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EDITORS

Yi-An Lin is a Geology Ph.D. candidate at the University of Houston. Her research involves Geodynamic modeling; comparing model predictions with seismic tomography and further testing plate models against regional geology. She works mainly in East Asia, the Aleutians, and the South China Sea. Yi-An received her bachelor degree in Geosciences from the National Taiwan University.

Committee Co-Chair - Lucien Nana Yobo obtained a B.S. in geology from Fresno State and an M.S. in geology from the University of Nebraska. He is currently a 4th year PhD candidate at the University of Houston. His research involves using multi-isotope proxy to understand the cause and expansion of anoxia during ocean anoxic event 2. When not studying, Lucien loves to read and engage in dialogue about governance and leadership in Africa.

Committee Co-Chair - Joshua Flores completed a BS in Geology from Brigham Young University in 2013 and then worked with EGI at the University of Utah as a research assistant before beginning his PhD in Geology at the University of Houston. His research focuses on plate triple junctions and their roles in boninite petrogenesis under the direction of John Casey

Faculty advisor for Student Research Day – Dr. Regina Capuano is an Associate Professor of Geosciences at the University of Houston. She completed her PhD in Geology at the University of Arizona.

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Oral Presentations

CLUSTERING SURFACE OZONE DIURNAL CYCLES TO UNDERSTAND THE IMPACT OF CIRCULATION PATTERNS IN HOUSTON, TX

Bernier, Claudia M., Yuxuan Wang, Mark Estes, Ruixue Lei, Sing-Chun Wang and Beixi Jiajia

The diurnal cycle of surface ozone can reflect much about the chemistry and meteorological processes which affect a region. This study examines diurnal patterns of surface ozone in the Houston-Galveston-Brazoria (HGB) region and links them to meteorological regimes. A clustering method was used to organize the diurnal ozone patterns for the days in June, July, and August (JJA) of three years (2011, 2014, 2015). The clustering is based on four features which represent times of the day when surface ozone is directly influenced by meteorological and chemical processes: decreasing slope during the early morning, daily minimum just before sunrise, increasing slope after the sun rises, and an average of consistently higher concentrations during the afternoon. The clustering results separated the three summers into four clusters, ranging from a less variable, mostly flat diurnal pattern of ozone with low mixing ratios (~ 20 ppbv) that barely deviate from the mean to a more variable, pronounced diurnal cycle with very high mixing ratios (> 70 ppbv) in the afternoon. The cluster-derived groups are characterized by distinctive circulation patterns and well-known regional meteorological processes that affect the HGB region such as the Low-Level Jet and Bermuda High. The clustering analysis linked to the meteorological regimes help elucidate ozone interannual variability for the three years. This work demonstrates the value of comprehending diurnal ozone cycle variability of a region for a better understanding of how and why surface ozone behaves as such due to meteorological processes on both daily and interannual timescales.

TECTONIC EVOLUTION OF THE AEGEAN DOMAIN, EASTERN MEDITERRANEAN, SINCE THE EARLY MESOZOIC BASED ON 3D SLAB MAPPING, UNFOLDING, AND CHARACTERIZATION FROM SEISMIC TOMOGRAPHY

Boyle, John P. and Jonny Wu

Tomographic studies have identified the Aegean, Egypt, and Emporios slab anomalies beneath the Aegean region, providing insights into the tectonic evolution of the western Tethyan domain since the Mesozoic. Geologically, this evolution is recorded by ophiolites and stacked nappes near Greece. One interpretation describes the Aegean slab anomaly as continuous to a depth of ~1300 km representing subduction consuming 2100-2500 km of lithosphere since ~110 Ma (van Hinsbergen et al., 2005). The Egypt and Emporios slabs are less understood. This study uses 3D mapping from global tomographic models (Amaru, 2007), slab unfolding, and characterization of intra-slab seismic velocities for comparison against published tectonic reconstructions, geology, and geodynamic models. From this, we test current interpretations of the Aegean slab and consider tomographically dependent tectonic reconstructions that are geologically viable. Slab mapping shows two trench-parallel discontinuities characterized by relatively slow P-wave velocities within the Aegean slab between 200-400 km and 650-800 km depths. Slab P-wave perturbations just above these low-velocity discontinuities are ~160% and ~150% faster respectively. Comparatively, we show a ~40% faster P-wave perturbation in oceanic lithosphere relative to continental across the Kephalonia Transform fault using a local tomography (Halpaap et al., 2018). Volume unfolding of the Aegean slab produces a slab volume of 1.66×10^8 km^3 which reasonably fits the tectonic model prediction between 118 Ma and 140 Ma. Unfolding of the Egypt slab gives a slab length of ~630 km, fitting subduction of West Vardar. Unfolding of the Emporios slab gives a ~2200 km long slab, fitting predictions for Paleo-Tethyan subduction. Our predicted slab discontinuities correspond to a local change in arc-volcanic geochemistry in northwest Greece and a regional 68-52 Ma magmatic gap. The tomographic identification of these features further implies that slab detachments, tears, and subduction discontinuities are resolvable in global tomography's. Unfolding of the Aegean slab implies an older subduction initiation age than recently proposed. The tectonically consistent unfolding results achieved for lower mantle slabs shows the effectiveness of slab unfolding for reconstructions back to the Triassic. The ~40% velocity difference between subducted oceanic and continental lithosphere provides insight for future studies imaging continental subduction.

