Aeolian transport of sediment, Lubbock, TTU campus, April 2019. Photo by K. Ardon-Dryer

13th Annual Department of Geosciences Research Day Abstracts Program

8th May 2019, 10:30-13:30, 2nd floor Science Building

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

Department of Geosciences
Texas Tech University
Research Day 2019
8th May 2019

Welcome to the 13th Annual Department of Geosciences Research Day!

The program this year presents 23 abstracts from graduate and undergraduate researchers covering a wide variety of topics highlighting ongoing research within the Department of Geosciences. Exactly 15 abstracts are first authored by geoscience graduates and 8 abstracts are authored by our undergraduates. These numbers reflect the fact that undergraduate research became an elective course starting from last year.

The Sedimentary Lab room in the Department of Geosciences was earmarked for remodel during the summer of 2018. In the process of that remodel, we were able to install a river flume table. To highlight the capabilities of that lab, we are running a fun demonstration during research day this year, specifically how fast the rivers can erode and encroach on surrounding buildings. We have placed two model house structures in the flume and research day attendees will be able to pick a time that erosion will encroach on each of the houses. The winner receives a Big Hunk candy bar.

The Geoscience Society is sponsoring our luncheon this year. Please thank the officers for the catered barbeque lunch. The Society also provides gifts to the three winning posters in each category. Starting in 2014, the Society created a plaque for all top posters. The plaque is presented in the 2nd floor display case. Please stop by to note the past winners.

I would also like to thank all of the presenters and their supervisors for their hard work and commitment to providing quality research. Be proud of your accomplishments!

And finally a huge shout out to Yuval Dryer for being this year's photographer of the Geosciences Research Day.

Let’s have some fun!

Branimir Segvic

Schedule of Events
10:30 Poster Presentations
12:30 J&M Bar-B-Q Lunch
1:15 Award Presentations

* and º indicate TTU undergraduate and graduate researchers, respectively

Investigation of the Fe-Ti-HFSE enrichment in the Raftsund Intrusion, Årsteinen, Lofoten-Vesterålen archipelago, Northern Norway

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Iron+Ti±P±HFSE enriched rocks are found in a variety of localities worldwide, including some that are temporally and spatially related to Proterozoic AMCG (Anorthosite-Mangerite-Charnokite-Granite) suites. The origin of these enriched rocks has been widely debated and petrogenetic models such as liquid-liquid immiscibility, fractional crystallization and mineral accumulation, hydrothermal fluid enrichment, and residual liquids concentrated by filter pressing have all been proposed to explain occurrences of these rocks associated with AMCG suites.

These mineralized zones are located as thin veins (up to 3 cm wide) located at the contact between two rock-types – an equigranular olivine-clinopyroxene-monzonite and a porphyritic orthopyroxene-clinopyroxene monzonite. Field relationships down to the microscale suggest the mineralization is related to the equigranular monzonite - the mineralized zones show planar contacts with the porphyritic monzonite, while it protrudes in between mesoperthitic feldspar grains of the equigranular monzonite. The mineralized zones likely developed from the equigranular monzonite, while the porphyritic monzonite served as a boundary for which the mineralization was concentrated.

Mg# and Fo% in clinopyroxene and olivine, respectively, are highest in phases of the mineralization (35.0 and 6.17) compared to the equigranular monzonite (22.2 and 2.50) and are can be suggested to be early-forming. However, subsolidus exchange between ferromagnesian phases and Fe-Ti-oxides can drive the compositions of ferromagnesian silicates to higher Mg/Fe ratios. Higher modal proportions of Fe-Ti-oxides in the mineralized zones could have resulted in greater amounts of exchange, resulting in Mg/Fe ratios in clinopyroxene and olivine to be higher. Lower Sr contents, and more negative Eu anomalies in apatite of the mineralization indicate being the most evolved. Coupled with field relationships, this can be used to fit the origins of the mineralization zones by crystallization of a late-stage iron-rich residual liquid at the margins of the equigranular monzonite.

Illite particle nucleation in Pennsylvanian shale from the American Mid-Continent region – inferences from clay mineralogy and K-Ar ages

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Paleozoic successions of Anadarko Basin in the central United States are largely composed of shale intervals and have historically been known as major hydrocarbon sources. Lately their importance arises from the perspective of unconventional reservoir exploitation. Clay mineral evolution in these sediments and, in particular, the processes related to illite growth have, however, remained relatively under-researched.

In order to elucidate on crystal growth processes and discriminate between the most commonly accepted ones, an integrated multi-methodological study is necessary. K-Ar data on illite has been proven to be very useful for the understanding of illitization processes in shale. Still, dating of mudstone by the K-Ar method may reveal a range of ages that are older, younger or coincide with stratigraphic ages due to various variables leading to the instability of the K/Ar ratio.

This research examines Paleozoic shale of the Anadarko Basin cored at depths from 2980 to 3160 m. Based on comparative mineralogical data - X-ray diffraction, electron microscopy and infrared attenuated total reflectance - and K-Ar age investigation performed on three illite fractions (<2 μm, <1 μm, and <0.2 μm), in this contribution we report on the mechanism of crystal growth of illite. Our results showed that the finest illite fraction yields about 20 Ma younger K-Ar ages than coarser particles and is dominated by smectite component, while the <2 μm fraction is abundant in illite. It is generally accepted that K-Ar ages younger than the sedimentation age may result from (1) the diffusional loss of radiogenic ^{40}Ar, (2) loss of ^{40}Ar derived from the K initially found in expandable layers of mixed-layer phases, and (3) addition of K induced by burial diagenesis that in turn increases the K-Ar ratio and lowers measured ages.

