EXAMINING LINKAGES BETWEEN CRITICAL WEDGES AND CRUSTAL CHANNELS: A COMBINED NUMERICAL, FIELD, AND LABORATORY INVESTIGATION

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ABSTRACT

In continental tectonics, questions remain regarding the dominant mechanisms of shortening accommodation during orogen evolution. Two quantitatively-supported models, critical wedge and channel flow, have been applied to the Himalaya. Although they represent fundamentally distinct mechanisms for explaining large-scale collisional behavior, it has been proposed that both can operate simultaneously. If correct, our empirical and theoretical understanding of the linkages remain poorly understood. Specifically, it is uncertain whether or not the relatively weak lower-mid crustal channel can act as the driving force for critical wedge deformation at mid- to upper-crustal levels, and if so, what mechanism(s) link these two distinct systems. To understand this, it is necessary to consider the magnitude of stress at the leading tip of the channel that can act as the driving force for critical wedge deformation. Also, if the channel is unable to drive critical wedge style deformation, it either suggests that the two mechanisms should be considered mutually exclusive or that there are other mechanisms operating. It is therefore proposed to the test linkages of these mechanisms by: (1) using coupled thermomechanical finite-element models to determine whether the channel can act as the driving force for critical wedge deformation and (2) comparing model-derived stress and temperature predictions with measured values for differential stress and deformation temperature experienced in multiple transects across the Lesser and Greater Himalayan tectonostratigraphic sequences in the Annapurna region of Nepal.

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CREATING A 4D MODEL OF FRACTURE AND FAULT DEVELOPMENT WITHIN THE ARBUCKLE MOUNTAINS, OKLAHOMA

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ABSTRACT

Fractures, faults, and fault zones are ubiquitous features in regions of folded and uplifted rocks. Their occurrence is relevant to hydrocarbon reservoir and water aquifer studies, as well as seismic hazard analysis. The Arbuckle Mountains, in south-central Oklahoma, provides an excellent natural laboratory to study the spatial and temporal evolution of fractures and faults over a varying range of scales from kilometers to micrometers. The proposed research has three objectives: 1) construct a digital fault and fracture map based on aerial imagery (Google Earth) and field geology that will enable detailed field studies to evaluate the distribution, density, and style of these features along the southern flank of the Arbuckle anticline, a major geologic feature in the southern mid-continent; 2) integrate these data sets into a geo-referenced ARCGIS database that may then be visualized using 3D ARCSCENE software; and 3) use this data set to test the following hypotheses: i) Fracture sets within the Arbuckle mountains predate the folding and faulting associated with the main phase of orogenesis in the region (e.g., the Ouachita Orogeny); ii) fracture characteristics are a function of rock type and may be correlated by rock type across the anticline; and, iii) tectonics associated with the Ouachita orogeny reactivated the preexisting fractures as a function of proximity to regional faults. Faults and naturally occurring fractures play a fundamental role in increasing permeability whether it be in a hydrocarbon reservoir or in an aquifer. The morphology and density of these structures controls how effectively fluids can move through the subsurface and the rate at which they can be extracted or injected. Hydraulic fracturing, or “fracking” in the modern vernacular, is a technique used to extract hydrocarbons by injecting over-pressured fluids into the subsurface thus enabling existing or new fractures to form, allowing the release and migration of hydrocarbons into a well bore. Such a process is also used to re-inject waste water into the subsurface. Critical data that can help in evaluating the nature of permeability pathways in the subsurface include detailed analysis of the spatial distribution and characteristics of fractures as observed in natural outcrops. The Arbuckle Mountains, south-central OK provide an excellent natural lab to evaluate the 4D evolution of fault and fracture networks.

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A LATE CRETACEOUS BROKEN FORELAND: EVIDENCE OF BASIN PARTITIONING IN THE WESTERN INTERIOR SEAWAY FROM DETRITAL ZIRCON GEOCHRONOLOGY ACROSS THE SOUTHWESTERN HIGH PLATEAUS, SOUTHERN UTAH

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ABSTRACT

The objective of this study is to decipher the spatiotemporal relationship between transverse and axial fluvial systems of the Late Cretaceous foreland basin in the Southwestern High Plateaus of southern Utah. Recently, convincing evidence from detrital zircon geochronology in the Kaiparowits Plateau for an axial river system flowing from the south, have raised questions about the lack of sediment input from the Sevier fold-and-thrust belt, and how the transverse fluvial systems were responding at this time. Currently, provenance and stratigraphic data is sparse on fluvial systems to the west of the Kaiparowits Plateau. However, distinct step-wise thickness changes of Late Cretaceous strata as early as the Cenomanian suspiciously coincide with Cenozoic normal faults, suggesting these faults may have been active reverse faults during the Cretaceous that were then re-activated as normal faults during the Cenozoic. This study will use detailed stratigraphy, paleocurrents, and sandstone petrography, combined with detrital zircon U-Pb geochronology of samples from across the Southwestern High Plateaus to decipher the stratigraphic architecture of transverse rivers and where they were sourced. Ultimately, this will allow us to determine if previous interpretations of a dominant axial river system are correct, and if the transverse and axial systems were being altered by active Laramide structures as early as the Cenomanian. If these hypotheses are true, it would imply that the timing and influence of Laramide tectonics on the foreland basin began much earlier than is previously assumed, altering deposition in the foredeep as early as the Turonian.