INVESTIGATING GLACIAL DYNAMICS OF THE AMUNDSEN SEA, WEST ANTARCTICA: PALEORECORDS OF STABILITY AND INSTABILITY

Clark, Rachel W.

Due to rapid, ongoing retreat of the West Antarctic Ice Sheet, the large, marine-based ice sheet is now the primary contributor to sea-level rise. The Amundsen Sea sector, which includes Thwaites and Pine Island glaciers, has long been cast as the "weak underbelly" of the West Antarctic Ice Sheet, yet the recent history of Amundsen Sea glacial systems remains poorly understood. Recent satellite observations indicate that the floating ice shelf of Thwaites Glacier is thinning, and the grounding line is retreating rapidly, forewarning probable glacial collapse. Recent retreat is largely attributed to warm Circumpolar Deep Water impinging onto the shelf and melting marine-based ice from below. Predictive ice sheet and sea level models require an understanding of controls on glacier mass balance, including oceanography and bathymetry of the seabed upon which the ice rests; the primary way in which these factors can be understood is through past records of glacial change. The proposed research investigates how Thwaites Glacier behaved during the Holocene using marine sediment records. Twenty-four sediment cores were collected at several sites across the Amundsen Sea during the two-month-long research cruise NBP1902. Cores will be analyzed for grain size and shape analysis to reconstruct past glacial environmental change and the timing of recent retreat. Both sedimentological analyses and magnetic susceptibility scans will be used to delineate facies associated with four main depositional environments: open marine, sub-ice shelf, grounding zone, and subglacial environments. Depositional environments shift with the grounding line position, and the sediment core samples should reflect facies shifts. To understand the timing of glacier change, sediments accumulated over the past 150 years will be dated using short-lived isotope chronology, including Pb-210 activity measured with a gamma spectrometer. Multibeam bathymetry and sub-bottom profiles provide geomorphic and stratigraphic context for the depositional history observed from cores. Results from NBP1902 will be used to plan coring strategies for a second research cruise in the Amundsen Sea in January, 2020.

MECHANICAL PROPERTIES OF PROPPED AND UNPROPPED EAGLE FORD SHALE AND 3D PRINTED ROCK MODELS UNDER TRIAXIAL STRESS.

Dande, Suresh, Robert Stewart, Michael Myers, Lori Hathon and Nikolay Dyaur

In a hydraulically fractured reservoir, estimating propped reservoir volume is key to predict production. In this study, we use various samples including 3D-printed models with air-filled and proppant-filled fractures and Eagle Ford Shale with artificially created fractures with air and proppant. From the 3D-printed model in bench-top and uniaxial compression experiments, we found that P, S velocities, and Young's modulus of propped models are lower than the air-filled or unpropped models suggesting that propped models may be more compliant. We extend this experiment with Eagle Ford Shale and calculate normal-to-tangential fracture compliance ratio (ZN/ZT) of the intact rock, artificially fractured rock with air-filled fractures, and artificially fractured rock with proppant-filled fractures. We test the hypothesis that ZN/ZT value and the attenuation measurements can discriminate between propped and unpropped fractured rock.