Taking into account the mineralogical and isotopic data we hypothesize that the illitization of I-S of progressively buried shale was essentially controlled by solid-state transformation processes followed by the fast precipitation and crystal ripening of illite particles.

Porphyroblast growth and elemental transport in heterogeneous matricies

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Porphyroblasts are thought to grow by two mechanisms: interface- or diffusion-controlled nucleation and growth [1]. Most studies on porphryroblast growth have focused on homogenous matrices due to easier modelling. During growth, fluids or intergranular diffusion deliver elements to growing porphyroblasts. Studies have suggested it is possible for both mechanisms to operate simultaneously [2,3]. To examine theories on porphyroblast growth and elemental transport in heterogeneous matrices, this study looks at the Castner Marble, TX, USA, a Mesoproterozoic, layered calc-silicate.

The Castner Marble contains garnets within marble layers and along marble-hornfels interfaces. Garnets are dominated by andradite and inversely correlated with a lesser grossular component. Garnets show a variety of elemental zoning textures that include oscillatory, patchy, and massive (no zoning). EBSD maps show that garnets are found as single crystallographically continuous crystals, polycrystals, and crystal agglomerates.

Garnets are surrounded by recrystallized calcite that is coarser grained than calcite in the matrix. Calcites near garnets show lower LREE concentrations, but similar MREE- HREE concentrations to those found in the matrix. This suggests that during porphyroblast growth, the LREEs were preferentially partitioned in to garnet relative to calcite. When REE concentration in calcite is plotted as a function of distance from garnet, the LREEs appear to be transported by intergranular diffusion while the MREE and HREE are controlled by another process.

Garnets in the Castner Marble, particularly polycrystals and crystal agglomerates, are growing by interface-controlled nucleation and growth. This shows that for elements necessary for growth, no compositional gradients existed. EBSD and WDS maps show garnets along the lithological interfaces are growing across the interface as a single crystal, while nucleating immediately adjacent to other garnets. REE data in calcites show that the LREEs are being transported to the growing garnets via intergranular diffusion, while the MREEs and HREEs are being controlled by another process. This suggests that the LREEs and the MREEs + HREEs are in disequilibrium and petrogenetic tests involving these elements should be applied with care.

[1] Carlson (2011) *Intl. Geol. Rev.* 53, 406-445. [2] Meth and Carlson (2005) *Can. Min*. 43, 157-182. [3] Gatewood et al. (2015) *Chem. Geol.* 401, 151-168.

Evidence that the Gulf of California is propagating through Southern California: An example of underside lithospheric erosion possibly driven by the onset of extension

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Developing a better understanding of how the continental margin and lithosphere of southern California evolved will help to improve our understanding of how the lithosphere evolves during rifting. The Salton Trough is a rift basin that appears to be the northern extension of rifting related to the opening of the Gulf of California. Crustal thinning north of the Salton Tough through the Mojave Desert and Death Valley appears to be much less than in the Salton Trough. A new way of processing Ps seismic receiver functions has enabled us to remove reverberations from layers within the crust that typically obscure P-to-S converted seismic waves from the lithosphere-asthenosphere boundary (LAB). This new processing enables us to produce better images of depths to the Moho (crust mantle boundary) and LAB than previously possible. These images of the lithosphere to the north of the Salton Trough suggest that the mantle lithosphere has been attenuated to a greater degree than has the crust. This lithospheric thinning appears to be a series of small pockets of thinned mantle lithosphere (shallow LAB) offset along a right-stepping pattern similar to that of rifts separated by transform faults that are responsible for the opening of the Gulf of California. The pattern of small pockets where the LAB is observed to be shallow suggests that the northward propagation of Gulf of California related rifting led us to the hypothesis that underside erosion of the lithosphere is thinning the mantle portion of the lithosphere more quickly than the crust is thinning due to extension. These pockets of thinned lithosphere are offset in a pattern that suggest that they are offset by transform fault driven relative motion between the North American and Pacific plates.

Electromagnetic characterization of a buried river channel in the Brazos River alluvium aquifer in Burleson County, Texas

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The Brazos River Alluvial Aquifer extends from the southern portions of Hill and Bosque Counties down to the eastern edge of Fort Bend County and beneath and adjacent to the modern Brazos River. This river flows through eastern Burleson County and by our research site that is situated within Texas A&M University's Research Farm and above the Brazos River Alluvial Aquifer. This alluvial aquifer was formed during the early Holocene Epoch and consists of a fining of sediments upwards with a top layer that is composed of a leaky confined clay. The aquifer's average thickness is 15 m, it has a max thickness of 168 m, and its water table is generally around 9 m below the surface. The leaky confined clay unit, also known as Ships clay, averages 7 m thick. This facie has been formed due to depositional events caused by the ancient Brazos River during the Early and Late Holocene Epoch.

In this work, we used a time domain electromagnetic (TDEM) instrument and an electrical resistivity tomography (ERT) instrument to image subsurface features. In our target area we found an ancient river channel, more accurately a buried oxbow lake. This tubular structure was imaged by both the TDEM and ERT instrument. We used the TDEM to produce 1D soundings of the target area and the ERT instrument to produce 2D vertical cross sections of that same area and interpolated the data as electrical resistivity measurements. The buried oxbow lake was clearly defined sand cores ~30 m in diameter inside an extended cushion of clay and silt. As the oxbow is encased in a clay/silt cushion and because it terminates in a natural spring, we conclude that this tubular structure not only contains water in its porous core but also is permeable to allow for enough hydraulic conductivity to feed a natural spring.