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EVOLUTION OF PALEOHYDROLOGY AND DEPOSITIONAL PATTERNS IN A DESERT ERG: RESOLVING REGIONAL-SCALE STRATIGRAPHY OF THE JURASSIC NAVAJO SANDSTONE, CENTRAL UTAH

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ABSTRACT

The eolian Jurassic Navajo Sandstone represents the largest erg to have existed on Earth. Despite the record of a vast dry desert, this prominent formation also contains distinctive surfaces and limestones that indicate periods of high-water table conditions. This research will examine the west-east basinal extent of lithofacies. Specifically, I will link stratigraphy between the established Navajo erg-center in southwestern Utah and the thin erg-margin in eastern Utah by examining intermediate localities in the San Rafael Swell of central Utah near Justensen Flats. The hypothesis of this study is that high-water table features are most concentrated in the eastern extent and at lower stratigraphic intervals, as predicted by an eastern Uncompahgre Uplift hydrologic catchment. The objectives to test this hypothesis are to 1) resolve regional-scale stratigraphic stacking patterns, 2) determine vertical changes in paleoclimate proxies, and 3) reconstruct bed-formation processes. This research will utilize direct field measurements, laboratory analyses, and model visualizations to reconstruct spatial stratigraphic variability in the Navajo erg deposition. Field studies will document detailed stratigraphic and sedimentological characterizations of the Navajo complex where it transitions towards the erg center. Analyses will enable synthesis of cross-sectional internal stratigraphic stacking, to reconstruct paleohydrology and paleoclimate through the vertical evolution of the basin deposition. This will culminate in determining whether there were substantial changes in groundwater and fluvial transport across the Navajo desert during early wet-eolian phases that transitioned into a drier erg through time.

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INCISED VALLEYS IN THE PARKMAN SANDSTONE, WYOMING: NEW SEQUENCE ANALYSIS OPENS UP NEW EXPLORATION AND DEVELOPMENT OPPORTUNITIES IN THE POWDER RIVER BASIN

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ABSTRACT

The Upper Cretaceous (lower Mesaverde) Parkman Sandstone (PS) of the Powder River Basin is a significant tight oil play that has continued to be a successful target even since the 2014 commodities price drop. The PS is a deltaic succession that displays an overall progradational parasequence set stacking, with depositional environments ranging from offshore marine to coastal plain deposits that show strong wave and some tidal influence. Shoreface facies of the PS are excellent reservoirs, however, lack of structural closure or stratigraphic trapping configurations meant that interest in the PS waned throughout the 90's until the discovery in 2002 of Savageton Field. The tight oil reservoir facies at Savageton is the distal portion of a single parasequence at the base of the lower PS. Several papers were published on the Parkman in the 1960s and 70s, prior to the advent of sequence stratigraphy. However, since then nothing has been published except for the publication on Savageton production. New ideas offer a great opportunity to increase prospectivity in the PS interval. The Parkman crops out along the western Powder River Basin at Teapot Dome. Nine sections were measured and integrated with observations of previous outcrop work to create a new proximal framework for the PS that suggests the occurrence of a previously unrecognized, major sequence boundary near the top of the lower Parkman in outcrop. Above the sequence boundary a valley fill system is composed of a series of estuarine to fluvial successions showing marine influence in the basal portion of the fill. Although relief on the larger valley incision has not yet been determined, individual fluvial channels display relief on the orders of meters, with multiple channels stacking 10's of meters thick. Abundant core, log and outcrop data integrated with new ideas on sequence frameworks in the PS have enabled a much improved understanding of the basinward reservoir potential and the potential for stratigraphic traps associated with incised valley development. Distal shale occurrences can be mapped landward to improve our understanding of inter-Parkman seals and baffles for much improved development planning.