A HYBRID AI HURRICANE FORECASTING SYSTEM: DEEP LEARNING ENSEMBLE APPROACH AND KALMAN FILTER

Eslami, Ebrahim, Yunsoo Choi, Ahmed K. Salman, Yannic Lops and Alqamah Sayeed

Dynamical models produce significant model-measurement errors in forecasting hurricanes. The challenge of dynamical models to predict a hurricane is the presence of both chaotic growth of errors in initial condition simulation and deficiencies in the model's physics. Hence, these issues entail a more comprehensive approach to improve hurricane prediction and reduce their hazards that pose a significant risk to society. This study proposes a novel, artificial intelligence-driven approach using deep learning models to predict hurricanes. Deep learning models are computationally efficient and are currently widely used for forecasting purposes. We developed a hybrid three-step (direction, distance traveled, and intensity) deep-learning based hurricane forecasting model using the output of dynamical hurricane models, remote sensing data, and observation network. This model was followed by a post-processing analysis by an ensemble Kalman filter. We used all tropical cyclones in the Atlantic Ocean before 2017 and test the model for cyclones in 2017. The preliminarily results of our model for 19 tropical storms in 2017 showed statistical advantages (~8% and ~30% improvement in track and intensity forecast biases respectively) over the National Hurricane Center official forecasts for 24-hours ahead forecasts.

QUANTITATIVE SEDIMENT PROVENANCE MIXING AND UNMIXING HIGHLIGHTS THE ABSENCE OF EASTERN CORDILLERAN DERIVED SEDIMENT IN THE PALEOGENE NORTHERN ALTIPLANO BASIN

Hensley, Jeffrey B., Joel Saylor, Tom Lapen, Payton McCain, Alexandra Peralta, Paola Usnayo, Gabriela Vargas-Curse and Jose Cardenas

Situated along the western margin of South America, the Andes constitute the longest (~7500 km N-S) modern orogenic system associated with ocean-continent subduction. Between 15°S and 27°S, the central Andes is marked by the Altiplano-Puna Plateau which is characterized by a broad, low relief, high topography (>3.5 km) region bound by the Eastern and Western cordilleras. Since the Mesoproterozoic, the Andes have experienced several phases of basin formation and subsequent sediment recycling. Sediment recycling mixed zircons with characteristic basement age groups, obscuring the ability to use their presence or absence to directly fingerprint sediment sources. However, differentiating between eastern and western sources impacts orogenic models for the northern Altiplano by defining the timing and locus of crustal shortening, exhumation, and topographic growth. This study uses quantitative similarity metrics of detrital U-Pb geochronology age distributions to discriminate eastern- versus western-derived sediments at multiple locations along and across strike during deposition of the Paleogene Muñani Formation and Puno Group. Previous U-Pb geochronology studies and sediment provenance modelling indicate dominant sourcing from the west. However, anomalously low Cross-correlation coefficients between reconstructed and measured basin samples in the late Oligocene–Miocene may suggest poorly characterized source distributions and/or the introduction of one or more undocumented sources. To address the aforementioned issue, we use a Monte Carlo model as well as non-negative matrix factorization of basin samples to characterize potential sources and define their contributions to Paleogene strata. The Monte Carlo model uses a top-down approach to fit well-characterized source age distributions to mixed basin samples. In contrast, non-negative matrix factorization approaches the problem from the bottom-up by low-rank factorization of source distributions from a large number of measured basin samples. Preliminary analysis on sediment sources indicate a distinct difference in sediment provenance from proximal to distal, specifically in the Altiplano back-thrust belt. In the back-thrust belt, basin samples are void of young volcanic grains suggesting the presence of a drainage divide between the Western Cordillera volcanic arc and distal basin. Finally, this study will highlight the ability to discriminate recycled sedimentary sources and establish a framework for future provenance studies in the central Andes.

PRECURSOR ANISOTROPY VARIATIONS BEFORE LARGE EARTHQUAKES IN CALIFORNIA

Hu, Hongru and Abing Li

Precursory phenomena such as dilatancy have been reported before rock rupture in laboratory 13 studies but are difficult to detect before earthquakes. We characterize temporal variations of 14 seismic anisotropy by analyzing shear wave splitting data before and after the 2014 M6 Napa 15 earthquake and 2012 M5.3 and M5.4 earthquakes in the Imperial Valley in California. The delay 16 time has the maximum value from the 2014 main shock at two nearby stations. It also increases 17 rapidly before the 2012 M5.3 and M5.4 earthquakes. Such anisotropy variations are only 18 observable at stations close to the mainshocks from well-clustered foreshocks, probably reflecting 19 dilatancy in the earthquake nucleation zone. The short-term increase of SWS delay time could be 20 a promising precursor for large earthquakes.

