TEXAS TECH UNIVERSITY
College *of* Arts & Sciences

Department of Geosciences

Department of Geosciences

Texas Tech University

Research Day 2009

Welcome everyone, to the Department of Geosciences 2009 Research Day. This event is in its 3rd year, and we are pleased that participation this year has been extended to include contributions from juniors, graduate students, researchers and faculty, as well as the department's graduating students.

All contributors are thanked for submitting abstracts and preparing posters and helping to demonstrate the diversity and vibrancy of research in the Department. However, while all contributions are greatly valued, the principle reason behind the poster session remains the same: for graduating students to present the results of their personal research experience. Posters from these students will be shown in room 230 and their abstracts, as well as those prepared by junior students, are highlighted in the index of this volume by a †.

A special thank you to the Chair of the Department, Prof. Cal Barnes, for supporting the event and contributing funding to provide new poster rails for the second floor corridor (we hope that department members will show posters presented to national and international meetings throughout the year), as well as cookies, coffee and a book certificate for the best poster from a graduating senior.

We would also like to thank the Geoscience Society who will host and sponsor a BBQ lunch immediately following the poster session. Lunch will be served in room 201 (Structure Lab) from 11:45 onwards.

Finally, we would like to thank everyone for coming to participate in the poster session, either as presenters or viewers. We hope that everyone enjoys the morning and will mark the day in their calendars for future years (Wednesday 5th May, 2010!)

Callum J. Hetherington, Chris Weiss and Hua-Wei Zhou

Magma Emplacement and the Development of Ghost Stratigraphy in the Andalshatten Pluton, Central Norway

H.S.ANDERSON[1*]. A.S. YOSHINOBU[1], K. CHAMBERLAIN[2], O. NORDGULEN[3], C.G.BARNES[1]

[1] Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*hs.anderson@ttu.edu)
[2] Dept. of Geology and Geophysics, Univ. of Wyoming, Laramie, WY,
[3] Norwegian Geol Survey, Trondheim, Norway

The Andalshatten pluton (AP), central Norway, is an 18 x 35 km mid-crustal (670 MPa) intrusion and consists of at least three pulses of magma, including an early eastern gneissic to schlieren-banded granodiorite and co-magmatic megacrystic granodiorite, dated at 442.67 ± 0.14 Ma and 441.53 ± 0.40 Ma (CA-TIMS 206Pb/238U zircon dating), and diorite. Crystallization ages span 600 kyr to 1.7 my. Elongate mafic magmatic enclaves swarms are subparallel to the magmatic fabric observed throughout the pluton. Sub-planar isolation of kilometer-scale xenoliths preserves a remnant host rock stratigraphy, while smaller-scale xenoliths show evidence for deformation in the magma.

The AP intruded four N-trending nappes within the Helgeland Nappe Complex (HNC), the highest tectonostratigraphic unit of the Norwegian Caledonides. Host rocks are Neo-Proterozoic to Ordovician medium to low-grade pelitic, calcareous, calc-silicate, and migmatitic rocks. Cross-cutting relations reveal at least two phases of host rock deformation prior to final pluton construction at 442 Ma. Tightened and refolded folds within the ~ 1 km-wide aureole are deformed about axial planes that mimic the lobate shape of the western pluton margin. The NW margin of the pluton is overprinted by a pervasive protomylonitic fabric defined by recrystallized potassium feldspar and top-to-the-west, thrust-related shearing.

These data are compatible with the following: a) magma emplacement by elongate pulses of kilometric scale at 442 Ma; b) the largest screens reflect stranded host rock ghost stratigraphy; c) pluton construction was facilitated by stoping and lateral/downward ductile displacement of host rocks; d) magmatic fabric formation likely occurred after emplacement of the diorite, relatively late in the emplacement process, and; d) shearing along the northwestern and eastern pluton margin occurred synchronous with emplacement and may be the result of regional 442 Ma deformation in the HNC.

Kinematic evidence for diapirism on Enceladus, an icy satellite of Saturn

C. BEDDINGFIELD[*] and A.S YOSHINOBU

Dept. of Geosciences, Texas Tech University, Lubbock, TX 79409-1053 (*chloe.beddingfield@ttu.edu)

Enceladus is an icy satellite of Saturn and may contain liquid water beneath an icy crust. Recent images from the Cassini mission demonstrated ejected vapor, liquid water and ice particles emanating from active geysers along four parallel fracture systems, termed the “Tiger Stripes” more than 80 km in length at the south pole.

We suggest that these and other crustal structures record evidence of an underlying active ice diapir. Prominent ‘glacial’ fold and thrust belts (ogives) as well as radially trending graben systems are centered around the Tiger Stripes and show a striking similarity to structures observed around modeled and natural salt diapirs on Earth. Similar but inactive structures are located in the equatorial region of Enceladus approximately 500 km north of the south polar region. These structures include paleo-ogive fold and thrust belts with a circumference in excess of 500 km, overprinted radial fracture systems, and extensional fracture systems similar to the active Tiger Stripes. The radius and/or angle of curvature of each of the observed structures on Enceladus progressively decreases from the equator to the pole.

The presence of large ridges with amplitudes of 1000 m separated by 120 degree junctions are analogous to pressure ridges developed on moving ice flows on Earth. We suggest that these features on Enceladus represent regions where ice fractured and resealed over a liquid substrate. This implies that at least a portion of the underlying diapir here was composed of liquid water during its active phase.

We hypothesize two alternative hypotheses to explain these observations. First, we propose that the migration of a single diapir occurred and deformed the overlying ice crust. The ice crust was mobile and was translated northward, while the diapir continued to ascend in the south polar region. In this context, the ice crust has moved in the stationary reference frame of the diapir, analogous to hot spot tectonics on Earth. An alternative hypothesis is that multiple episodes of diapirism have occurred between these two regions and that diapir ‘centers’ have progressively moved southward.

High Frequency Sequence Stratigraphic Controls on Stratal Architecture of an Upper Pennsylvanian “Regressive Limestone” (Bethany Falls Limestone), Midcontinent, USA

G. BUTLER *, P. HOLTERHOFF

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*graham.butler@ttu.edu)

The Bethany Falls Limestone (BFL) is the highstand – falling stage carbonate member of the Swope high frequency sequence as developed on the northern platform of the Mid-continent Basin. It is underlain by the condensed, maximum flooding Hushpuckney Shale and is overlain by the lowstand Galesburg Shale. The Swope sequence is Early Missourian in age and is a significant hydrocarbon reservoir unit in western Kansas. Although the BFL is often considered a uniform shallowing – upward carbonate system, we hypothesize that traceable flooding and erosion surfaces can be recognized within the BFL and that these surfaces define basinward – stepping carbonate clinothems. Recognizing this internal architecture is critical for understanding the potential controls on the deposition and diagenesis of oolite facies developed across the region with the BFL.

Flooding surfaces within the BFL are recognized by mudrock (clay-rich shale) partings within the carbonate succession with associated distinctive conodont biofacies. Although not without some ambiguity, the conodont faunas collected from these mudrocks aid in correlation and provide some confidence in mapping these surfaces across the region. Preliminary correlations indicate that basinward stepping clinothem packages can be recognized within the BFL.