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FLUVIAL SEQUENCE STRATIGRAPHY, ARCHITECTURAL-ELEMENT SPATIAL STATISTICS, AND SIGNIFICANCE OF MULTISCALE FLUVIAL HETEROGENEITY, BURRO CANYON FORMATION, SOUTHERN PICEANCE BASIN, COLORADO

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ABSTRACT

This study addresses the multiscale characterization from the definition of a sequence stratigraphic framework, the spatial analysis distribution to the implications of the heterogeneity for braided fluvial deposits of the Burro Canyon Formation, Piceance Basin, Colorado. The Burro Canyon Formation was deposited in a braided fluvial system composed of different architectural elements (transversal bar-sets, longitudinal bar-sets, and flood plain) the exposure of this elements is shown in an excellent tree-dimensional exposure along the Gunnison river close to Grand Junction Colorado. Field descriptions, petrography, and a combination of UAV- based digital photogrammetry, ground control points, and three dimensional models will be used to define the sequence stratigraphic framework, to map the abundance, stratigraphic position and dimensions of the architectural elements and to analyze the heterogeneity of the reservoir and its implications at field scale of this braided fluvial system. The resulting statistics extracted from outcrop characterization (dimension and spatial distribution), will be used as input data for constraining the generation of tree-dimensional models using subsurface information from log-data from 473 wells drilled northern direction from the study area. The characterization of this system can be used as analog for braided fluvial reservoirs where the success in the development plan for oil and gas fields is certainly associated to the understanding of the reservoir distribution and properties. Therefore, the use of analogues for understanding of the stratigraphy and elements that control the deposition of this fluvial systems is crucial for effective and efficient development plans in oil and gas fields.

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REGIONAL TECTONIC ANALYSIS OF LARAMIDE OROGENESIS USING FIELD STUDIES, APATITE FISSION TRACK, AND (U-TH)/HE THERMOCHRONOLOGY

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ABSTRACT

The Cretaceous-Tertiary Laramide orogeny remains a controversial episode of tectonic activity. Characteristics such as inboard deformation, magmatic shutoff, and anastomosing basement-cored arches have made the Laramide difficult to explain by traditional plate tectonic theory, and have invoked models whereby flat-slab (<15º) subduction of the Farallon plate is attributed to the progressive eastward "sweep" of stress and magmatism from ~90 to ~45 Ma. This event culminated in uplift of the Rocky Mountains. Active flat-slab subduction accompanied by magmatic shutoff and basement-cored arches is observed in Argentina, providing a modern-day analog for the flat-slab model. However, recent criticism of this "guiding paradigm" and areas of anomalously non-sweep magmatism (Colorado Mineral Belt) suggests that a thorough study is required to review and test geodynamic models for Laramide deformation. Proposed geodynamic mechanisms for the Laramide orogeny includes slab shallowing, passage of conjugate oceanic plateaus, widespread distributed basal tractions and crustal detachment, mid-crustal flow, west-dipping subduction, and/or lack of a flat-slab. I propose that timing data from apatite fission track (AFT) and (U-Th)/He (AHe) thermochronology, given their sensitivity to <4 km crustal uplift, will be appropriate methods to test the kinematic plausibility of these geodynamic models. In order to do so, a compilation of all AFT and AHe data for the Laramide ranges is currently underway, and will be supplemented with strategic sampling conducted in this study. The completed dataset will then be modeled and used to interpret the regional distribution, timing, and kinematic sense of Laramide deformation from Montana to Arizona/New Mexico.

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LATERAL VARIABILITY OF SANDSTONE COMPOSITIONS: DETRITAL ZIRCON U-PB AND PETROGRAPHIC INSIGHTS INTO SEDIMENT MIXING IN AN EMERGENT FORELAND BASIN SYSTEM

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ABSTRACT

The Eocene Castissent sandstone of the south-central Pyrenean foreland basin provides an opportunity to examine the vertical and lateral compositional variability of a single continuous source-to-sink system. World-class seismic scale outcrops of fluvial to deep marine depozones of the Castissent Fm and its deep marine equivalents (Fosado and Arro Turbidites) preserve an entire sediment delivery system from proximal alluvial deposits to distal submarine fan deposits. Preliminary detrital zircon (DZ) geochronometric results from the Castissent, Fosado and Arro Fms indicate the sandstone provenance progressively changes in downstream direction. A number of processes have been hypothesized to lead to this change, including sediment staging, recycling of floodplain material, hydrodynamic fractionation of the heavy mineral phase, and sediment mixing from axis transverse tributaries mixing with the axis parallel main trunk river system. This project aims to examine the sediment composition sampled from the main trunk river, tributary rivers, and the deep marine equivalents to model the relative sediment contribution from different source catchments. We hypothesize that the relative sediment contribution from the rapidly exhuming Pyrenean fold-thrust belt sources drowns out the signal of the axial foreland derived sediment supply, producing the observed compositions in the deep marine record. To test this hypothesis we will systematically examine the variability in provenance proxies of the system as a function of N-S location (transverse to axial) and intra-formational hydrodynamics. The results from this study will aid in the understanding of Pyrenean foreland basin evolution, and are translatable to other foreland basin systems around the world.