Using trace element compositions to calculate melt compositions: A case study from the Kentallen clinopyroxene-olivine monzonites

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The distribution of trace elements between coexisting mineral phases and melt in a system are controlled by partition coefficients. This relationship can be used to calculate the composition of a melt that a mineral crystallized from. This relationship is useful in rocks where process such as fractional crystallization or accumulation produce rocks where the bulk composition doesn't reflect the composition of the melt that the minerals in it crystallized from.

The appinites surrounding the Ballachulish Igneous Complex are a series of ultramafic to mafic igneous rocks [1-4]. Based on field relationships, these rocks predate the intrusion of the main Ballachulish Igneous Complex but were emplaced after regional metamorphism [3]. A suite of olivine monzonites, locally referred to as Kentallenites, contain the assemblage of ol + cpx + bt + kfs + pl + ox with accessory ap. These rocks are interpreted to have evolved from a composition similar to the average of the suite through accumulation, fractional crystallization, or a combination of the two processes [3]. The purpose of this study is to determine the conditions in which the Kentallenites were emplaced and the composition of the melt from which the minerals crystallized from.

The minerals in the Kentallenites crystallized olivine first followed by clinopyroxene, apatite, biotite, and feldspars. Pheocrysts of clinopyroxene crystallized at approximately 1285°C and ~14.5 kbar. Melt compositions calculated from the REE compositions of cpx suggest that the melt these minerals crystallized from was more enriched than the bulk composition in the all of the LREEs, while it overlaps with the bulk composition for Gd, Er, Tm, Yb and Lu. Melt compositions calculated from the REE compositions of ap suggest that the melt these minerals crystallized from was more enriched in REEs than the bulk rock composition. The apatites appear to have crystallized from a melt similar to that the clinopyroxenes crystallized from. [1] Bowes & Wright (1967) Trans. of the Royal Soc. of Edinburgh 67, 109-143. [2] Hamidullah (1983) Petrogenetic studies of the Appinite Suite of W. Scotland, Univ. of Glasgow. [3] Pattison & Harte (1997) Scottish Jrnl of Geo. 33, 1-29. [4] Wright and Bowes

(1979) The Caledonides of the British Isles-reviewed, 669-704.

Timing of partial melting of Rattlesnake Creek amphibolite—initiation of the Nevadan orogeny?

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The Rattlesnake Creek terrane (RCt) of the Klamath Mountains structurally overlies the Condrey Mountain Schist (CMS) along the Condrey Mountain fault. The central RCt was metamorphosed to amphibolite (and locally granulite) facies conditions. The outer unit of the CMS locally preserves an inverted metamorphic gradient of greenschist to epidote amphibolite facies approaching the RCt[1].

Zircons were extracted from leucosomes in partially melted RCt amphibolite that crops out in the upper Applegate River and in the Scott River at Tompkins Creek. These zircons were dated by CA-ID-TIMS at Princeton University. Zircon from the northern Applegate River site yielded a 206Pb/238U age of 157.10 ± 0.14 Ma (9 grains) and the southern Scott River site yielded a 206Pb/238U age of 155.32 ± 0.30 Ma (10 grains). These ages are slightly older than 40Ar/39Ar (hornblende) ages of 153.0 ± 2.2 Ma at the Applegate River site and 154.3 ± 3.1 Ma at the Scott River site [2]. Ti-in-zircon thermometry yielded temperatures of ~630°C. This agrees with P-T ranges calculated at Scott River of ~600-700°C via garnet-hornblende thermometry [3] and ~6-8 kbar via garnet-hornblende-plagioclase barometry [4].

These temperatures are too low to result from dehydration partial melting of amphibole and instead indicate that melting occurred under H2O-saturated conditions. We propose that the excess water originated from the exterior unit of the subjacent CMS. We propose that starting at or shortly before 157 Ma, the CMS was thrust underneath the RCt along the Condrey Mountain fault. Heat from the RCt resulted in an increase in grade of the CMS, with resulting fluids infiltrating the overlying RCt. Addition of aqueous fluids allowed the already hot RCt to melt, producing migmatites. The 157 Ma zircon age from the Applegate River represents the earliest stage of melting of the RCt amphibolite.

Historically, the Nevadan orogeny was proposed to begin after deposition of the Galice Formation to the west (ca. 153 Ma) [5]. We suggest that the thrusting of the outer unit of the CMS beneath the RCt at ~157 Ma may mark even earlier Nevadan deformation. [1] Barrows (1969) Abstracts Int 30, 5096B-5097B. [2] Hacker et al. (1995) *Tectonics* 14, 677-703. [3] Graham & Powell (1984) *J. Met. Geol.*, 2, 13-31. [4] Kohn et al. (1997) *J. Petrol.*, 38, 1255-1277. [5] Miller et al. (2003) Abstracts with Programs 35, 113.