The conodont abundances and species occurrences also shed light on the depositional environments of the flooding surfaces. Proximal occurrences of the mudrock partings contain a lower abundance, lower diversity fauna compared to more distal locations along a clinoform profile. Surprising faunas of deepwater species and high abundances in the lower BFL are noted at some locations. These occurrences appear to coincide with structural highs and may represent a transitional facies with the underlying condensed horizon.

Distinctive lithofacies offsets and internal exposure surfaces also indicate the presence of high frequency sequence boundaries with the BFL. These offsets are mappable and, like the flooding surfaces, also define clinothem packages within the BFL. The distribution of carbonate lithologies within these stratal packages is consistent with basinward progradation of facies throughout clinothem deposition. Using this combined knowledge it is possible to identify high frequency sequence boundaries (HFSB) within this forced regressive package.

GIS-Based Reconstructions of the Canadian High Arctic at 8500 ^{14}C yr B.P.

S. CALDERON

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (sc.calderon@ttu.edu)

In this research, GIS and image processing software were used to reconstruct the topography and bathymetry of the Canadian High Arctic at 8500 ^{14}C yr B.P. A database of paleotopography was created by subtracting interpolated isobase data from a database of modern topography. The paleotopographic database was used to make map visualizations and to estimate percentage changes in the surface exposure of major islands. In general the Queen Elizabeth Islands were much lower in elevation at 8500 ^{14}C yr B.P., and several were below sea level at this time. The Innuitian Ice Sheet covered parts of the region, including some of the submerged islands.

Analysis of Moho Depth and Crustal Vp/Vs Ratios in the vicinity of the Delaware Aulacogen

K. CASTILLE, H. GURROLA

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (sc.calderon@ttu.edu)

The purpose of this study is to determine if the Delaware Aulacogen (DA) can be distinguished from the surrounding crust using seismic receiver function analysis. The depth to the Moho and the average Vp/Vs ratio of the crust (P-wave velocity divided by S-wave velocity) can be estimated by analysis of the moveout (delay time vs incoming angle) of P-to-S conversions (Ps) and reverberations ending in an S-phase (Pps and Pss). In general, these phases will only line up when stacked and converted to depth if the correct Vp/Vs ratio is used in depth conversion. Data was acquired from permanent seismic stations MNTX and MSTX jointly operated by Texas Tech University, IRIS and EarthScope, and USARRAY transportable array stations TA126, TA127, TA226, TA227, TA326, TA327, TA328, TA427, TA428, TAZ26, and TAZ27, which are located in West Texas and Eastern New Mexico along the central basin platform. The Vp/Vs ratio that best stacks data from these stations range from 1.75 to 1.93 with an average of 1.84. According to Gilbert Hersh and Anne Sheehan (2004), lower values of Vp/Vs are associated with felsic rocks and higher values are associated with mafic rocks. Most of the values that we found from the stations near the DA are on the higher side of 1.8 indicating the crust may be more mafic than normal continental crust.

Hersh et al (2004) , J. Geophys. Res.109, 1-15.

The Gabbro-Diorite Layered Intrusions of Saint-Jean-du-Doigt (France) and Beaucette (Guernsey, Channel Islands), Armorican Massif: An Emplacement Model.

N. COINT[(1*)], M. CAROFF[(2)], E. HALLOT[(3)], J-J. PEUCAT[(3

[(1)] Department of Geosciences, Texas Tech University, Lubbock, TX 79409, USA (*nolween.coint@ttu.edu)
[(2)] UMR n°6538, Institut Universitaire Européen de la Mer, Université de Bretagne Occidentale, Brest F-29200, France
[(3)] UMR n°6118, Géosciences Rennes, CNRS-Université de Rennes 1, Campus de Beaulieu, Rennes Cedex, F-35042, France

The gabbro-diorite bodies of Saint-Jean-du-Doigt (France) and Beaucette (North Guernsey) belong to the Mafic-Silicic Layered Intrusions (MASLI; cf Wiebe, 1996) group [1]. Both are located in the Armorican Massif, but their formation is ascribed to different orogenies. The 570 Ma Northern Complex of Guernsey has calc-alkaline affinities and is associated with a Cadomian volcanic arc. The 300 Ma Saint-Jean-du-Doigt intrusion shows continental tholeiitic affinities and is related to late-Variscan extension.

At the base of the Saint-Jean-du-Doigt intrusion, diorite occurs as sheets within homogeneous gabbro. Sr and Nd isotopes data show that the diorite is not related to the gabbro by simple fractional crystallisation, which implies the existence of at least two contrasting parent magmas. To account for the field observations, we propose that several batches of diorite replenished the crystallizing gabbroic reservoir. Dioritic batches rose through the gabbroic mush to levels of neutral buoyancy, where they turned into horizontal sheets. Emplacement of these sheets was progressively higher as the gabbro crystallized. As the diorite layers cool, evolved residual liquid accumulated at the upper boundary of the sheet and then formed small granitic/pegmatitic diapirs.

The layered lower part of the Northern Guernsey intrusion (Beaucette) is more complex. Dark and grey gabbroic

macrorythmic layers, which are lacking in Saint-Jean-du-Doigt, are present. The layers are crossed by dioritic veins, sheets, and inclined pipes. We propose that the macrorythmic units correspond to sequences of accumulation of ferro-magnesian phenocrysts (dark units), locally coupled with plagioclase crystals (grey units). The leucocratic veins and pipes from Beaucette should derive from Saint-Peter-Port–type layered cumulates. Both formations have An80 plagioclase, which suggests crystallization under high water pressures, as does the association of mafic pegmatoids with cumulate facies.

[1] Wiebe, R.A. (1996) *Trans. Royal Soc. Edinburgh: Earth Sci*, 87: 233-242.

Does the Altitude of the Charge Source Region Influence Stroke Multiplicity?

C. CYREK*, K.C. WIENS

Atmospheric Sciences Group, Texas Tech University, Box 42101, Lubbock, TX 79409-2101 (*Candace.L.Cyrek@ttu.edu)

Many differences exist between positive and negative cloud-to-ground (CG) lightning flashes, though these differences are not well understood. Observations show that negative CG flashes tend to have multiple return strokes with little continuing current from each stroke, whereas positive CG flashes tend to have only one return stroke with continuing current. Though the reason for this polarity asymmetry in terms of multiple strokes has not been identified, the leading hypothesis is related to the idea that the return stroke channel needs to be maintained by infusion of current from within the cloud. Insufficient infusion of current in the initial return stroke may lead to channel decay, thus resulting in a successive stroke. One possible factor involved in this process is the difference in the altitude of the charge source region of positive CG versus negative CG flashes. If the source region for negative CG flashes is further from ground, then negative CG flashes would require a longer channel to the ground. A longer channel length may require a larger infusion of current to maintain it and thus be more likely to decay and require a subsequent stroke. Our hypothesis is that, regardless of polarity, longer channel lengths lead to multiple strokes, whereas shorter channels are more likely to be single-stroke with continuing current.

We will test this hypothesis by using the National Lightning Detection Network (NLDN) and Lightning Mapping Arrays (LMAs) to determine the relationships among polarity, number of strokes, and source altitude.

Magma Mixing and Crystal-Liquid Separation: Harrison Pass Pluton, North East Nevada.