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POTENTIAL FOR LACUSTRINE-EMBAYMENT DEPOSITS WITHIN MARINE UNCONVENTIONAL WOODFORD SHALE IN CENTRAL AND SOUTH OKLAHOMA

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ABSTRACT

Research over the past few years has focused on the stratigraphy and sedimentology of the Devonian-Lower Mississippian Woodford Shale. The Woodford is not only a good mid-continent (U.S.A.) oil and gas producer, but also a good analog for other 'siliceous' unconventional resource shales, particularly if they are underlain by carbonates. The studies have emphasized detailed mapping and stratigraphic characterization of the Woodford, but have also provided a foundation for extending into relating stratigraphy to geophysical, geochemical (organic and inorganic) and geomechanical characterization. It is generally assumed by shale researchers that the Woodford (and most analog resource shales) is wholly of marine origin. RockEval analyses usually indicate Type II kerogen, however, occasionally a Type I kerogen is detected. Other unconventional resource shales show a similar pattern, but these anomalies are often shrugged off as analytical error.

3D seismic surveys reveal an unconformity surface on top of underlying carbonate rocks, with considerable karst topography and > 100m of vertical relief. From this, a geological model has been developed which claims that during lowstand of sea level, karst topography forms an irregular surface which can provide discontinuous catchment areas for ponding of hypersaline/lacustrine water masses, forming restricted water circulation and establishing conditions for the deposition and preservation of Type I kerogen. 3D seismic surveys inverted to provide TOC maps have shown discontinuous, "podlike" areas of anomalously high TOC and thickness in the lower Woodford. This is in contrast to common thinking that organic-rich strata are deposited from marine waters in a blanket fashion.

This proposed research tests the hypothesis that within dominantly marine unconventional resource shales there will be some horizons that are of hypersaline/lacustrine origin, and which will contain Type I, oil-prone intervals. The same features could apply to other resource shales underlain by carbonates; these shales will also be tested. Of practical importance is the greater chance for improved oil generation in areas that have been condemned for exploration because of gross-interval screening techniques.

This research is the first to evaluate the presence of periodic restricted, hypersaline/lacustrine deposits within an unconventional resource marine shale. The products of this research will determine if rocks of a marine environment under very restricted conditions can additionally support the accumulation of hypersaline/lacustrine organic matter. If so, in large interval analysis of unconventional shales where the marine rock intervals are in high thermal maturity the liquid hydrocarbons are cracked to gas, but in similar maturity level for the lacustrine deposits, the sourced oil will be preserved or more resistant to thermal cracking, thus providing previously unidentified exploration and prospectivity targets in unconventional marine shales.

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A NEW METHOD TO RECONSTRUCT METHANE FLUXES: 34 S ISOTOPES OF BULK MARINE SEDIMENT

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ABSTRACT

Methane occurs in marine sediments along continental margins throughout the global oceans. This methane is produced by microbial degradation and thermal decomposition of organic carbon and once formed, it can reside, ephemerally, in gas hydrate reservoirs or leave the seafloor at methane seeps. The sulfate methane transition zone (SMTZ) is an interface in anoxic marine sediments where microbes drive the anaerobic oxidation of methane (AOM), precipitating pyrite and authigenic carbonates. There is a strong connection between the magnitude of upward methane flux and the position of the SMTZ within seafloor sediments. Understanding how the position of the SMTZ has migrated through time indicates how methane flux has changed through time. The purpose of this project is to develop a new method that uses 34S isotopes of bulk marine sediment to identify paleo-positions of the SMTZ. Previous efforts relied on a labor-intensive chemical treatment to isolate the mineral bound sulfur from the sediment. However, in sediments that have undergone full pyritization I believe that 34S isotopes from bulk sediment may be a sufficient indicator of paleo-SMTZ positions. To test my approach, I will analyze the sulfur isotope composition of paired bulk sediment and treated sediments from cores taken from Hydrate Ridge on the Cascadia margin. I will utilize records that have undergone full pyritization, have age models, and show some evidence of AOM. My results will allow me to reconstruct the timing and positions of paleo-SMTZs as a proxy for changing methane fluxes in this region through time.

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TRIASSIC NORTH AMERICAN PALEODRAINAGE NETWORKS AND SEDIMENT DISPERSAL OF THE CHINLE FORMATION: A QUANTITATIVE APPROACH UTILIZING DETRITAL ZIRCONS

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ABSTRACT

The Triassic Chinle Formation is a fluvial succession deposited in a backarc setting across the present-day Colorado Plateau of the southwestern United States. The Chinle represents the first integrated and preserved east-to-west trans-continental fluvial system following development of the Appalachian-Ouachita cordillera. This study will collect new samples for detrital zircon analysis, as well as upgrade existing samples (to n=300) from previous studies to improve the resolution of Triassic sediment provenance from source to sink. The improved dataset allows appraisal of the multiple provenance terranes that contributed to the Chinle depositional system to delineate and reconstruct paleodrainage patterns. The additional samples will be collected systematically from the base of the Chinle, and vertically throughout the section to capture a regional story of how the continental scale drainage reorganized through time. U-Pb ages of detrital zircons will be utilized to provide quantitative fingerprinting information to constrain interpretations for the origin and transport history of the Chinle fluvial succession in time and space. This systematically collected dataset will aid in the development of a well constrained model for sediment routing and paleodrainage in the Chinle, which is essential to understand and predict the nature and spatial distribution of ancient fluvial deposits, and predict large-scale facies distributions in fluvial aquifers and petroleum reservoirs.