TESTING EARLY ONSET OF LARAMIDE DEFORMATION VIA ANALYSIS OF THE FRONTIER FORMATION, CENTRAL WYOMING

Jacobs, Makayla, Joel Saylor and Kurt Rudolph

The North American Cordillera foreland basin system has a complex geometry due to the spatial and temporal interaction of two deformational styles. Sevier orogenesis (Late Jurassic-early Eocene) was dominated by thin-skinned deformation in a well-organized fold-thrust belt resulting in a classic retroarc foreland basin system. However, the style of deformation dramatically changed during Laramide orogenesis (Late Cretaceous-early Eocene) to a thick-skinned deformational style characterized by basement-cored uplifts, bounded by reverse faults. The change in deformation style has been linked to flattening of the subducting Farallon slab, but controversy persists regarding the mechanism of deformation. This overlap in deformational styles during Late Cretaceous-early Eocene changed the distribution of depositional environments as well as the locus and rate of subsidence resulting in a change to the overall basin geometry.

This project will address the question of when Laramide-style deformation began in the greater Green River Basin. We will implement bedrock zircon (U-Th)/He thermochronology to understand the timing of uplift of the Granite Mountains, and detrital zircon U-Pb geochronology to document provenance changes in associated stratigraphy. We will delve into the depositional history of the Frontier Formation by analyzing maximum depositional ages using U-Pb zircon geochronology, as well as stratigraphic correlations using well-log and outcrop data. The accommodation, provenance, and sediment dispersal patterns of the Frontier Formation may also provide insight on the flexural effects of Laramide-style uplifts. Preliminary results obtained from literature, measured sections, and well-log data highlight southward thinning and a north-south proximal-distal depositional relationships south of the Granite Mountains. This is consistent with flexural accommodation due to sediment sourcing from the Granite Mountains during their exhumation. Furthermore, the orientation of thinning and the proximal-distal relationship parallels the Sevier thrust front, suggesting that exhumation of, and loading by the Sevier fold-thrust belt had minimal impact on deposition of the Frontier Formation in the Great Divide Basin. Maximum depositional ages of the Frontier Formation taken near the Granite Mountains range from 86.7-93 Ma are also consistent with the hypothesis that Laramide deformation in central Wyoming started as early as 100-90 Ma.

TECTONIC, STRUCTURAL, AND STRATIGRAPHIC CONTROLS ON HYDROCARBON PROSPECTIVITY IN THE MEXICAN RIDGES DEEP-WATER FOLD-BELT, WESTERN GULF OF MEXICO

Kenning, Jack and Paul Mann

The Mexican Ridges fold-belt (MRFB) is a 600-km-long, submarine, passive margin, fold-thrust belt that trends parallel in water depths of 500 to 3000 m along the eastern continental margin of Mexico. The MRFB is detaches on Paleogene shales deposited above a substrate of either thinned continental crust or late Jurassic oceanic crust that post-dated the separation of the Louann salt body of the northern Gulf of Mexico (GOM) and the Campeche salt body of the southern GOM. A 20,000 km grid of 2D depth-converted industry seismic data, tied to two wells, was used to map the underlying structure, shale-based detachments, and the regional structural geometry of the MRFB to assess its along-strike, hydrocarbon prospectivity. A fundamental control on the structural style of the MRFB is the presence, map-view shape, and thickness of mass transport deposits (MTDs) of Eocene and Oligocene age. Seismic characterization and mapping has identified these detachment shales as a 500-1500-m-thick wedge of stacked MTDs. Deposition of these regionally extensive MTD units is interpreted to be a result of Laramide orogenic activity that produced uplift and deformation along the adjacent Sierra Madre Oriental orogenic front. In areas of the northern MRFB where composite MTDs are up to 1500-m in thickness, the overlying fold-belt displays: 1) shorter wavelengths (2-7-km), 2) larger amplitudes (350-1,050-m), and 3) tighter inter-limb angles (50-105°). The presence of thicker, mechanically weaker, MTD shales relative to overburden thickness in the north is interpreted to have resulted in faster gravitational spreading and could partially explain observed differences in fold geometry and distribution. Our observations suggest that: 1) MRFB MTD shales are over-pressured, with overpressure distribution interpreted as a primary control on detachment, as has been suggested in the analogous Niger Delta, 2) over-pressured clay-rich MTDs thicker than 150-m likely form regional seals for hydrocarbons generated in the underlying Mesozoic section, 3) despite the presence of thicker detachment shales in the northern MRFB, there is still good hydrocarbon prospectivity in overlying fold-belt Miocene reservoirs where locally thrust faults are present that cut through the Paleogene shale MTDs, acting as potential migration pathways.