J. R. DEANS*, C. G. BARNES

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*jedeans@ttu.edu)

The 36 Ma Harrison Pass pluton located in the Ruby Mountains metamorphic core complex is composed of four units separated by an early and late phase. The early phase is defined by the Toyn Creek hornblende biotite granodiorite and the Corral Creek biotite monzogranite. The late phase is defined by sheets of leucocratic two-mica monzogranite and the Green Mountain Creek two-mica monzogranite. Quartz grains in Toyn Creek range from less than a millimeter, interstitial, anhedral grains to three millimeter phenocrysts. No SEM-CL zoning in the quartz was observed. Cores were chosen as the geometric centers, and rims were chosen based on proximity to mafic silicates such as biotite. Titanite grains, only found in the Toyn Creek unit, are euhedral ranging in size from less than one millimeter to over three millimeters. Using LA-ICP-MS, trace elements were measured from quartz and titanite. The TitaniQ thermometer for Ti in quartz [1] and the Zr in titanite thermobarometer [2] were used to estimate temperature variation from core to rim. Quartz and titanite grains from Toyn Creek are reversely zoned defined by crystallization temperature of an average 709^{o}C in the core to a peak of 719^{o}C to 691^{o}C in the rim of quartz and 716^{o}C to 722^{o}C to 704^{o}C in titanite. The temperature pattern of the titanite grains are more complex compared to the quartz. Quartz grains from the Corral Creek and Green Mountain Creek units show a general decrease in crystallization temperatures in quartz from an average of 733^{o}C in the core to 698^{o}C at the rim in the Corral Creek and an average of 681^{o}C in the core to 660^{o}C at the rim in the Green Mountain Creek. This study shows chemical variation in individual crystals, which is easily overlooked at the whole rock scale. The temperature variations in quartz and titanite suggest magma mixing occurred in the Toyn Creek unit. The Corral Creek and Green Mountain Creek units show fractional crystallization cooling trends.

[1] Wark, D. A., and Watson, E. B. (2006) *Contrib. Min. Pet.* **152**, 743-754.

[2] Hayden, D. A. et al. (2008) *Contrib. Min. Pet.* **155**, 529-540.

[3] Barnes, C. G. et al. (2001) *J. Pet.* **42**, 901-929.

Kinematic and Thermodynamic Gradients Observed in the Near-Tornado Environment.

J. DREESSEN*, C.C. WEISS

Dept. of Geosciences, Atmospheric Sciences Group, Texas Tech University, Box 42101, Lubbock, TX 79409-2101 (*Joel.Dreessen@ttu.edu)

Data acquired during the Multiple Observations of Boundaries In the Local storm Environment (MOBILE) 2008 project using Texas Tech's StickNet (SN) provide a unique look at supercell variability and structure. A SN array deployed in the vicinity of Eden, Texas captured the thermodynamic and kinematic evolution of a supercell during hook echo development and subsequent tornadogenesis on May 14, 2008. Extreme deficits in equivalent and virtual potential temperature greater than 10K within the RFD were observed prior to tornado development.

Storm rotation developed as a pre-existing frontal boundary moved northward and interacted with the storm. Accelerated progress of the rear flank gust front (RFGF) and merging with the pre-existing front did not occur until storm scale rotation became established. A distinct lag in thermodynamic deficits exists between the leading edge of the RFGF and the cold pool. Development of surface vorticity occurs on the northern side of the RFGF surge apex as inferred by surface wind field morphology. Surface pressure is seen to also increase prior to

passage of the RFGF and assoiciated cold pool, causing a veering in the surface wind direction during the boundary's approach. The modification to the surface wind was believed to possibly hinder tornado development earlier within the storm; however, the surging RFGF re-establishes suitable horizontal shear for the development of surface rotation.

A reinterpretation of the 1970, Hales, Onshore-Offshore refraction line in the Northern Gulf of Mexico

G. DUNCAN, H. GURROLA

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053

This project is a re-interpretation of seismic refraction data from the Northern Gulf of Mexico and the Gulf Coast Plain that was collected and analyzed by Hales (1970) and then reinterpreted Gurrola (1985). The data set is a north-south trending line extending 350 km along the Texas Louisiana border and extending offshore to the Sigsbee Escarpment. The shots were all offshore and included 21 one ton shots and almost a hundred 100 to 150 pound shots. The smaller shots were only recorded to distance of up to 90 km but the larger shots were recorded to 750 km offset. The technology available to Hales in 1970 enabled a 2-D model to be developed by connecting a series of traditional 1-D to 1.5-D models. Gurrola later used 2-D tracing to re-interpret these data. We will be reinterpreting this data set using modern raytracing and finite element modeling (forward and inverse) that allows 2-D velocity gradients.

The current model by Gurrola 1985 found the basement to be only about 3 km deep at the Sabine Uplift sloping to a depth of 13 km just past the coast line and continues to deepen only slightly more southward. The continental crust-basement is thinned to about 16 km beneath the continental shelf. The Moho beneath the continental shelf has a velocity of 7.4 km/sec at a depth of about 30 km. Normal mantle velocities (8.0 to 8.2 km/sec) are found at 46 km beneath the continental shelf. The Moho beneath the Sabine Uplift is 40 km deep and has a velocity of 8.0 km/sec. The seismic data indicated that the 6 km/sec layer shallowed to about 8 km toward the Sigsbee Escarpment. Gurrola interpreted this as a continental fragment. Since basement is denser than sediment, it was necessary to deepen the Moho to about 35 km to model the gravity data. More recent models of the Gulf of Mexico have found the salt to be much thicker near the Sigsbee Escarpment than assumed in our previous model. It is, therefore, likely that the shallowing high velocities in the refraction data are due to a salt body. The low density of the salt would not require a deep crustal root. This poster summarizes new one-dimensional to familiarize ourselves with these data but we will be using modern 2-D modeling programs in the future.

Texas Tech University's Hurricanes at Landfall Project - 2008

I. M. GIAMMANCO[1*], T. M. BROWN[1] J.L. SCHROEDER[2]

[1]Wind Science and Engineering, Texas Tech University, 10th and Akron, Lubbock, TX 79409 (*ian.giammanco@ttu.edu)

[2] Atmospheric Science Group, Texas Tech University, Box 42101, Lubbock, TX 79409

The 2008 Atlantic Hurricane Season provided the first opportunity for the Texas Tech University Hurricane Research Team (TTUHRT) to deploy a newly developed surface observing system referred to as "StickNet" [1]. TTUHRT currently operates 24 StickNet probes which collect high resolution wind data at 2.25 m height in addition to the standard meteorological variables. Three deployments were made during the 2008 season: Hurricanes Dolly, Gustav, and Ike. These deployments illustrated the versatility and ruggedness of the StickNet platforms in tropical cyclone conditions. StickNet probes also provided measurements from the immediate shoreline for both Hurricane Dolly and Hurricane Ike, and provided some of the only continuous records from the hurricane landfall regions. The peak instantaneous wind speed recorded by a StickNet probe was 51.4 ms^{-1} (115 mph) measured during Hurricane Ike. Data collected during the 2008 season has also shed light onto surface roughness changes associated with shallow inundation due to both storm surge and freshwater flooding.