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IDENTIFICATION AND GENESIS OF PALEO-FLUID FLOW FEATURES IN THE EXMOUTH PLATEAU OF THE NORTHERN CARNARVON BASIN

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ABSTRACT

The Northern Carnarvon Basin, offshore northwest Australia, is a Late Carboniferous rift basin that underwent episodic rifting through the Jurassic and Early Cretaceous before becoming a passive margin basin. The basin is one of Australia's premier hydrocarbon exploration regions though the outboard portion of the basin is less explored. Paleo-focussed fluid flow features had been previously identified in the Northern Carnarvon Basin however there is very little published documentation detailing them. This project aims to document and propose generation mechanisms for fluid flow events in the basin, along with assessing fluid migration pathways in relation to the fluid flow events. The project methodology will focus on seismic interpretation and data attribute analysis of 3D seismic data to identify active and/or paleo fluid flow features in the Northern Carnarvon Basin. A generation mechanism for the fluid flow features will then be proposed. This study has the potential to develop regional understanding for fluid flow generating mechanisms and fluid migration pathways in the Northern Carnarvon basin. Identification of fluid flow features could have either a positive or negative impact on the hydrocarbon prospectivity of an area. At the same time, better understanding of fluid migration pathways could open up new exploration plays that were previously untested.

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MULTI-PROXY INVESTIGATION OF THE WILKINS PEAK MEMBER, GREEN RIVER FORMATION VIA XRF CORE SCANNING: DEVELOPMENT OF A NEW HIGH-RESOLUTION ASTROCHRONOLOGY TO EVALUATE LAKE EXPANSION-CONTRACTION CYCLES AND IMPROVE TERRESTRIAL-MARINE CORRELATION IN THE EOCENE

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ABSTRACT

The Eocene Green River Formation of Wyoming, Utah, and Colorado is one of the world's premier lacustrine records, holding vast oil shale and mineral deposits and a particularly rich terrestrial archive of climate dynamics, tectonics, biology, and geomorphology for the most recent period of prolonged global warming, the Early Eocene Climatic Optimum (~53-50 Ma). These strata have been the focus of more than a century of study, however an extensive, high-resolution, multi-proxy record of this formation is currently lacking. X-ray fluorescence core scanning methods can offer significant strides forward in this regard, with continuous measurement of over 16 elements at sub-millimeter to centimeter scale resolution. Application of this tool to the Wilkins Peak Member of the Green River Formation, in combination with a suite of statistical testing approaches, will produce both a new multi-proxy elemental record and an astrochronologic model for the Wilkins Peak Member of the Green River Formation, enabling (1) a characterization of Green River Formation chemo-lithofacies with unparalleled detail and scope, (2) a rigorous evaluation of the potential astronomical influences on depositional variability in this formation, including observed lake expansion-contraction cycles, and (3) an improvement of global stratigraphic correlation for the early Eocene through application of a new radioisotopically anchored astrochronology to the Eocene time scale. This information will improve our understanding of the Green River Formation lithofacies composition, distribution, and depositional controls, critical to understanding this lacustrine system and other analogs around the globe.

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NATURAL FRACTURE CHARACTERIZATION AND PREDICTION IN UNCONVENTIONAL RESERVOIRS OF THE "MISSISSIPPIAN LIMESTONE", NORTH-CENTRAL OKLAHOMA, USA

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ABSTRACT

Natural fractures are common in several unconventional carbonate reservoirs in both the U.S. and around the world. Although many are sealed, these natural fractures may assist in the propagation of induced fractures during hydraulic fracturing and, therefore, are an important component for characterizing and producing from these reservoirs. This study is focused on correlating fracture types and intensity to petrophysically-significant facies and to an established sequence stratigraphic framework in the unconventional "Mississippian Limestone" in north-central Oklahoma. Four types of natural fractures are observed: ptygmatic, vertical extension, shear, and mixed types of fractures, with the ptygmatic fractures being the most abundant type. Most of the fractures are sealed with calcite cement. Fractured zones are both laterally and vertically heterogeneous at various scales, indicating variability in rock mechanics. Within individual cores, fractures are commonly discontinuous and exhibit variable widths at the millimeter scale, as revealed by thin sections and micro-CT imaging. At the centimeter scale, ptygmatic fractures exhibit variable termination patterns in relation to bedding planes, suggesting a mineralogical control on fracture propagation and rock mechanics. At the meter scale, the highest fracture abundance corresponds to facies with the highest calcite content, and consequently, to the regressive phases of "third-order" sequences which are commonly defined by these facies. Laterally, fracture abundance varies among individual cores, likely attributed to variations in the proportion of petrophysically significant facies, variations in structural settings throughout the region, variable patterns in the evolution of rock mechanics, and clustered fracture distribution related to the geographic separation of the cores. Although there is a potential mismatch between the present-day fracture stratigraphy and the mechanical stratigraphy at the time of fracturing related to evolution of rock mechanics (e.g., structural diagenesis), the sequence stratigraphic framework, which governs the distribution of petrophysically significant facies and impacts the evolution of diagenesis and rock mechanics, can provide insight that may enhance the prediction of natural fracture distribution in these and other unconventional mixed carbonate-siliciclastic reservoirs.