METASOMATISM AND WATER CONTENTS OF MANTLE LITHOSPHERE OF THE CENTRAL SLAVE CRATON (LAC DE GRAS)

Kilgore, McKensie L., Anne H Peslier and Alan D. Brandon

Whether water incorporated in nominally anhydrous minerals of the mantle plays a role in the strength and longevity of the thick cratonic lithosphere is a matter of debate. In particular, the percolation of water-bearing melts and fluids through the mantle lithosphere could potentially add water to it and weaken its olivines. The role of metasomatism on water concentration of cratonic mantle minerals can be tested in the mantle xenoliths from the Slave Craton (Canada) because they show extensive evidence for metasomatism that resulted in a layered cratonic mantle. Here, minerals from mantle xenoliths from the Diavik mine in the Lac de Gras kimberlite area located at the center of the Archean Slave craton were analyzed by FTIR for water concentrations and by Mössbauer for mantle redox estimations. Additionally, minerals from 7 of the xenoliths were analyzed by EMP for major element concentrations and by ICP-MS for trace element concentrations. These 18 peridotites, 2 pyroxenites, one websterite, and one wehrlite span an equilibration range from 3.8 to 8.0 GPa and include samples from the shallow (≤ 5 GPa) oxidized ultra-depleted layer, the deeper (~5 - 6 GPa) reduced less depleted layer, and a newly identified ultra-deep (≥ 6 GPa) layer below Lac de Gras. Olivine, orthopyroxene, clinopyroxene and garnet from peridotites contain 29 - 146, 109 – 224, 104 – 284, 2 – 104 ppm H_2O, respectively. Within each layer, correlations between the water contents of minerals and major and trace elements concentrations not related to melting demonstrate the control of metasomatism on the water contents of mantle minerals. The viscosity of mantle minerals from the deepest portion of the Slave lithosphere, calculated from their olivine water contents, is similar to that of the asthenosphere. However, the kimberlite pipes that entrain these mantle xenoliths might preferentially sample the most metasomatized portions of the lithosphere and, therefore, not accurately represent the average viscosity of the cratonic root.

IS THE PAMIR SALIENT AN INHERITED FEATURE FROM THE LATE PALEOZOIC?

Li, Yipeng and Alexander Robinson

Over the past 25 years, the northward convex Pamir salient has been interpreted to be a Cenozoic feature, which resulted from terranes of the Pamir originally lying along a linear trend and then experiencing ~300 km of northward translation during Cenozoic. However, three lines of evidence suggest that the Pamir salient has not experienced significant translation, and maybe an inherited feature from the Late Paleozoic southern margin of Asia: 1) Kinematic models of Cenozoic Pamir indentation predict either ~300 km arc-parallel extension or truncation of North Pamir terranes at the margins of the salient during the Cenozoic, both of which are inconsistent with the regional geology and structural evolution. 2) There is a pronounced shift in detrital zircon age signatures of the Darvaz-Oytag-Kunlun terrane from the NW to the NE Pamir which suggests the regions were not directly connected (i.e. part of a continuous linear belt), and were fed from distinct cratons. 3) An absence of Triassic arc/forearc flysch deposits and arc plutons in the NW Pamir suggests the possibility of a transform boundary segment along the Triassic Paleo-Tethys oceanic subduction zone. This requires a curvature along the Triassic southern Asian margin, and a possible embayment. Based on these observations, we suggest an embayment existed between Tarim and Karakum Cratons after their amalgamation to the southern margin of Asia in the Early Permian. During the Triassic, colliding Gondwanan Cimmerian terranes (Central-South Pamir) filled in the embayment, resulting in a northward deflection in the trace of the Paleotethyan suture zone and Gondwanan terranes. Subsequent Cenozoic northward indentation of the Pamir is interpreted to be only ~30-35 km, and no more than ~80-100 km.