[1] Weiss, CC., & Schroeder, J.L. (2008) *88th Annual Meeting of the American Meteorological Society*, New Orleans Louisiana..

3D Models of Faults of the Corsair Trend, Offshore Texas.

B. HAMBY, S. NAGIHARA*

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*seiichi.nagihara@ttu.edu)

The Corsair fault system has produced numerous hydrocarbon reservoirs, yet little is known about the less significant faults that make up the fault system. The purpose of this research is to study the many smaller faults that make up the Corsair fault system. The 3D models of the faults were constructed to aid in understanding them better. To create the models, I took the raw data from 2D seismic profiles and created time slice maps of the faults. From these maps I was able, with the aid of technology, to create 3D models of the faults. The help of 3D modeling of faults will lead to better understanding of all faults. This research has indicated that the faults that make up the Corsair fault system are considered a glide fault system.

Syndepositional Deformation of Permian Strata in the Sacramento Mountains, Otero County, New Mexico

B. HARGROVE

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (brendan.hargrove@ttu.edu)

The Sacramento Mountains of south-central New Mexico are a roughly north-south trending cuesta demarcating the Pedernal Uplift, one of a series of uplifts associated with the Marathon-Ouachita Orogeny of late Paleozoic time and the uplift of the Ancestral Rocky Mountains. Evidence exists of multiple deformation events affecting the region in the form of both extensional and compressional structures overprinting one another, as well as obliquity between these structures in pre-Permian strata [1]. The Fresnal Fault, a major north-south trending high angle fault with a reverse sense of displacement in the north and a normal sense of displacement in the south, represents the most prominent structure in the mapped portion of the escarpment.

The study area is dominated by units of Pennsylvanian and Permian age. Pennsylvanian strata, consisting of the Gobbler, Beeman, and Holder Formations, are composed primarily of sequences of limestones, sandy muddy limestones, and interbedded limestones and marine shales. Permian strata of the Laborcita and Abo Formations are composed primarily of red and reddish-brown sandstones, sandy mudstones, mudstones, and conglomerates. Tertiary dikes of intermediate composition cut across the study area, trending northeast-southwest [1].

Initial displacement along the Fresnal Fault during late Pennsylvanian-early Permian time resulted in the uplift and erosion of the Pennsylvanian Holder Formation and subsequent deposition of the Permian Laborcita and Abo Formations. Permian beds form growth strata along the Fresnal Fault and related folds, providing time constraints on this episode of deformation. The Fresnal Fault is interpreted to be compressional, and obliquity between it and adjacent folds suggests some oblique-slip along the fault [1]. It has been speculated that many Ancestral Rockies structures could be inherited from preexisting weaknesses in Precambrian basement [2], which may explain why the Fresnal Fault and related folds show differing trends.

[1] Howell, A.W., 2003, M.S Thesis. Fort Collins, Colorado State University.

[2] Thomas, W.A., 2007, Geosphere, 3(3) 119.

Metasomatic Alteration of Monazite: Dating Mass Transport Events

C. J. HETHERINGTON[1*], D.E. HARLOV[2]

[1]Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 ([*]callum.hetherington@ttu.edu)
[2]Deutsches GeoForschungsZentrum, Telegrafenberg, D-14473 Potsdam, Germany

Monazite [(LREE)PO4] is a common Th-bearing LREE orthophosphate mineral in both igneous1 and metamorphic rocks. Thorium enrichment in monazite as $ThSiO_4$ and/or $CaTh(PO_4)_2$ can occur in the form of overgrowths, uniform enrichment, magmatic zoning, or as patchy, curvilinear intergrowths with sharp compositional boundaries, both along the monazite grain rim as well as in the grain interior. Recent advances in the dating of monazite using the electron microprobe have indicated that these overgrowths and intergrowths, whether enriched or depleted in Th, can give ages younger than the original monazite. The morphology of the intergrowths suggests that the original monazite grain has been partly metasomatised by a fluid in which Th, Si, and Ca are mobile. This hypothesis has been tested in the piston-cylinder apparatus at 1000 MPa and 900°C utilizing a natural, unzoned, homogeneous, Th-bearing monazite-(Ce) plus a series of alkali fluids including 2N NaOH, 2N KOH, and H_2O + $Na_2Si_2O_5$. In each experiment a subset of the monazite grains acquired $ThSiO_4$-enriched intergrowths with sharp compositional boundaries that show no evidence of being overgrowths. These experiments support the hypothesis that Th-enriched and Th-depleted intergrowths observed in natural monazite can be metasomatically induced yielding information concerning the nature of the fluid present under a variety of P-T conditions. Subsequently, these intergrowths could also be used to date multiple metasomatic events assuming that all the original Pb was removed during alteration. The results of these experiments also seriously question the use of monazite-based ceramics as repositories for radioactive waste since under high pH conditions, they could be susceptible to partial dissolution and the subsequent release of Th into local aquifers.

Examination of the Coastal Transition Zone of Hurricane Frances

B.D. HIRTH[*] AND J.L. SCHROEDER

Atmospheric Sciences Group, Texas Tech University, Box 42101, Lubbock, TX 79409-2101 (*brian.hirth@ttu.edu)

The structure of the coastal internal boundary layer (IBL) has important ramifications on operational forecasting, structural design, and post-storm damage assessment. Despite these important issues, it is unclear how the structure of the IBL evolves at the coastline on micro and mesoscales during a landfalling hurricane event. Changes in IBL structure are expected due to changes in coastal geometry and surface roughness, but other enhancements may also result from the passage of convective precipitation and associated downdrafts. Though observations from the coastal transition zone in the onshore flow region of a hurricane are rare, a comprehensive dataset was acquired from Hurricane Frances (2004).

Wind speed data were obtained from 33 instrumented towers at various locations on the Cape Canaveral Air Force Station and Kennedy Space Center (CCAFS/KSC) complex. Complete data records were collected by 24 towers, while the remaining nine failed at various times during the event. The tower data were coupled with single and dual-Doppler data sets collected by the Shared Mobile Atmospheric Research and Teaching (SMART) radars. The radars were located at Merrit Island Airport and Space Coast Regional Airport in Titusville, resulting in a baseline of 21.9 km, and placing much of the CCAFS/KSC tower network within dual-Doppler coverage. The complexity of the Cape Canaveral coastline and the highly convective nature of the outer portion of Hurricane Frances provide a useful examination of IBL structure during a hurricane landfall. Analysis will be presented from periods when stratiform and convective precipitation

progressed over the Cape Canaveral mesonet and moved inland into the adjacent Florida peninsula.

Possible Volcanic Origin of the Martian Outflow Channel, Hrad Vallis

J.P. HOPPER*, D. LEVERINGTON

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053. (*p.hopper@ttu.edu)

Located on the northwestern flank of Elsium Mons sits the Martian outflow system, Hrad Vallis. Hrad Vallis is a ~435m deep, ~1450km long outflow system that heads at 34.2°N, 141.5°W. The origins of Hrad Vallis have been debated and no clear conclusion has been reached, though previous studies have favored development of Hrad Vallis through violent interaction between magma and ground ice. The purpose of this project is to describe the basic nature of Hrad Vallis, and to use the morphology of the system to help constrain possible mechanisms of development. Although large channel systems can be formed by the flow of water, many lunar and Venusian channels are believed to have formed by the flow of lava, and these systems share many of the same characteristics as Hrad Vallis (e.g., streamlined islands, anastomosing reaches, and heads at topographic depressions). It is arguable that the simplest interpretation of martian outflow systems that extend from topographic depressions at volcanic sources onto volcanic plains involves development by the flow of lava. However, most workers consider that the flow of lava cannot act to incise channels and thus create such features as those seen at Hrad Vallis. If Hrad Vallis formed volcanically, basic thermal assumptions and channel volumetric estimates suggest a minimum erupted lava volume of 1.08×10^5 km^3.