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EVALUATION OF EFFECTIVENESS OF ORDOVICIAN LOW-ABUNDANCE CARBONATE SOURCE ROCKS WITH AND WITHOUT HYDROCARBON EXPULSION IN THE PLATFORM OF TARIM BASIN

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ABSTRACT

The term hydrocarbon expulsion threshold refers to the critical conditions whereby hydrocarbon generation by source rocks meets the particular residual hydrocarbon requirements and begins to discharge free-phase hydrocarbon in quantity. Only source rocks that reach a hydrocarbon expulsion threshold can be referred to as effective source rocks. The objective of this project is to distinguish between Ordovician low-abundance carbonate source rocks with and without hydrocarbon expulsion in the platform of Tarim Basin and to identify the effective low-abundance carbonate source rocks with hydrocarbon expulsion. In this work, first, we will conduct pyrolysis, organic carbon, vitrinite reflectance, and other related experiments on core and cuttings samples. Next, we will measure the actual residual hydrocarbon content of the rock and, based on the hydrocarbon expulsion threshold theory and the experimental parameters obtained, calculate the maximum residual hydrocarbon content of source rocks at the same buried depth. Finally, we will establish a mathematical model for determining source rock with and without hydrocarbon expulsion. When the actual residual hydrocarbon content of the rock is greater than or equal to the calculated maximum residual hydrocarbon content at the hydrocarbon expulsion threshold, we can determine hydrocarbon expulsion to have occurred and the source rock can be classified as an effective low-abundance source rock. Otherwise, the source rock will be classified as ineffective. Through this project, we hope to demonstrate that not all low-abundance carbonate source rocks are effective and, specifically, that only low-abundance carbonate source rock with hydrocarbon expulsion is effective source rock.

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AN INTEGRATED STUDY OF FLUVIAL MEGAFAN SYSTEMS: SEDIMENTARY PROCESS, MORPHODYNAMICS RESPONSES, AND ITS AUTOGENIC BEHAVIORS

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ABSTRACT

Various large fluvial fan systems have been recognized in the geological record. Yet their sedimentologic and stratigraphic differences are unclear. This study recognizes the Early Eocene Green River Formation in the Uinta Basin and the Cretaceous Williams Fork Formation in the Piceance Basin as fluvial megafans, as seen by their lateral extent, internal architecture, and lateral and vertical facies transitions. Outcrop measured sections, photomosaics, and georeferenced aerial photographs taken by drone were integrated to study sedimentary facies variability, channel to floodplain ratio, and areal mapping of channel dimensions. By comparing outcrop data with results from experiments and mathematical models, as well as modern fluvial fans on satellite images, some common characteristics stand out. Fluvial megafans are a radial set of channels created by successive nodal avulsions, where generally only one channel is active at one time. This is seen in both basins that the sandying upward successions exist and an increase in channel to floodplain ratio, channel size, and degree of amalgamation in various scales ranging from avulsion to lobe switching. The lateral extent and vertical thickness of each sandying upward successions are documented for the target geologic units across the basin. Dominance of Froude supercritical flow is critically responsible for the unique barform geometry and the upstream migrating channel fills, as seen in Green River Formation, which is testified by physical experiments and mathematical models. These systems were proved to be sediment supply driven rather than accommodation driven in both basins, regardless of sea level or lake level control.

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SIBUMASU'S LATE CAMBRIAN TRILOBITES: THE KEY TO PALEOGEOGRAPHIC AND BIOSTRATIGRAPHIC RESOLUTION

