectivity, and spectrum width) data to determine how the thunderstorm's dynamics compared with those typically observed in the Type A model [1]. The data matched results from [1]; where wind speeds in excess of 30 m/s were observed from folded Doppler velocities of the convective front-to-rear and rear-to-front flow regions of the storm, and 0C line reflectivity data and inferred charge regions aligned with those of a Type A model [1,2] throughout the 50-minute interval.

LMA charge analysis has the advantage that it does not require the multiple/ or position adjusted measurements throughout the MCS, as in [1], although limited to reproducing a

three-stacked charge structure. Three-dimensional lightning mapping therefore enables charge structure determination without requiring in-situ data, while providing comparable confirmation of an observable basic electrical structure.

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[2] Evtushenko, A., & Mareev, E. (2009). On the generation of charge layers in MCS stratiform regions. Atmospheric Research, 91, 272-280.

## ENSEMBLE KALMAN FILTER ANALYSES OF INTERNAL REAR-FLANK DOWNDRAFT MOMENTUM SURGES WITHIN THE 18 MAY 2010 DUMAS, TEXAS SUPERCELL

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Several platforms participating in the second Verification of the Origin of Rotation in Tornadoes Experiment (VORTEX2) observed a series of four internal rear-flank downdraft (RFD) momentum surges coincident with the development and decay of a low-level mesocyclone in a supercell near Dumas, Texas on 18 May 2010. Analysis of fine-scale dual-Doppler data from two Ka-band mobile Doppler radars operated by Texas Tech University (TTUKa) coupled with volumetric single-Doppler data collected by the X-band, phased array MWR-05XP mobile Doppler radar reveals that the second through fourth internal RFD surges develop in a region of inferred downward-directed vertical perturbation pressure gradient forcing, suggesting that they may be the surface manifestation of an occlusion downdraft.

The observational analyses are extended through data assimilation of Doppler radar data at X-band (DOW), C-band (SMART-R) and S-band (WSR-88D) with an ensemble Kalman filter (EnKF). A suite of three ensemble analyses have been produced, using varying microphysical parameterizations to address uncertainty in the thermodynamic environment within the Dumas supercell. Each of the analyses produces a representative three-dimensional wind field capturing the development and decay of the low-level mesocyclone and internal RFD surges, though with varying cold pool intensity. As the assimilation of radial velocity values does not update the perturbation pressure field in the numerical simulation, three-dimensional perturbation pressures have been dynamically retrieved from the simulated wind and buoyancy fields, allowing the relative contributions of dynamic and buoyancy forcing to the development of the internal RFD surges to be assessed.

## THE GEOMORPHOLOGY OF CONES, CRATERS, AND CHANNELS IN THE MARIUS HILLS REGION OF THE MOON

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The Marius Hills region of the Moon is located northwest of crater Kepler, in Oceanus Procellarum. The region is best known for its volcanic channels and its dozens of small volcanic shields. This study involved the quantitative characterization of the general forms of cones, craters, and channels in the Marius Hills region. In addition, the forms of local channels were used to help estimate past flow conditions for associated formative lava flows. Two prominent sinuous rilles are located within the Marius Hills, and a third is located immediately proximal to the region; these volcanic channels range from about 43 km to 140 km in length and about 500 m to 2 km in width. The depths of the rilles vary with longitudinal position and with local topography, reaching depths as great as ~600 m relative to adjacent upland plains. As is typical of sinuous rilles, the three volcanic channels studied here are characterized by head regions defined by local topographic depressions, and by longitudinal slopes of channels of well under 1 degree. Quantitative models of the flows that formed the rilles suggest that the flow of lava through associated channels was likely to have been fully turbulent if viscosities were of the expected magnitude (1 Pa s), with estimated Reynolds numbers reaching as high as ~550,000 for 15-m-deep flows on slopes of 0.5 degrees. Estimated thermal and mechanical incision rates for a lava depth of 10 m and a longitudinal slope of 0.2 degrees are both ~80 cm per day. For 10-m-deep flows, slopes greater than about 0.2 degrees produce higher estimates for mechanical erosion than for thermal erosion. Estimated lava discharge rates exceed 50000 cubic meters per second for a lava depth of 5 m and slope of 0.2 degrees, and exceed 450000 cubic meters per second for a lava depth of 15 m on the same slope. The largest crater within the study area is Marius crater, a ~40-km-diameter and 1800-m-deep impact feature that has a flat floor that appears to have resulted from substantial infilling by low-viscosity lavas. The study region contains dozens of small shield volcanoes; the 37 shield features studied here have average diameters of ~13 km and average heights of ~320 m.