2D Tomographic Velocity Model Building in Tilted Transversely Isotropic Media

F. JIANG*, H-W ZHOU

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*fan.jiang@ttu.edu)

Seismic anisotropy, the variation of the speed of seismic waves as a function of traveling direction, is caused by alignments of mineral crystals, fractures, and thin layers of alternative velocities. The presence of tilted transverse isotropy (TTI) is a good approximation of the velocity structure for many dipping sand and shale strata and fractured carbonates. We evaluate the effectiveness of tomographic inversion for 2D models consisting of several thickness-varying layers. Each model layer has a set of constant TTI parameters, the two anisotropic parameters, the tilted angle of the symmetry axis, and the velocity along the axis. Several synthetic tests indicate that some combinations of the above TTI parameters plus the layer thickness are invertible using first-arrival traveltimes. Our tests show that error in estimating the tilted angle and layer thickness may lead to significant error in estimating the anisotropic parameters. Hence it is erroneous to estimate anisotropic parameters assuming a vertical symmetry axis in TTI media. A general workflow for TTI velocity model building is proposed and to be tested with further studies.

Sea Level and Climate Controls on Lithofacies of the Bead Mountain Sequence.

R. LELLIS*, P. HOLTERHOFF

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*ryan.m.lellis@ttu.edu)

The Bead Mountain composite sequence consists of the lower Valera Shale and overlying Bead Mountain Limestone (lower Permian) of the Wichita-Albany Group of the Eastern Shelf of the Midland Basin of north-central Texas. The Bead Mountain composite sequence appears to be of late Artinskian age, straddling the Wolfcampian – Leonardian boundary.

The Bead Mountain composite sequence is divided into two sequences based upon the recognition of lowstand siliciclastic packages containing evidence of subaerial exposure. Internally, these sequences consist of two sets of major facies couplets. Each sequence has a lower couplet set dominated by siliciclastic mudstones with thin carbonate interbeds and an upper couplet set dominated by carbonates with thin carbonaceous shale partings. Mudstone dominated intervals are generally drab in color (black to medium gray green), contain abundant plant material, conchostracans (fresh water arthropods), and weakly developed paleosols in the lower sequence as indicated by clay slickensides and red and yellow mottles. The associated carbonate beds are generally thin skeletal packstones or peloidal wackestones. These muddy intervals are interpreted as overbank or lacustrine facies, and contain potential sequence boundaries. Carbonate dominated intervals are thick packages of bioturbated mollusk packstones and grainstones which are interbedded with thin, laterally discontinuous, carbonaceous shales. A horizon of crinoid fossils near the top of the upper sequence signifies the most open marine facies in the Bead Mountain composite sequence.

Gamma ray spectrometry reveals that the relative abundance of thorium and calculated volume of shale in these carbonate-dominated intervals decreases towards the top of each package. This trend indicates a reduction of detrital input into the carbonate platform system upward through each sequence. These carbonate intervals are interpreted as deepening upwards shallow marine facies with the potential maximum flooding surfaces of each sequence located near their top.

A significant question for the Bead Mountain package is the origin of the limestone/shale couplets. The carbonate and shale couplets may represent changes from wet to dry climate. Carbonate deposition could have become dominant during dry periods due to low terrestrial sediment influence. In contrast, a wet climate would supply more siliciclastic material and fresh water into the system, in turn hampering carbonate production. Continued outcrop description and correlation, spectral gamma ray profiling, geochemical analysis, and thin section examination will help determine the dominant driver for Bead Mountain couplets.

Discrimination of Sedimentary Lithologies Through Unmixing of EO-1 Hyperion Data: Melville Island, Canadian High Arctic

D.W. LEVERINGTON

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053
(david.leverington@ttu.edu, h.zhou@ttu.edu)

The use of remote-sensing techniques in the discrimination of rock and soil classes in northern regions can help support a diverse range of activities including environmental characterization, mineral exploration, and the study of Quaternary paleoenvironments. Images of low spectral resolution can commonly be used in the mapping of lithological classes possessing distinct spectral characteristics, but hyperspectral databases offer greater potential for discrimination of materials distinguished by more subtle reflectance properties. Orbiting sensors offer an especially flexible and cost-effective means for acquisition of data to workers lacking the resources to conduct airborne surveys. In an effort to better constrain the utility of hyperspectral datasets in northern research, this study undertook to investigate the effectiveness of EO-1 Hyperion data in the discrimination and mapping of surface classes at a study area on Melville Island, Nunavut. Bedrock units in the immediate study area consist of late-Paleozoic clastic and carbonate sequences of the Sverdrup Basin. Weathered and frost-shattered felsenmeer, predominantly taking the form of boulder- to pebble-sized clasts that have accumulated in place and that mantle parent bedrock units, is the most common surface material in the study area. Hyperion data were converted from at-sensor radiance to reflectance, and were then linearly unmixed on the basis of end-member spectra measured from field samples. Hyperion unmixing results effectively portray the general fractional cover of six end members, although the fraction images of several materials contain background values that in some areas overestimate surface exposure. The best separated end members include the snow, green vegetation, and red-weathering sandstone classes, whereas the classes most negatively affected by elevated fraction values include the mudstone, limestone, and "other" sandstone classes. Local overestimates of fractional cover are likely related to the shared lithological and weathering characteristics of several clastic and carbonate units, and may also be related to the lower radiometric precision characteristic of Hyperion data. Despite these issues, the databases generated in this study successfully provide useful complementary information to that provided by maps of local bedrock geology.

First Arrival Tomography Using Depth-Varying Velocity Gradients

H. LIU*, H-W. ZHOU

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*hui.liu@ttu.edu)

Tomography has become an effective way of velocity model building for near-surface static corrections, migration velocity analysis, and lithologic interpretation. One common method is cell tomography, which models the velocity field using a number of cells, and inverts for the velocities of these cells. Another method is layer tomography that is applicable where geologic features such as weathering zones, stratigraphic units, and salt bodies can be represented easily by layers. Layer tomography may directly invert for the geometry of layer interfaces. These cell and layer tomography methods assume that the velocity or velocity perturbation is constant within each cell or layer. When the velocity field varies continuously which is very common in the real world, traditional cell or layer tomography methods will be problematic. While it will be erroneous to approximate the velocity field using few constant-velocity cells, using too many cells will increase the number of inversion variables and the computation cost for both ray tracing and inversion. Here we improve a first arrival layer tomography to invert for the interface geometry and depth-varying velocity gradient of each model layer. An efficient ray tracing is also developed for the model with depth-varying velocity gradients by allowing velocity increases linearly with depth at each model location. This improvement leads to a more accurate and faster ray tracing, and incorporates fewer model parameters for tomographic inversion at places of continuous velocity variation. The improved method is shown using 2D examples.