Revealing major controls on the diagenesis of pyroclastic rocks on the example of the Ugljevik Basin tuffs (Bosnia-Herzegovina, SE Europe)

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The Ugljevik Basin, located in the center of the Dinaric Alps, renders part of the Dinaride Lake System (DLS). Numerous tuffs from early and middle Miocene are recovered from DLS indicating extensive volcanic activity. At the time the prevailing depositional conditions were stable allowing more confidence when constraining the impact of diagenetic variables to the alteration products of tuffs.

Six tuffaceous horizons intercalated between marine to freshwater marls and limestones were sampled for the purpose of this research. Tuffs show high levels of alteration testified by the emergence of dense clay matrix in which only the contours of volcanic glass have been preserved. Their mineralogy is dominated by illite-smectite and calcite, while quartz, muscovite, biotite, plagioclase, K-feldspars and amphiboles represent minor phases. Chemical composition of tuffs is featured by low amounts of K (K_2O = 0.53-3.18wt%) and Na (NaO = 0.05-1.28 wt.%), and strong variations in the content of Ti (TiO_2 = 0.07-0.23 wt.%) and Si (SiO_2 = 20.29-54.90 wt.%). The loss of ignition ranges from 16.5 to 36.5 wt.% indicating a high level of alteration. The Nb/Y vs Zr/Ti discrimination diagram defines the tuffs overwhelmingly as andesites with only one sample classified as rhyolite. Generally, the original magmatism must have been evolved (~6-40 times chondrite concentrations) with a modest enrichment of LREE over HREE [(La/Lu)cn = 6.00-11.34]. A clear trend has been established between the crystallinity of the main alteration product of tuffs – illite-smectite – and their age, whereby the older horizons show abundance of well

crystallized but disorder illite-smectite. It is hypothesized that the evolving Miocene volcanism, or eventually a decreasing salinity, are the variables which might have had an impact on this trend. Further research which will include microbeam techniques and isotopic analyses will provide a more conclusive insight on this problematic.

Depositional facies, sediment origin, and diagenesis of the Barnett Shale Formation, Permian Basin, West Texas

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Many shales within the Permian Basin have solely been studied as a hydrocarbon source rock neglecting information towards geological controls of sediment and organic matter dispersal, deposition, and diagenesis. Furthermore, understanding the depositional history, origin, and diagenetic occurrences of inorganic and organic matter will provide clarity towards the paleoconditions under which the Permian Basin was subject to create a more robust geological model.

Approximately 200 ft. of core containing Late Paleozoic strata was obtained by Wayland Baptist University from Borden County, Texas along with well log and organic geochemical data from Wetherford Laboritories that were made available to the authors for this study. Core descriptions were made and representative sampling was conducted for thin sections and whole rock analysis. Mineralogical and inorganic geochemical data were obtained using XRD, XRF, and LA-ICP-MS.

Core descriptions show four main lithofacies 1) Dark grey – black laminated claystone – siltstone 2) Dark grey – black shale 3) Dark grey – black laminated mudstone 4) Dark grey massive fossiliferous grainstone. Whole rock XRD indicate primary mineral phases of quartz, calcite, feldspar, pyrite, muscovite, illite, chlorite, and interstratified illite/smectite. Geochemical data show consistent concentrations of major oxides, normalized trace, and rare-earth elements. Organic matter data from Rock-Eval pyrolysis calculations indicated type III kerogens, 0.86% TOC, a vitrinite reflectance (Ro) of 0.78%, hydrogen index of 41 ppm, oxygen index 15 ppm, and Tmax value of 441°C.

Normalized elemental abundances indicate felsic to intermediate igneous sources of shale components. Data suggest a shallow marginal carbonate setting influenced by siliciclastic sedimentation. The preservation of vitrinite and type III kerogens indicates deposition in anxoic to dysoxic water conditions and possible terrestrial source of organic matter. Further analyses will help create a robust post-sedimentation model for the Permian Basin which will utilize comparative maturation studies based on organic matter and clay mineral indices.

Ferrodiorites from Lofoten-Vesterålen and potential implications for AMCG (Anorthosite-Mangerite-Charnockite-Granite) magmatism

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AMCG suites also contain gabbro, leuco-gabbro, troctolite, norite, and ferrodiorite. These suites are widespread in the Proterozoic and have numerous hypotheses as to their formation. The Raftsund Batholith is a monzonitic/quartz-monzonitic pluton that is intruded by numerous ferrodioritic dikes. The dikes and their host rocks were petrographically and geochemically studied to determine petrogenetic origins and potential links.

The dikes are fine-grained, with subophitic to nesophitic texture and a mineral assemblage of plagioclase + clinopyroxene + biotite + Fe-Ti-oxides + apatite ± orthopyroxene ± Fe-sulfides with occasional 1-2 cm plagioclase laths. One of the sampled dikes contain coarser crystal aggregates of plagioclase with a Na-enriched rim, fayalitic olivine (with exsolved Fe-oxides and orthopyroxene rims), euhedral apatite, ilmenite, magnetite and pyrite. Many apatite grains contain two populations of melt inclusions: one dominated by silicate minerals, and the other by Fe-(Ti)-oxides. Many the dikes have high abundances of FeOtot (14-21 wt.%), TiO_2 (> 2.5 wt.%) and P_2O_5 (>1.4 wt.%).

Fractional crystallization modelling has been unable to yield magmas with sufficiently high P2O5. Silicate liquid immiscibility could explain both the elevated phosphorus and the two distinct populations of melt inclusions. Crystal aggregates may have formed from preferential wetting of the Fe-rich end-member of an immiscible pair onto early crystallizing phases.