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ABSTRACT

A lack of stratigraphic and paleogeographic resolution currently challenges attempts to understand the late Cambrian (Furongian) of Gondwana. Global scarcity of Furongian volcanic impedes calibrating biostratigraphy using radioisotopically datable zircons. Additionally, post-Devonian tectonics overprinted the Cambrian-Ordovician structural signatures traditionally used to resolve the paleogeography. The Sibumasu block (western Thailand, eastern Myanmar, and the Baoshan region of western Yunnan) is the only region of the world with known late Cambrian volcanics occurring at multiple stratigraphic levels. Those rhyolitic tuffs are interbedded with trilobitic sandstones, thus providing a means of calibrating late Cambrian biostratigraphy of Sibumasu. As Sibumasu's trilobites are biostratigraphically correlative with trilobites on other Gondwanan continents and tectonic blocks (i.e. Australia, North China, South China, and Bhutan), Sibumasu's U/Pb dates will be integrated with global stratigraphy and both trilobites and ashes will be useful in the reconstruction of the biogeographic relationships between marginal Gondwanan continents. The completion of this project requires the collection of detailed measured sections, trilobite fossils, and bulk ash bed samples through field work on Tarutao Island of Thailand, in the Linwe region of the Southern Shan State, Myanmar, and in central Baoshan. U/Pb dating will provide the ages of ash beds. Division of fossiliferous strata into trilobite biozones will apply those dates to calibrating Sibumasu's Furongian biostratigraphic record. Correlation with other regions using the CONOP (Constrained Optimization) software and traditional biozones will calibrate trilobite biostratigraphy across Gondwana. Cluster analysis of Furongian trilobite assemblages across northern Gondwana will reveal the biogeographic relationships between continents.

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THE INFLUENCE OF MECHANICAL STRATIGRAPHY ON THRUST TYPE EARTHQUAKES WITH IMPLICATIONS FOR SEISMIC INTERPRETATION AND RESERVOIR RESPONSE TO HYDRAULIC FRACTURING, SOUTHERN CALIFORNIA

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ABSTRACT

The main objective of this project is to examine an alternate model of thrust fault nucleation which takes into account vertical variation in mechanical strength of sedimentary rocks. This model maintains that thrust ramps nucleate in structurally strong units then propagate both upward and downward into weaker units. Evidence for ramp-first style of faulting is in both seismic and small scale outcrop data, but there is a crucial need to study large scale structures and the basic mechanics of the problem. Questions about the ramp-first model include: 1) What changes in stress state or material properties cause failure at ramps, and 2) what governs the continued propagation or arrest of thrust-type earthquakes? We hypothesize that the mechanical stratigraphy of faulted rocks may create a significant stress heterogeneity within the system and exert a first-order control on these factors. Methods for this project include the study of large-scale examples of ramp-first faulting and examination of the fundamental mechanics of thrust fault ramps with numerical modeling. The intended results for this project include 1) a suite of outcrop data collected from a large ramp-first style thrust (cross sections, stratigraphy, mechanical data), and 2) models in finite element modeling program ABAQUS in which we alter rheology, geometry, and spacing of thrust ramps. Shedding light on this faulting style will influence how structures are interpreted in seismic, how wells are planned, and it also informs how mechanically layered rocks will respond to stimulation from hydraulic fracturing.

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INVESTIGATING THE ORGANIC PORE STRUCTURE OF OHIO SHALES

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ABSTRACT

The recoverable resource of shale gas is 25 trillion cubic meter, 33% of which is stored in transitional shales in China. We investigate the effects of organic and inorganic compositions on the development of Upper Paleozoic transitional shale pore structures through a combination of petrophysical and geochemical measurements. 42 shale samples were collected from marsh-lagoon and coastal delta settings in the Ordos Basin, NW China. The samples include the Upper Permian Shanxi shale (average total organic carbon (TOC) of 1.58 wt.%, Type III kerogen, average Ro 2.6%), and the Upper Carboniferous Benxi shale (average TOC of 1.91 wt.%, Type III kerogen, average Ro 2.74%) at the over-mature stage or dry gas window. An important characteristic of these shales is the large proportion of clay minerals (~69% in Benxi shale and 54% in Shanxi shale). The quartz content is ~17% and 40% for Benxi and Shanxi shales, respectively. The pore structure of three samples and one isolated kerogen sample is analyzed via both low-pressure nitrogen and carbon dioxide adsorption methods. Low pressure nitrogen adsorption experiments show that Benxi and Shanxi shales characterized by ultra-low porosity and permeability develop mainly silt-shaped pores and potentially ink-bottle-shaped pores. We find that increasing fractions of OM result in a decrease in both total pore volume and specific surface area (SSA). Low pressure carbon dioxide adsorption experiments show that micropore volumes nonlinearly increase with increasing OM, although the contribution of organic micropore volume is limited. The mesopore and macropore volumes of inorganic compositions contribute mostly to the total pore volume. The OM in transitional shales in Yanchang mainly develop mesopores (with < 5 nm diameters), which significantly contribute to the SSA, while micropores are the main contributor to SSA in the inorganic matter. For thermally over-mature transitional shales, clay minerals contribute the most to SSA and pore volume as well as the storage capacity of absorbed and free gas.