Classifying Digital Imagery of Modern Isolated Carbonate Platforms for Facies Conditioning of Reservoir Models: Alacran Reef, Gulf of Mexico.

J.J. LODGE*, D. LEVERINGTON, P. HOLTERHOFF.

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*Jason.J.Lodge@ttu.edu)

Alacran Reef is a modern isolated carbonate platform located 75 miles north of the Yucatan Peninsula in the southernmost region of the Gulf of Mexico. The reef sits on the edge of the Campeche shelf and is a relatively large platform (~25 by 13 kilometers). This platform has been extensively studied and has been well characterized with regard to sediment distribution patterns, which allows for robust calibration and classification of facies using satellite imagery. Using a modern carbonate environment as an analog for the subsurface is common practice in the petroleum industry today. However, qualitative analysis of the scales of facies heterogeneity and spatial dimensions of these environments leaves much room for interpretation.

At Alacran Reef, each facies generally reflects incident radiation in a characteristic manner, and the diverse reflective properties of reef materials allow for the classification and statistical analysis of the platform. Alacran Reef was

characterized in this study using a supervised classification method involving selection of training sites on the basis of previously published sample data. The utilized satellite image was generated by the Landsat Thematic Mapper sensor (30 meter pixel size, 7 separate spectral bands). Image bands of special interest in this study included those generated in the blue, green, red, and near-infrared regions of the electromagnetic spectrum. After classification, statistics were generated to produce facies frequency and uncertainty maps using bins of different scale.

The potential impact of image resolution on aspects of image analysis and the characterization of facies is of considerable interest in this study. Future work will involve empirical evaluation of resolution effects at Alacran Reef through additional analysis of high-resolution imagery generated by the Ikonos sensor (1 meter panchromatic and 4 meter multispectral pixels). Results generated using the Thematic Mapper and Ikonos images will be compared to determine if higher resolution imagery will yield a better statistical representation of the platform.

Statistics generated for four modern isolated carbonate platforms in Belize will follow the analysis of Alacran Reef, and will allow for comparisons of platforms with varying shapes and sizes.

Statistical Investigation of the Formation and Disaggregation of Enclaves in the Vega Intrusive Complex

W.T. MARKO

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (wayne.t.marko@ttu.edu)

The 475 Ma Vega granodiorite unit in the Vega Intrusive Complex in north central Norway contains on the order of 13% enclaves by volume. Enclave types consist of surmicaceous, felsic aggregate (quartzite), felsic gneiss, mica schist and gneiss, migmatite, calc-silicate, igneous, mafic magmatic, and meta-peridotite varieties. Cumulative size-frequency distributions for surmicaceous, quartz aggregates, and calc-silicate types collected from different locations across the intrusion are self-similar or fractal for enclaves with radii < 37 cm in length. The fractal dimensions for these enclave populations range from about 1.9 to about 3. However, not all enclaves observed within the intrusion fit within these distributions. Many quartzite, migmatite, and calc-silicate xenolith sizes exceed the largest enclaves observed within designated count areas and fail to fit within the linear distribution. Therefore, smaller enclaves in the Vega granodiorite may have formed by catastrophic fragmentation which often results in fractal particle size distributions and characteristic fractal dimensions greater than about 1.4 [1], while large xenoliths may have formed by emplacement processes that did not result in catastrophic fragmentation of host rocks. In the case of surmicaceous enclaves, fragmentation likely took place deeper in the plutonic system, possibly during liberation of magma and residuum by partial melting. However, quartzite xenoliths, which are similar to some Vega host rock lithologies where disaggregated by progressive reduction in xenolith size during emplacement of the intrusion.

[1] D.L., Turcotte, Fractals and Fragmentation, J. Geophys. Res. 91 (1986) 1921-1926.

A Vertebrate Fauna from the Carnian Mott VPL 3869, Garza County, Texas, USA.

B. D. MUELLER

[1]Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (bill.mueller@ttu.edu)

The section of the “lower Cooper Canyon Formation” (Carnian, Late Triassic) at MOTT VPL 3869 is composed of conglomerates, sandstones, siltstones, and mudstones deposited in a fluvial environment. This locality has produced a diverse fauna during the past decade. The locality is in the lower portion of the Dockum Group and is producing fossils that are Carnian in age. At the beginning of the year 2000, there were ten specimens from MOTT VPL 3869 catalogued into the Museum of Texas Tech Vertebrate Paleontology collections database. A program of thorough collecting at the locality started in 2000. Since that time, over 140 visits to the locality have been made. Now there are approximately 1500 elements catalogued into the collection’s database. The vertebrate fauna is very diverse and includes an argonodontid, a palaeoniscid, metoposaurids, a variety of archosauromorphs, phytosaurs, aetosaurs, poposaurids, crocodylimorphs, dino-sauromorphs, synapsids, and more. The faunal list includes over two dozen distinct taxa and approximately 20% of these represent undescribed taxa. The fauna from the locality is providing important information on the biostratigraphy and paleo-ecology of the “lower Cooper Canyon Formation” of the Dockum Group.

Syndepositional Features and Evolution of an Ancestral Rocky Mountains Basin, Sacramento Mountains, Otero County, New Mexico

M. MUNCY

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (mike.muncy@ttu.edu)

The Ancestral Rocky Mountains are a series of Pennsylvanian north-northwest trending elongate basins and associated uplifts in Oklahoma, Texas, New Mexico, Colorado and Utah [1,2]. Two leading hypotheses for the mechanisms of uplift in the Ancestral Rocky Mountains include: 1) deformation and timing was coeval with the Ouachita-Marathon collisional belt [1]; and 2) Andean-type margin and subduction zone along the southwestern margin of North America proposed by Ye et al. [2]. While both models provide testable hypotheses regarding the kinematics of deformation in the basin-uplift systems, little is known regarding the kinematic evolution of Pennsylvanian-Permian faults within the orogen. This is due to 1) poor or no exposure of the actual faults; and 2) overprinting relations by younger faults systems.

The Fresnal Fault System in the Sacramento Mountains escarpment is an Ancestral Rocky Mountain basin where few studies have been published that document the kinematics for the faults, as well as any other Ancestral Rockies basin-uplift pairs. The preliminary results of this study suggest compressional forces with later overprinting by younger orogenic events. The main

focus for this study will be conducted in Permian syndepositional growth strata to infer the kinematics for the Fresnal Fault System. Models demonstrating mechanisms for growth strata include limb lengthening by kink-band migration [3], or progressive limb-rotation [4]. Current results favour progressive limb-rotation indicating fault-propagation folding as one possible mechanism during Paleozoic deformation.

[1] Kluth, C.F., and Coney, P.J. (1981) *Geology*, v. 9, p. 10-15
[2] Ye et al. (1996) *AAPG Bulletin*, v. 80, no. 9, p. 1397-1432.
[3] Suppe et al. (1992) *Thrust Tectonics*, 105-121.
[4] Hardy, S. and Poblet, J. (1994) *Geology* **22**, 371-374.