Tectonic subsidence analysis of the Midland Basin and Eastern Shelf from the Pennsylvanian through Early Permian

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The Midland Basin (MB) and Eastern Shelf (ES) are located in Northwest Texas and are part of the greater Permian Basin region. The MB began to form in the Early Pennsylvanian due to the collision between Laurentia and Gondwana and is considered an Ancestral Rocky Mountain (ARM) basin. Applying subsidence analysis to the MB and ES can illuminate the basin evolution and inform ARM tectonic models. For this research, chronostratigraphic surfaces within the Pennsylvanian and early Permian were constructed from >2000 well reports across the MB. Six locations have been chosen, three within the basin and three along the shelf. I hypothesize that the Midland Basin will favor a specific ARM tectonic model. If peak subsidence occurs in the Late Pennsylvanian but decreased in the early Permian, then the pattern is similar to the two-phase subsidence model previously proposed for the ARM. I further hypothesize that subsidence varied along the strike of the Eastern Shelf such that, the southern area experienced a higher magnitude of subsidence. Preliminary results yielded curves similar to the two-phase subsidence model and showed the southern area of the ES experienced a higher magnitude of subsidence. This research will further the understanding of petroleum basin models while also informing ARM deformation models.

Liberation of molecular hydrogen and light hydrocarbon gases from source rocks during pyrolysis experiments

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Hydrocarbon generation in both, natural sedimentary basins and artificial pyrolysis experiments is still in the hot debate and several phenomena are not understood fully, for instance the abnormally low values of Rock-Eval HI, the difficulty in integrating Rock-Eval HI and atomic H/C ratios. These indicate that some factors in the kerogen cracking are not recognized and understood. H_2 ignored in previous studies is little in natural gas but much in pyrolysis gas. The open system pyrolysis experiments indicate H_2 is sourced from organic matter and show much higher pyrolytic yields than CH_4. H_2 liberation patterns are discussed and summarized in the source rocks with different depositional environment and thermal maturities, and its release has a significant effect on the evaluation of hydrogen content (HI). In the closed system pyrolysis (MSSV), H_2 yields depend strongly on the mass of organic matter and pressure in the reaction vessels, which are much lower than CH_4 yields. High pressures building up in the MSSV tubes favor H transferring reactions contributing to the hydrocarbon generation.

Understanding the origin and paleoclimate implications of paleosols from the Blackwater Draw Formation in Bushland Playa near Amarillo, TX

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The Blackwater Draw Formation is a series of stacked paleosols formed as a result of repetitious periods of aeolian deposition followed by landscape stability and pedogenesis. The accumulation of the Blackwater Draw Formation is coeval with the Mid-Pleistocene Transition and, therefore, likely records climate and environmental changes across this time period. This study aims to build a comprehensive pedogenetic framework of paleosols using clay mineralogy and geochemistry as well as K-Ar ages of illite. It will further on shed light on sediment provenance and provide information on the dynamics of pedogenesis in the context of evolving paleoenvironmental and paleoclimatic conditions. Soil clay minerals are highly susceptible to changes in environmental and climatic conditions. The clay mineral speciation and their geochemical and morphological variability can, therefore, be used to infer on the condition of clay formation, which in turn serves as an indicator of paleoclimate.

This research examines the entire 14 m of profile of the Blackwater Draw Formation, which was cored in the vicinity

of Amarillo in Northern Texas. Representative samples were taken from 18 locations throughout the entire length of the core and were analyzed by X-ray diffraction, laser ablation inductively coupled plasma mass spectrometry, and X-ray fluorescence. Our preliminary results show firm evidences of pedogenesis, most notably being the formation of multiple generations of illite-smectite characterized by variable amounts of smectite component. Geochemical correlations of transitional metals (e.g. Mn, Fe, Co, V, and Cr) are indicative for the emergence of the peculiar pedogenetic features like Fe-Mn nodules, which is subject to further microbeam investigation. We hypothesize that the clay mineralogy of the core is susceptible to the sediment cyclic deposition and ensuing pedogenesis in the context of the prevailing climatic conditions, which is corroborated by our preliminary data showing a relatively good correlation between the geochemical index of alteration (CCPI) and abundance of smectite component in I-S.

Crystal accumulation – the most significant differentiation process in silicic plutons?

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In silicic plutonic systems, bulk-rock compositional trends are commonly used to infer magmatic processes (e.g fractionation, mixing, assimilation). Crystal accumulation is only rarely considered and has traditionally been difficult to recognize. Hornblende (Hbl) chemometry [1] and Hbl-melt Fe/Mg partitioning tests [2] provide the means by which individual bulk-rock samples can be evaluated for crystal accumulation and/or melt loss. We first assess whether these tests are applicable to Hbl from plutonic systems by calculating crystallization temperatures using Hbl thermometry and then by comparing plutonic and volcanic Hbl compositions. We then apply Hbl chemometry and Fe/Mg partitioning tests to a wide compositional range of bulk-rocks and glasses from plutonic and volcanic systems.

Our findings indicate that magmatic histories are preserved in Hbl from plutons and that Hbl chemometry and Fe/Mg partitioning tests are applicable. These approaches indicate that the bulk-rock compositional variability in several plutonic systems is primarily due to variations in crystal accumulation rather than to changes in melt composition. The plutonic bulk-rocks investigated here (diorite to granite) are generally more mafic than the calculated melts, which are dominantly rhyolitic in composition, indicating that silicic melts were removed. The equilibrium relationships between Hbl and volcanic bulk-rocks and glasses is complex, particularly in more mafic samples. This complexity may reflect some combination of crystal accumulation and magma mingling/mixing. [1] Zhang et al., (2017) *AmMin* 102, 1353-1367. [2] Putirka, (2016) *AmMin* 101, 841-858.