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PATTERN AND HISTORY OF MIOCENE TECTONIC EXHUMATION IN NORTHERN KENYA RIFT: IMPLICATIONS FOR POST-RIFT SEDIMENT ACCUMULATION IN RIFT BASINS, KENYA

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ABSTRACT

The East Africa Rift System (EARS) is one the earth's major active extensional tectonic regimes in the continental crust. Considerable quantity of hydrocarbons has been reported and explored within the rift basins of the EARS, including the Omo-Turkana Basin, a large lacustrine basin of the northern Kenya Rift. Oil exploration by seismic methods and deep drill have shown an up to 7 km thick sediment sequence until mid-Miocene. The shoulders of the northern Kenya Rift has been considered as a major sediment sources as well as sediment barrier during post-rift extension and exhumation. Nevertheless, data are too few and unevenly distributed in space and time to evaluate the spatial and temporal variations of exhumation rates of northern Kenya Rift. This proposed work will focus on the reconstruction of the exhumation history and distribution pattern of northern Kenya Rift to identify sediment sources and supply path to the rift basins. It will combine quantitative geomorphic analysis, available geochronological and geomagnetic data, numerical model, and various geomorphic proxies to determinate long-term exhumation rate since Miocene and their distribution pattern throughout the northern Kenya Rift. The potential results will enable the correlation between tectonic exhumation and rift basin evolution in a rift setting. Also, by quantifying the exhumation rate and pattern, the result of this work will reveal the favorable geodynamic setting and rift sediments input history in the Omo-Turkana Basin.

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ON THE GENESIS OF SHALES AND CLAY DIAGENESIS CONTROL ON RESERVOIR QUALITY PARAMETERS OF LATE DEVONIAN TO LATE PENNSYLVANIAN UNCONVENTIONAL RESERVOIRS OF THE ANADARKO BASIN, OKLAHOMA

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ABSTRACT

The foreland Anadarko Basin in southeastern Oklahoma is one of the deepest and most prolific hydrocarbon producing basins in North America. In its deepest portion of approximately 40,000 feet, the basin consists of a thick Cambrian carbonate sequence overlain by 25,000 feet thick stack of alternating sandstone and shale layers of principally Upper Paleozoic age. Historically, the Anadarko Basin shales have been known as major hydrocarbon sources, while lately their importance continuously arises from the perspective of unconventional reservoir exploitation. Yet, the shaley units remained relatively under-researched with respect to their clay mineralogy and diagenetic control over the reservoir rock properties.

Focusing on the Late Devonian to Late Pennsylvanian shales of the Anadarko Basin and combining state-of-the-art analytical techniques such as transmission electron microscopy (TEM), whole-rock major and trace element geochemistry and X-ray diffraction (XRD) on clay fraction, this study aims to unravel the genesis and diagenetic evolution of shales as well as their impact on the distribution of reservoir characteristics in the subsurface. This research is hypothesis-driven and it starts with the premise that shale reservoir characteristics like microporosity, permeability and comportment of organic matter are intrinsically linked to the type, the mode of origin and diagenetic evolution of shaley clay component. By conducting this investigation I hope to open some new venues in understanding of fundamental characteristics of the Anadarko Basin shales (i.e. their origin and diagenetic history) which are known to effectively control the reservoir quality distribution in a variety of unconventional reservoirs.

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SEDIMENTOLOGICAL EVIDENCE OF AN INCREASE IN PRECIPITATION EXTREMES ACROSS THE PALEOCENE-EOCENE BOUNDARY IN THE SAN JUAN BASIN OF NEW MEXICO

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ABSTRACT

A growing number of studies document a change from sedimentary deposits characteristic of perennial river systems to deposits characteristic of highly seasonal river systems occurring at the Paleocene-Eocene (P-E) boundary in multiple Laramide sedimentary basins. This shift is indicative of a change to more seasonal precipitation in the form of prolonged droughts punctuated by intense terrestrial flooding occurring in coincidence with a rapid global warming event, the Paleocene-Eocene Thermal Maximum (PETM). The San Juan Basin (SJB) of New Mexico and Colorado is the southwestern-most Laramide basin known to contain a succession of sedimentary deposits spanning the (P-E) boundary. This study will investigate the late-Paleocene Nacimiento formation and the early-Eocene San Jose formation (Cuba Mesa - Regina members) in the San Juan Basin. The goals of this study are to (1) better constrain the location of the Paleocene-Eocene boundary within the San Juan Basin deposits, (2) document river morphodynamics across the late-Paleocene to early-Eocene, and (3) compare the data collected with published datasets from the Bighorn Basin, Piceance Creek Basin, and Uinta Basin. The methods applied will include the collection of detailed measured sections, channel measurements, photomosaics of outcrops, and samples for stable isotope analysis of bulk organic carbon. Based on the results of preliminary research, we hypothesize that the Cuba Mesa member of the San Jose formation records a shift in the seasonality of precipitation that is similar to what has been documented in the more northerly basins, and the change may coincide with the PETM.

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