Sedimentary Thermal History Models for the Eastern Deepwater Gulf of Mexico

O. AJIBOYE, K. CASTILLE, F. JIANG, H. LIU, O. OLUWOLE, I. VERSTAD, Z. ZOU

Students of the Basin Analysis course (GPH5300-002) examined geothermal heat flow data and seismic stratigraphic interpretations previously reported from the eastern deep-water region of the Gulf of Mexico. Using these datasets and the software package *PetroMod* (Schlumberger), they each constructed models of sedimentary thermal history for different parts of the region. Models are intended for assessing hydrocarbon maturities of the sediments.

Magmatism and Metamorphism at Ylvingen, North-Central Norway.

J.A.G. OALMANN*, W.T. MARKO, C.G. BARNES, C.J. HETHERINGTON

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*jeffrey.oalmann@ttu.edu)

The island of Ylvingen in north-central Norway is underlain by a 476 Ma (Geosphere [1]) granitic pluton that is hosted by amphibolite grade metasedimentary rocks of the Helgeland Nappe Complex. The plutonic rocks are part of a larger intrusive suite that is dominated by S-type granodiorite exposed on the nearby island of Vega. Geochronology and field relationships indicate that the Ylvingen granite and Vega granodiorite were comagmatic.

The pluton at Ylvingen consists of biotite granite, garnet biotite granite, and diatexite. Enclaves in the pluton consist of calc-silicate schist, marble, gneiss, and biotite schist. The contact between biotite granite and garnet biotite granite is gradational. Diatexite occurs as discrete bodies within the pluton and consists of quartz + feldspar + biotite ± garnet ± muscovite ± kyanite ± sillimanite ± staurolite. Most granitic samples are peraluminous and have SiO_2 contents that range from 60.9–69.8 wt % and overlap between the units. Samples with lower SiO_2 content contain abundant biotite.

The host rocks consist of 1) interbedded psammites, semipelites, and conglomerates, and 2) calc-silicate schist and marble. Prograde assemblages in the semipelites include quartz + feldspar ± biotite ± garnet ± muscovite ± sillimanite ± kyanite ± staurolite. The contact between the pluton and metamorphic rocks is covered, but is subparallel to foliation in the host rocks.

Preliminary thermodynamic modelling of a diatexite sample constrains peak pressure to 6.0–8.5 kbar, solidus temperature to ~700ºC, and max temperature to ~750ºC. Peak temperature of a semipelite sample did not exceed ~600ºC, while peak pressure varies with fluid composition in the models.

Bivariate plots generally produce scattered arrays for the plutonic rocks. A lack of hyperbolic arrays on ratio plots rules out magma mixing. Linear arrays are common for elements that have high partition coefficients for biotite, suggesting, along with field observations, that accumulation of biotite occurred at the level of exposure. Similar compostions and prograde assemblages of diatexite and host rocks and the presence of metacarbonate xenoliths suggest that the covered host rock–pluton contact is intrusive in nature.

[1] Barnes et al. (2007) *Geosphere* **3**, 683-703.

Integrating Three Dimensional Laser Scanning and DGPS Technologies for Precise Outcrop Mapping: Hayes Sandstone, Guadalupe Mountains

S. OJEDA*, S. NAGIHARA, P. HOLTERHOFF

Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*sergio.ojeda@ttu.edu)

Gilson Canyon is located in southeastern New Mexico, in the Guadalupe Mountains. The Hayes Sandstone (Late Permian, Guadalupian) is a well exposed marker bed. The purpose of this research is to build a three dimensional (3-D) framework model of the Hayes Sandstone to better understand the stratal geometry of the underlying beds. I integrated light detection and ranging (LIDAR), Differential Global Positioning System (DGPS), and GIS technologies to generate a digital 3-D map of the Hayes Sandstone. LIDAR, an optical ranging technology, uses pulses of laser light to strike a surface and measures the time for the pulse to return. LIDAR technology gives researchers the ability to make full 3-D photorealistic outcrop images and acquire the position of a remote object by the point- and- shoot method. The *Quarryman Pro* Laser Scanner (MDL) was used to make a full 3-D scan of the topography of the mouth of the canyon and to apply a point-and-shoot method in mapping stratigraphic horizons. DGPS was also used in the stop-and-go kinematic mode for mapping parts of the Hayes bed that were not captured by LIDAR. In GIS, a digital elevation model (DEM) of the scan area was. Digital aerial photographs of the study area were draped over the DEM yielded and the 3-D prospective view. The DGPS and point-and-shoot method position data for the Hayes bed were interpolated into a triangulated irregular network (TIN) file; from which the slope and aspect maps were generated. Further geometric examination of the 3-D prospective shows that the structural dip of the Hayes Sandstone is north to north-east while the depositional dip direction is due south.

Lithofacies, Stratal Architecture, and Depositional Model of an Inner Platform Transgressive Rudist Complex, Basal Edwards Formation, West-Central Texas.

A. M. OYEDEJI*, P. HOLTEROFF

[1]Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*a.oyedeji@ttu.edu)

This study focuses on the Edwards Formation at an inner platform study site south of Sweetwater, Texas. The basal unit of the Edwards is a 3 to 4 meter thick rudist complex representing the transgressive systems tract of the Edwards sequence. This transgressive rudist complex is bounded above and below by planar contacts, giving the unit a tabular external morphology. Well-developed platform – stepping oblique and sigmoidal bedding surfaces produce a complex internal architecture.

Three lithofacies are characteristic of specific portions of the clinothems. Ooid– mollusk grainstones which compose the bulk of the toe- sets, downlapping onto the lowstand marl and grading upward into the rudist rudstone. The rudstone facies is the thickest portion of the clinothem and grades upward into the flat – lying ooid– peloid grainstones. This complex clinoform architecture and lithofacies/rock property partitioning would greatly reduce connectivity and fluid flow through this apparently tabular flow unit analog.

The basal Edwards rudist complex was deposited as an aggrading and back-stepping shoal system developed at the transition from the southern inner platform facies belt to the northern open platform. The ooid – mollusk grainstones were deposited as mound flank aprons and shoal top washover lobes downlapping onto the inner platform marl facies. Rudstones are loose accumulations of rudists set up as a mosaic of mounds or patches backstepping over the washover and flank grainstones. The ooid– peloid grainstones were deposited as shoal top sand flats that are the ultimate source of ooids in the toe set grainstones.

An Examination of a West Texas Playa Lake by Geophysical Means.

W.C. ROBINSON*, H. GURROLA

[1]Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*William.Curtis.Robinson@ttu.edu)

Frequently it is difficult or impossible to physically sample soil and rock underlying a specific location, due to cost limitations or difficulty obtaining samples. Various electrical, magnetic, and seismic methods have been developed to fill this gap. This study will investigate a West Texas playa lake using electromagnetic, seismic, electroseismic, and physical sampling. There are several goals for this study. First is to determine whether or not the playa lake substructure, specifically the caliche layer known to exist at approximately two meters depth, has become eroded and if so the degree of erosion. Second, models will be developed that explain the variations in seismic/electrical velocity due to changes in porosity and bulk density. Third, electrical/magnetic methods will be used to arrive at a model of the distribution of clay in the lake bed and the permiability of the playa lake floor. Lastly, the models will be compared to physical sampling, and differences will be explained.