## ENVIRONMENTAL ANALYSIS OF THE COLONY CREEK CYCLOTHEM (LATE PENNSYLVANIAN) NEAR BRAD, TEXAS

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The Upper Pennsylvanian Colony Creek Shale near Brad, Texas, is a cyclothem dominated by terrigenous clastics, which formed in response to a eustatic rise in sea level near a prograding delta system. The abundance of conodont elements was determined through the marine part of the cyclothem to test the model of conodont distribution in cycothemic strata. Previous workers have reported on the distribution of holothurian sclerites, stable isotopes, and total organic carbon

(TOC), and major and trace elements form the same Colony Creek section at Brad in a series of unrelated studies. The data from these studies were combined with the conodont data to determine whether they are compatible with the cyclothem model.

Deeper water, offshore conodonts (*Gondolella; Idioprioniodus*) occur at the base of the Colony Creek, the normal marine form *Idiognathodus* occurs throughout, and shallow water, nearshore conodonts (*Hindeodus; Adetognathus*) occur in the upper part. A slight decrease in del oxygen-18 in the middle of the section also suggests shallowing upward. The slightly higher concentrations of TOC and trace metals (Cr, V, Ni,Zn) near the base indicate that low oxygen conditions were present but just a minor factor low in the cyclothem. The abundance of some metals (Ca, Sr, Mn, and Zn) in the upper part corresponds to where carbonate fossils like holothurian sclerites are more common and diverse. Overall, these results compare well with what has been described from Upper Pennsylvanian cyclothems that formed near prograding delta systems in the Midcontinent region.

## MULTI-YEAR TRACKING OF THE MOVEMENT OF A TRANSVERSE SAND DUNE IN THE MONAHANS SANDHILLS STATE PARK

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Aeolian sand dunes are comprised of loose sediments that have been transported and deposited into place by wind action above the Earth's surface. The Monahans Sandhills State Park, located in southwest Texas, represents a dynamic environment that involves movement of sand particles to create expansive sets of sand dunes, which are constantly changing their orientation. The purpose of this study was to focus on a specific transverse dune and track its change in orientation and potential migration from October 2011 to August 2013. Transverse dunes that remain free of vegetation are seasonally active in the Monahans, yet no previous research has tracked movement of the dunes for periods longer than a full year in high accuracy. In order to conduct this research, individual elevation measurements using GPS (Global Positioning System) receivers mounted on surveying poles were taken along the dune's crest, slope, and slip face. Once these readings had been stored, a 3-D surface model of the dune's elevation was created through the ArcMap program in GIS (Geographic Information Systems). Jennifer Allen, who graduated from Texas Tech in May 2012, conducted similar elevation measurements in October of 2011 and March of 2012 on one of the transverse dunes in the State Park. I carried an additional, third survey of the same dune in August of 2013. From each set of surveys, digital elevation models of the dune were created and compared in order to track its changes in elevation. Wind data during this time frame was also collected from a nearby weather station. The results showed that the dune's crest had migrated approximately 2.94 meters northwest. The dune has also increased in height by as much as 2.5 meters in the northwest and decreased in height by as much as 2.34 meters in the southeast. The wind data shows that the predominant wind direction during this time was from the southeast. Therefore the direction of the crest movement is consistent to the wind direction. These observations suggest that the dune may not be stable in periods longer than one year.

## EVOLVING DOMINANT CHARGE STRUCTURES IN WEST TEXAS ON 4 JUNE 2012

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On 4 June 2012 isolated storms initiated within range of the West Texas Lightning Mapping Array (LMA) and grew upscale into a mesoscale convective system. Part of the MCS remained over the West Texas LMA and Southwest Oklahoma LMA domains until it dissipated overnight. Initial storm cells developed within a relatively dry midlevel environment and were observed to contain a mid-level positive charge and predominantly –IC flashes. Only storms with this charge structure were observed for the first 40 minutes of convection. However, later storm cells and multicellular clusters, both further east in deeper moisture and within areas that had previously been moistened by convection, were primarily observed to contain a mid-level negative charge and +ICs at upper levels in each cell. Both -IC and +IC dominated storm cells were observed simultaneously for at least 90 minutes during this transition. As this case involves many storm cells of differing charge structures over a relatively long period, it will be used to examine the utility of existing models of electrification and microphysics processes in predicting the influence of environmental controls, including temperature and moisture, on the resulting charge structure.