Fusulinid biostratigraphy constrains early Permian deformation on the Northwest Shelf of the Permian Basin, SE New Mexico

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Broadly, the Permian Basin region localizes Pennsylvanian and Permian subsidence to the Midland and Delaware basins and surrounding shelfal areas. Structural deformation has largely been observed surrounding the Central Basin Platform and in the southern part of the province in close proximity to the Marathon Fold and Thrust belt. Here we present evidence of Late Pennsylvanian to early Permian deformation on the northwest shelf of the Delaware Basin. Fusulinid biostratigraphy denotes a region in southeast New Mexico where Wolfcampian strata rests unconformably upon variable strata of Pennsylvanian age. Within this region, Cisco-aged (Virgilian) strata are not present. Strawn-aged (Desmoinesian) and Canyon-aged (Missourian) strata are only locally present. Fusulinid biostratigraphically constrained cross-sections across this unconformable region indicate that the Pennsylvanian strata is broadly folded when hung on a top of Wolfcampian datum. One low angle fault is also recognized. This fault is identified by missing strata and thus likely had normal slip motion. However, the angle of the fault is most consistent with a thrust fault. Potentially the fault was first active as a thrust and later extension reactivated the fault plane allowing normal slip. Alternative scenarios for the unconformable region, such as variable erosion creating topography are inconsistent with the geometries constrained by fusulinid occurrences in the cross-section. Timing of the deformation was latest Pennsylvanian to early Permian as Canyon (Missourian) strata are involved in the folded strata and overlying Wolfcampian strata are not.

Jarosite solubility at 50°C

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Jarosite is a common mineral in acidic iron-sulfate environments and has been studied for its environmental impact, being detected on Mars, and for use in metallurgy. Jarosite dissolution has been shown to be incongruent, and dissolution leads to formation of iron oxy/hydroxide phases at pH > 1.5. This study examines data from 8 samples collected during an experiment completed by Frost (2005) by speciating concentrations of dissolution products to refine results [1]. Although hematite is the most stable phase for iron hydroxides that could form, the conditions necessary for formation were not present in the experiment conducted. An assumption is made that Goethite is the most stable phase formed from solution, and an expression for the solubility product is defined as log Ksp = 2 log[$SO4^{2-}$] + log[K^{+}] + 2 log[Fe^{3+}]. Equilibrium was not reached within the experiment, and so log Qsp was found to be -15.63 ± 0.40. Different behavior is thought to occur within dissolution of pH ≤ 1.5 because the samples in this group are the only ones to experience no change in pH as reactions progress. The approach used in this study defines jarosite dissolution as being inseparable from the study of formation of iron hydroxide solids and their behavior at different pH values. Further work should be done to assess the evolution of Goethite and/or other iron (III) solids from aqueous products at variable pH. [1] Frost, G. (2005) *Ms. Thesis*, TTU.

Grain-size and mineralogical characterization of experimentally created fault gouge during shear of 1 m^3 sandstone block

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Previous experiments indicate that fault gouge derived from porous sandstone do not form either log-normal or self-similar particle distributions, but reflect mixed log-normal components inherited from the grain-size distribution of framework grains and an admixture of broken calcite cement because sandstone is not critically packed. Thus, the porosity is a cushion that allows the grains to roll around and very little comminution occurs. However, we are creating new grains from the pre-existing microfractures and these control the final grain-size distribution. We took a block of common sandstone and subjected it to controlled stress and then measured the grain-size and volume distributions of the gouge created on the fault surface. The results indicate that pre-existing features in the quartz grains cannot account for the grain-size observed if all sand-sized quartz grains broke along those pre-existing fractures. Instead, continued comminution must have occurred to create the distribution observed.

Petrology and geochemistry of the Illinois basement and related rocks from the St. Francois Mts., Missouri

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The granite-rhyolite province (GRP), formed between 1.5-1.3 billion years ago, is the Precambrian basement that underlies the Illinois Basin. It is an extensive suite of rhyolite and granite extending from the Great Lakes region to the southwest and represents a belt of felsic magmatism that extended through Laurentia and into the modern southwestern United States. GRP rocks are diachronous in age, with ages concentrating at 1.47 Ga (+/-) and 1.37 Ga (+/-). Rocks of the GRP are only locally exposed, and so have largely been studied through drill cuttings and cores. The GRP is comprised of volcanic rocks with associated epizonal granites. Core and cuttings from 26 widely-spaced wells throughout Illinois were examined to better characterize the variation and architecture observed in the basement, as were rocks from the St. Francois Mountains in SE Missouri. The principal rock types are alkali-feldspar granite, syenogranites, and rhyolites. The rhyolites are further subdivided into quartz-bearing, feldspar-bearing, and aphanitic. All granites are magnetite bearing, with ilmenite present as exsolution lamellae within magnetite crystals. Accessory minerals include apatite, titanite, and zircon. Magmatic allanite is rare. Granites range from fine- to coarse-grained, with rare instances of pegmatitic textures. Heterogeneity is demonstrated both laterally and vertically across the Illinois basement. Quartz-feldspar intergrowths (graphic texture) characterize shallower granites and suggest hypabyssal emplacement. Whole rock compositions of the Illinois basement and St. Francois mountains were compared to other granite-rhyolite complexes