Model for Wind Resource Analysis and for Wind Farm Planning

K. ROZSAVOLGYI

Wind Science and Engineering Research Center, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*rozsavolgyi_unideb@hotmail.com)

My research is on the spatial allocation of possible wind energy usage. I would like to carry this out with a newly developed model (CMPAM = Complex Multifactoral Polygenetic Adaptive Model), which basically is a climate-oriented system, but other kind of factors are also considered. With this model those areas and terrains can be located where construction of wind farms would be reasonable. The wind field modeling core of CMPAM is mainly based on sequential Gaussian simulation (sGs) otherwise known as geostatistics. But concepts from atmospheric physics and Geographical Information Systems (GIS) are used as well. For application for Hungary WAsP generated 10 m wind speed data was used as input data The geocorrection (geometric correction) of this data was performed by GIS. Using optimized variography and sGs, results were received for Hungary in different heights. Wind flow simulation results for different heights are summarized furthermore, complete analysis is also presented for wind farm planning purposes in map. Using sGs spatial uncertainty of wind field was also computed for various altitudes. The final and partial CMPAM outcomes produce basis for certain several possible sites for the utilization of wind energy under given conditions.

By the help of CMPAM new scientific results can be made and these can help decision makers in the wind industry as well during wind farm project development. Further model developments of CMPAM are planned by the help of West Texas Mesonet data in the close future.

Observations of the Surface Boundary Structure within Supercell Thunderstorms.

P.S. SKINNER*, C.C. WEISS

Atmospheric Sciences Group, Texas Tech University, Box 42101,Lubbock, TX 79409-2101 (*patrick.skinner@ttu.edu)

The Multiple Observations of Boundaries in the Local-storm Environment 2007 (MOBILE-07) field campaign collected in-situ observations of supercells with unprecedented spatial resolution utilizing a newly developed, rapidly deployable, unmanned surface observing system dubbed StickNet. In combination with a mobile mesonet, StickNet probes were able to capture snapshots

of the near-surface boundary structure within three supercells, two of which were weakly tornadic. The boundary structure of two additional supercells, one tornadic, was sampled by the mobile mesonet alone.

Data analysis revealed a persistent, primarily thermodynamic boundary across the forward-flank reflectivity gradient (FFRG) of each supercell. The boundary was characterized by a modest deficit of virtual potential temperature coincident with a small positive perturbation of equivalent potential temperature with respect to inflow conditions outside of the precipitation shield of the supercell.

Virtual potential temperature deficits across the FFRG have been identified as an important source region for baroclinically-generated streamwise horizontal vorticity that can be tilted into the vertical and subsequently stretched by accelerations in the updraft to induce low-level mesocyclogenesis in both observational and numerical modeling studies. Additionally, prior mobile mesonet studies have identified supercells exhibiting small thermodynamic deficits and greater potential instability across the FFRG as more likely to be tornadic.

The previously undocumented findings of positive perturbations of equivalent potential temperature across the FFRG suggest that air entering the low-level updraft originating across the FFRG has the potential to be both a source of baroclinically-generated streamwise horizontal vorticity and enhanced potential instability for supercell thunderstorms.

Detailed Mapping of Easternmost Laramide Structures, Southeastern Marathon Uplift, West Tesxas.

R. SONNTAG[1*] J.I. SATTERFIELD[2]

[1]Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*r.sonntag@ttu.edu)
[2]Department of Physics, Angelo State University, ASU Station #10904, San Angelo, TX 76909

A detailed, 1:10,000-scale geologic map of a thirty km^2 region within the Slaughter Ranch, West Texas, shows three outcrop-scale and map-scale deformation phases. The Slaughter Ranch, approximately 50 km northeast of Persimmon Gap in Big Bend National Park, is within the eastern margin of Laramide deformation which includes the southeastern Marathon uplift. The first deformation event (D1) formed outcrop- and map-scale folds and a penetrative axial-planar foliation within pre-Permian rock units (Caballos Novaculite and Tesnus Formation) during the Ouachita orogeny. D1 axial plane orientations are ~N84E 20SE. The second deformation event (D2) formed map-scale folds within Cretaceous and older rocks during the Laramide orogeny. Cretaceous map units overlying an angular unconformity include a basal Glen Rose siliciclastic member, Glen Rose Limestone, Maxon Sandstone, Telephone Canyon Fm., Del Carmen Limestone, Sue Peaks Fm., and Santa Elena Limestone. Cretaceous units fit Big Bend strata descriptions by Maxwell and others [1], except for the unusually thick Maxon Sandstone (169 m thickness). A D2 anticline, locally overturned and adjacent to an overturned syncline, extends outside the map area ~10 kilometers. D2 axial plane orientations are ~N48W 22SW. The third deformation event (D3) formed outcrop- and map-scale folds, some overturned. A map-scale D3 anticline appears to overprint the lengthy D2 anticline. D3 axial planes are oriented N34W 69SW. Relative timing relations between D2 and D3 folds are poorly documented and could be reversed. D3 folds correlate with the single phase of Laramide folds widespread in Sierra del Carmen and throughout in the Big Bend region.

[1] Maxwell, R.A., et. al.. 1967, Geology of Big Bend National Park, Brewster County, Texas: Texas Bureau of Economic Geology Publication 6711, 320 p., map scale 1:62,500.

Mapping of Syndepositional Structures, Sacramento Mountains, New Mexico.

R. SONNTAG

[1]Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*r.sonntag@ttu.edu)

The Sacramento Mountains in south central New Mexico offer an excellent opportunity to examine and study well developed syndepositional structures. Through detailed mapping (1:12000-scale) of Salado and Fresnal Canyons within the Sacramento Mountains, a map-scale northerly trending high angle fault, a series of folds throughout the Pennsylvanian and Permian rock units along with another smaller, northeast trending normal fault have been identified. Salado and Fresnal Canyon are located approximately nine miles east of Alamogordo, New Mexico adjacent to U.S. highway 83. With late Pennsylvanian to early Permian faults and structures overlain by undeformed Permian beds, the timing of deformation can be well constrained. It is interpreted that the main map-scale Fresnal fault is a syndepositional fault with a reverse sense of movement that was active in the late Pennslyvanian to early Permian time period. Outcrop and map-scale folds, including overturned folds, have been identified within both the Pennsylvanian and Permian strata indicating that deformation was still active in the early Permian.

The Role of Acquisition Geometry and Components for Imaging Micro-earthquake.

Z. ZOU[1*], H-W. ZHOU[2]

[1]Dept. of Geosciences, Texas Tech University, Box 41053, Lubbock, TX 79409-1053 (*e-mail address)

Radiation pattern of microseismicity is an important indicator of fracture orientation and distribution during reservoir fluid injection events. The quality of mapping the source radiation pattern by reverse time modeling is evaluated here. Among many factors influencing the imaging quality, the acquisition geometry and the component of input data are the most important. For instance, using a straight line of receivers will resulted in two imaged sources: the true source and a mirror source. The amplitudes of the two imaged sources are the same for single-component data, but the true imaged source has much higher amplitude than that of the mirror source for two-component data. One way to improve the image quality is to increase the array aperture, such as using both surface and wellbore receivers rather than just the surface receivers. Our results show that a larger

aperture will result in better imaged source that matches well with the true source in both amplitude distribution and angle distribution of displacement. Those results will be useful for reservoir monitoring acquisition design and the study of induced microseismicity.

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