## EFFICACY OF USING A TEMPORARY DEPLOYMENT OF A SINGLE-COMPONENT ARRAY TO CREATE RECEIVER FUNCTIONS

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Receiver functions (RF) produced from 2 year deployments of broadband seismometers have become a standard way to image the crust and upper mantle. Quicker, cheaper and more efficient methods of RF imaging need to be explored. Geophones are small, lightweight, rugged and inexpensive seismometers whereas broadband seismometers are large, heavy, fragile, and very expensive, so there are significant advantages to replacing broadband instruments with geophones. However, geophones are higher frequency and thus will operate in a noisier part of the phase spectrum. I am testing to see if array processing of a short deployment of 15 single component geophones can produce results comparable to longer

deployments of fewer instruments. Signal generated noise (scattering from 3D structure) is more significant and problematic than ambient noise in receiver function analysis. I believe that a short, few week long deployment of lower cost, short period instruments in a small, linear array can produce be used to successfully image crustal structure.

I conducted a four week deployment of 15 single component 4.5 Hz geophone seismometers with Reftek TEXAN data loggers north of Lubbock across the Matador arch at a ~3 km spacing with hopes of resolving the geological feature with emphasis on imaging the Moho. The Matador arch was chosen due to its proximity and the possibility that it may have lower crustal structure that can be imaged with RFs.

The goal is to use different methods of deconvolving the signal from all of these stations to combine the signals into a stacked receiver function. The stacked RFs were compared to the RFs produced by broadband stations that were deployed nearby. I hope the improved noise reduction of an array will replace the functionality of a longer deployment in producing an image of the Moho. These stations were beam formed to produce a common P source function for each event (seven events were used) which was then used as the source function to produce RFs for each individual station. I compared a receiver function produced from data recorded by the temporary array to a receiver function produced using nine years of data recorded by nearby permanent broadband seismic stations and found a comparable depth to the Moho and a possible mid crustal layer.

## PETROLOGY OF THE OGALLALA FORMATION AT CAPROCK CANYONS STATE PARK, TEXAS

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Outcrops of the Ogallala Formation at Caprock Canyons State Park in Briscoe County, Texas, provide an exposure of a major drainage divide or "paleo-upland" where Ogallala sediments are relatively thin. These paleo-uplands were covered primarily with eolian sediment, while the intervening paleo-valleys accumulated mostly fluvial sediment. Only the lower part of the section at Caprock Canyons consists of coarse-grained fluvial facies, but there are two distinct fining-upward sequences. Samples of the lower and upper fluvial intervals were sieved into three grain-size fractions, embedded in epoxy, and made into thin sections for point counting. There are significant compositional differences between grain-size fractions. Lithic grains dominate the coarsest size fraction, while quartz is most abundant in the fine size fraction. The Caprock Canyons samples are generally similar in composition to Ogallala fluvial sand and gravel from elsewhere around the High Plains. Compositional differences between lower and upper fluvial intervals are most evident in the coarsest grain-size fraction. Basaltic lithic grains occur in the upper fluvial interval, and indicate that most of the section here accumulated late during Ogallala deposition. The lower and upper intervals indicate that fluvial sediments lapped well onto the paleo-upland, and that the thick eolian deposits here blanketed over the region toward the end of Ogallala deposition.