of similar age and composition, including the Wolf River batholith, WI; the Arbuckles Mountains, OK; Gold Butte granite, NV; the Oracle and Estrella granites, AZ; Log Cabin batholith, CO; Texas Panhandle basement rocks; and the Sherman granite, WY. The entirety of GRP analyses classify rocks as ranging from alkalic to calc-alkalic, peraluminous to metaluminous, and ferroan to magnesian. When comparing chemistry based on ages, older suites are mores strongly ferroan, are depleted in Sr, enriched in Rb and Zr, and enriched in K_2O. Tectonic discrimination diagrams plot older suites in the Within-Plate Granite fields, whereas younger rocks dominantly plot as Volcanic Arc Granites.

Pennsylvanian-Permian Climate-sensitive Facies from Low Latitude Rainsville Trough in Northern New Mexico

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Stratigraphic records of chemical sedimentation as well as characteristics of clastic influx in a basin can archive the paleoclimate data of that region. Formation of coals are indicative of continually recurring wet climates whereas deposition of chemical rocks i.e., evaporites and/or carbonates are linked to dry climates. Increases in clastic sediment influx to the basin is usually related to highly seasonal wet-dry climates in the source region. Thus, stratigraphic records of climate-sensitive sediments provide valuable clues to assess paleoclimatic information of that region. Climate-sensitive facies, observed in the subsurface Rainsville trough, are utilized to reconstruct late Paleozoic paleoclimate of northern New Mexico.

Taos-Rainsville trough, also known as the Rowe-Mora basin, is one of the ancestral Rocky Mountains (ARM) basins located near low latitude during the Pennsylvanian-Permian. Within the Rainsville trough, late Paleozoic sediments are mostly in subsurface. Therefore, available petrophysical well-log data were used for lithologic interpretation, largely through the development of Matlab codes. Significant repetitive coal bed occurrences along with great clastic influxes within the Sandia and Sangre de Cristo formations indicate that a seasonal wet to tropical rainy climatic condition prevailed during both the Atokan and Wolfcampian, respectively. Dominance of marine carbonate and associated evaporite intervals characterize the mid-late Pennsylvanian Porvenir and Alamitos formations and indicate semiarid to arid conditions. The Leonardian Yeso Formation, containing thick gypsum beds indicate an arid climate.

Climatic records show spatial and temporal variability during the Pennsylvanian-Permian time in the low latitude North American continent. Traditionally late Paleozoic has been interpreted as a wet climatic period that gradually became drier during late Pennsylvanian through early Permian. However, evaporite content in the Porvenir Formation, and repetitive coals and thick clastic depositions in the Sangre de Cristo Formation within the Rainsville trough suggests significantly a drier period during the middle to late Pennsylvanian, which became relatively more seasonal and wetter during the Wolfcampian.

Reexamination of geometry within the Hamburg-McGuffy Creek Area, Klamath Mountains, California

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The Hambur-McGuffy Creek area map covers a region of approximately 14 square miles east of Scott Bar, CA and north of the Scott Bar River in the Klamath Mountains, northern California. This map displays inconstant foliation and lineation that is worthy of examination as to how this could have come to be. Data utilized in this investigation was hand measured from two theses maps by Barrows (1969) and Hanks (1981). These units are the hangingwall rocks of the Rattlesnake Creek terrane (RCt) and footwall rocks of the Condrey Mountain terrane (CMD). The geologic units are a greenschist facies, albite chlorite peridotite actinolite schist (GS), an albite epidote hornblende semi-schist of epidote amphibolite grade (EAM), an hornblende-plagioclase gneiss of amphibolite grade (AM), a quartzite and serpentine categorized as a basic gneiss (BGM), the Lake Mountain Metasedimentary rocks (LMM) with related amphibolite, marble, quartzite, assorted ultramafic rocks including dunite, harzburgite, hornblende-harzburgite and serpentine (UM), and an intrusive hornblende quartz diorite (HQD). Subunits within the hangingwall include rocks of the AM, UM, LMM, and HQD and rocks within the footwall include the GS and EAM. A prominent ultramafic body, called the Tom Martin Ultramafic Complex r(TMUC) runs NW to SE parallel to the

contact between the hangingwall and footwall rocks and dominates the center of the map.

Strike and dip measurements taken from Barrows and Hanks maps where collated and plotted onto Stereonet for analysis. Additionally, a foliation and lineation trend map was created from the Barrows data to visualize trends over the extent of the map area and referenced to their geographical locations. Broadly speaking across the map all units tend south and dip moderately to shallowly west. Lineations in general trend N-S, trends are consist across hangingwall and footwall rocks. However, unit LMM displays far less of a strong trend than the surrounding units of the fault block do. In the southern area that is in contact with the HQD intrusive unit there is an east west lineation that then curves north to south when approaching the (TUMC). The interior of the LMM unit's foliation is not well defined in any direction, unlike other units in this area. It would appear that as the foot wall fault block impacted the hanging wall the (TUMC) proved a buffer for the LMM unit behind it. Evidence for this hypothesis cannot only be seen in the relative lack of uniform lineation in LMM interior but in the way that the foot wall's unit's lineations' bend around the southern end of the Ultramafic Complex. We therefore hypothesize that structures that predate thrusting of the RCt over the CMD have been preserved in the LMM, whereas units proximal to the contact in both the hangingwall and footwall record deformation related to juxtaposition of the two units.