## CRYSTAL PREFERRED ORIENTATION IN QUARTZ FROM THE AUREOLE OF THE PRIEST PLUTON: DISTRIBUTION OF MICROFABRICS AND IMPACT ON THERMAL CONDUCTIVITY

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Quartz crystal preferred orientation (CPO) data, as well as grain size and aspect ratio measurements, have been measured in a suite of nine quartzites from the thermal aureole of the Priest Pluton, Manzano Mountains (NM). With increasing proximity to the pluton there is a weak, general decrease in grain size until immediately before the pluton contact, where grain size increases. There is no correlation in the length-to-width ratio with distance from pluton or mineral assemblage. CPO data shows variable intensity of deformation: samples collected between 200 and 550 m from the pluton have strong preferred orientation; samples closer to the pluton have weaker to absent CPO. Immediately adjacent to the pluton, samples have strong CPO fabrics. Steady state thermal conductivity measurements perpendicular to foliation range from 5.0 to 8.5 W/(m*K) and values parallel to foliation range from 7.4 to 8.3 W/(m*K). Differences between measurements parallel and perpendicular were expected because of quartz's thermal anisotropy. However, contrary to expectations, the difference between perpendicular and parallel measurements, as well as the maximum thermal conductivity is greatest in samples with lower CPO intensity. On the other hand, a weak positive correlation between grain size and thermal conductivity for samples with grain sizes <0.02 $mm^2$ is noted. The dataset suggests three conclusions: 1) samples >300 m from the contact retain regional deformation fabrics, while those <300 m from the pluton recrystallized during thermal metamorphism; 2) the strong fabric adjacent to the pluton may reflect deformation associated with pluton accommodation; and, 3) quartzite fabrics and their orientation impact thermal conductivity and, together with mica, may contribute to rates of heat transport in metamorphic terranes and partially explain why the width of contact aureoles vary around a pluton.

## SURFACE CHARGE DEVELOPMENT AT THE BARITE–WATER INTERFACE IN NACL MEDIA, FROM 15 TO 65°C

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Barite is found in a variety of geologic environments; it is deposited in marine environments by evaporation and biogenic processes, and is found in hydrothermally mineralized veins. Barite is used extensively in drilling fluids for oil and gas exploration; conversely, it may be present as scales in industrial pipes. Numerous studies have, therefore, evaluated crystal growth and dissolution of barite. The solubility of barite has been shown to increase, when barite is present in an aqueous

system also comprising calcite or gypsum. These precipitation/dissolution processes take place at the mineral-water interfaces, and are controlled by proton induced surface charge. Consequently, the surface charging behavior of barite is being investigated by potentiometric titration.

A commercial barite sample is being used in this study. The sample has been characterized extensively by SEM and TEM imaging, XRD, and BET surface area measurements. The particles are euhedral, approximately 50 nm in diameter, and have a surface area of 23 $m^2/g$. The potentiometric titrations are being performed in NaCl media, at ionic strengths from 0.03 to 0.3 *m*. The titrations are being performed as a function temperature form 15 to 65 ºC, and a pH range of 3 to 10. The background-corrected titration curves show some common features. At all temperatures the titration curves are shallow between pH 3 and 8, then steepen significantly. The proton induced surface charge of the barite shows strong temperature dependence. The barite surface becomes progressively more positive (deficit of $H^+$ in solution) with increasing temperature. At 0.03 *m* ionic strength, the barite surface is positively charged at all pH suggesting a high pH for the zero net proton charge ($pH_{znpc}$) value.

## THERMAL CONDUCTIVITY VERSUS POROSITY RELATIONSHIP FOR CONTINENTAL SHELF SEDIMENTS OFF TEXAS AND LOUISIANA

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Knowledge of the relationship between porosity and thermal conductivity is useful for geoscientists in assessing thermal maturity of potential source rocks. My research examines if a statistically meaningful relationship exists between thermal conductivity and porosity for rock samples obtained in the continental shelf off east Texas and Louisiana. Porosity data was previously obtained from wireline log measurements from 6 boreholes in the High Island, West Cameron, and Eugene Island areas. There were 4 wells in the High Island area, 1 well in the West Cameron area and 1 well in the Eugene Island area. Porosity in the High Island study area ranged from 22% to 39%, porosity in the West Cameron area ranged from 20.5% to 25%, and the porosity in the Eugene Island study area ranged from 26% to 51%. I made thermal conductivity measurements from 58 core samples taken from 6 wells of the same or nearby boreholes. Thermal conductivity in the High Island study area ranged from .852 to 2.082 W/mK, thermal conductivity in the West Cameron study area ranged from .983 to 2.921 W/mK, and thermal conductivity in the Eugene Island study area ranges from .834 to 1.901 W/mK. The porosity and thermal conductivity data correlate and show a relationship similar to what previous researchers found for core samples from south Texas. This relationship is that porosity measurements decrease with increasing thermal conductivity measurements.