Two new species of the conodont Caudicriodus from Oklahoma: Faunal provinciality in the early Lochkovian

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Conodont biostratigraphy of the Silurian–Devonian boundary interval and lower Devonian is complex and in flux. Occurrence and stratigraphic ranges of species of *Caudicriodus* Bultynck, 1976 are key to resolving the zonation. Herein, we describe two new species assigned to *Caudicriodus* from the lower Devonian Henryhouse and Haragan formations of Oklahoma (southwestern Laurentia). Carbon isotope chemostratigraphy demonstrates that these species occur coeval with other species in other localities: *C. hesperius* (Klapper and Murphy, 1975) in Nevada and *C. woschmidti* (Ziegler, 1960) in Podolia (Ukraine). Widespread lower Devonian localities that exhibit distinct conodont species indicate that Devonian conodont provinciality occurred much earlier than previously thought. The geographic pattern of provinciality is congruent with that of lower Devonian brachiopods.

Grain-size Analysis of the Quaternary Blackwater Draw Formation of the Southern High Plains

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The Blackwater Draw Formation is the topmost formation of the Southern High Plains (SHP). It covers roughly 120,000 km^2 and is described as an entirely aggradational eolian sequence deposited after the Pecos River Valley to the southwest of the plains eroded through the Caprock Caliche and isolated the SHP from the Rocky Mountains. This thesis proposes to test that the northward fining of grain size observed in the Blackwater Draw Formation is not solely a product of the downwind winnowing, but instead two entirely different provenances. I hypothesize that the Blackwater Draw Formation was at least partially sourced by silt-sized sediment created during northern hemisphere glaciations of the Pleistocene. If the Blackwater Draw Formation demonstrates a northern provenance signal, then progressively younger sediments of the Blackwater Draw Formation should exhibit geochemical, mineralogical and sedimentologic characteristics with affinity to continental loess of the northern Great Plains. If a northern provenance is demonstrated, then the Blackwater Draw Formation would represent the farthest southwest locality of glacially formed silt. Current models of silt distribution do not provide a mechanism for transporting the material onto the SHP, thus, a positive test to this hypothesis indicates that those models should be revised. Secondarily, macro- and micro-pedogenic characteristics will be coupled with whole-rock geochemistry and grain-size analysis to identify buried soil (i.e. paleosol) horizons.

Preliminary results from grain-size analysis of a 13.9 m push core, taken from the northern portion of the SHP, near Bushland, TX, indicate a fining upward trend in the buried soil profiles. In comparison to the type section, located farther south near Lubbock, TX, the Bushland Playa site exhibits a general finer grain size throughout the core and lacks the sand

component observed towards the base of the section to the south. These results are consistent with both the Pecos River down-wind fining model and a two-source model. Future geochemical and mineralogic provenance work is planned to further help resolve the distribution of sediment on the SHP.

The comparison and characteristics of aerosol particles on clear and dusty days in Lubbock, Texas

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High winds often blow through West Texas, kicking up large amounts of dust particles. On April 10, 2019, a large dust storm blew through Lubbock, Texas. The particle concentrations were high enough to reduce the visibility down to zero, creating hazards for the public's health and safety. In contrast, a week later, the day of April 17, 2019 was a seemingly clear day with no apparent natural or anthropogenic events. Particulate samples were collected on filters on both days using equipment that is positioned in our Aerosol Research Observatory Station (AEROS), located at the center of the Texas Tech University campus. The aerosol particles were analyzed for elemental composition and size distribution using CASM Zeiss microscope. Larger particles were found in the samples taken on the day of the dust storm. During that day, the particles sizes ranged from 0.8 up to 30 μm, with an average of 3.1±2.5 μm, while on the clean day the particles sizes ranged from 0.3 up to 13 μm, with an average of 2.3±2.2 μm. Elemental composition analysis revealed that both days contained dust particles, however, more were present in the samples taken on the day of the dust storm, as expected. The samples from both days also contained small amounts of anthropogenic particles, with more of them in the samples taken on the "clean" day. Biological and kaolinite particles were also observed in the samples from both days. Taking into account the prevalence of dust storms in this area, it is a possibility that upon the examination of other dust storms we will have different results, evident in the dust composition, depending on the source and cause of the event.

Changes of meteorological parameters during dust storms

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Dust storms are common in the South Plains of West Texas, mainly during spring and fall seasons. During such dust storm events, there is an increase in the number of particles in the atmosphere which therefore can reduce the visibility and have a negative impact on driver safety and human health. During April 10th, 2019 a large dust storm hit the West Texas region. In the afternoon, an upper-level storm system created a widespread and severe wind gust across this area. These strong winds lofted large amounts of dust from northern Mexico, southern New Mexico and West Texas.

We were able to measure different meteorological parameters by using the Davis Vantage Vue® meteorological sensor, which is located in our Aerosol Research Observatory Station (AEROS) in the center of Texas Tech University campus. Meteorological measurements were collected for three days, starting the day before the dust storm and ending a day after the dust storm. The values for pressure, dew point, wind speed and wind gust were different when comparing the values recorded during the day of the dust storm against those recorded the days before and after. An increase in the atmospheric particle concentrations was found to be associated with the increase in wind speed and wind gust.