TRACING INDUSTRIAL POLLUTION IN GALVESTON BAY, TEXAS: LEAD ISOTOPES AND HEAVY METAL CONCENTRATIONS

Lopez, Amanda M., Alan Brandon, Jessica Fitzsimmons and Frank Ramos

Galveston Bay, Texas is an anthropogenic estuary where industrial runoff, wastewater, and shipping vessel oil enter the bay via incoming freshwaters. These freshwaters can contain heavy metals, either dissolved in the waters or sorbed onto inflowing sediments, which can be toxic for pelagic and benthic communities in the bay. Because lead (Pb) isotopes do not undergo detectable fractionation in the natural environment, each Pb source possesses a unique isotopic composition by which it can be traced. Galveston Bay surface sediments have been analyzed for both Pb isotopes and heavy metal concentrations to identify heavy metal pollution hotspots, understand pollutant mobility, and constrain pollutant sources and fluxes. During sediment analysis all samples underwent a leaching procedure to distinguish leachable pollutant Pb from residual non-pollutant Pb. Preliminary Pb isotope data from leached Galveston Bay sediments show that leachates fall within the range of previously reported Pb isotopic values for North American coal, similar to pollutants expected from Houston area industries, while residues lie within the Pb isotopic range of marine sediments. These results indicate that pollutant Pb is present in Galveston Bay sediments and may pose a risk to biota within the bay.

RECONSTRUCTION OF MISSING REMOTE SENSING DATA USING AN ADVANCED DEEP LEARNING ALGORITHM

Lops, Yannic, Yunsoo Choi, Ahmed K. Salman, Ebrahim Eslami, Sojin Lee, and Jia Jung

Remote sensing data of Aerosol Optical Depth (AOD) faces the limitations of data occlusion due to cloud cover. While the data, provided by the Geostationary Ocean Color Imager (GOCI) satellite, is generally available over a long period of time, it cannot be directly used for extracting coherent patterns and mechanistic correlations. The only recourse is to spatially and temporally interpolate the data both to organize the recordings to a regular grid and to query the data for predictions at a particular location or time of interest. A widely used interpolation approach is kriging. However, kriging has a computational cost that scales to the cube of the number of data points, resulting in cubic time complexity for each point of interest. Here, we utilized a deep learning technique, called partial convolution, as a generalized model for the reconstruction of GOCI AOD images. The model receives full hourly AOD images (with 27 km spatial resolution), provided by Community Multi-scale Air Quality Model (CAMQ) without missing data as input to reconstruct the original image with an intended randomized missing area(s). The advantage of partial convolution over 2D deep convolutional neural network (CNN) is the use of extracted features from the earlier layers as residual information for later layers. The kriging and partial convolution methods are directly compared to evaluate the performance of both models. For training and testing process of the partial convolutional model, CMAQ AOD data from 2014-2016 were used. Results indicate that the partial convolutional model can predict missing data with a lower mean absolute error (MAE) than kriging (0.05 MAE for partial convolution and 0.06 MAE for kriging). Furthermore, the model has on average 2% higher Index of Agreement (IOA) and Pearson correlation coefficient (r) than Kriging. The partial convolution model had on average less than 1% lower Structural Similarity Index (SSIM) than Kriging. The partial convolution model was achieving more stable results with less variance of predictions than kriging in all statistical evaluation methods. Moreover, deep learning models make predictions considerably faster, requiring only one-time training for predicting an entire year - saving considerable processing time.

CHROMIUM ISOTOPE RESPONSE TO OAE 2 RECORDED IN THE EAGLE FORD FORMATION, WESTERN INTERIOR SEAWAY.

Nana Yobo, Lucien, Chris Holmden and Alan Brandon

Chromium is a redox sensitive element with mass dependent fractionations that reflect changes in its oxidation state. Cr(VI) is the dominant oxidation state of Cr in the oceans where it forms the soluble chromate oxyanion. In biologically active regions of the oceans, Cr(VI) is susceptible to reduction to Cr(III) species, which are less soluble and, thus, prone to scavenging and removal by sinking particles. Reduction favors enrichment of the light Cr isotopes in Cr(III). Therefore, in settings where the produced Cr(III) is removed, the residual pool of Cr(VI) is shifted to higher δ53Cr values. Opening up the possibility of using Cr isotopes as paleo-redox proxy. Expanding ocean anoxia in the geological past should correlate increased sedimentary δ53Cr values in marine sediment.

We explore this potential in order to understand the paleoredox condition of the ocean during the OAE2 from pelagic successions of marine carbonate rich rock and mudrocks of the Cretaceous Eagle Ford Formation. Using a leaching technique that minimizes detrital contributions, we present a new high-resolution data over this interval. Our results, thus far, show the same negative excursion in δ53Cr values during OAE2 reported in the earlier study of the Portland#1 Core, with one important difference, the excursion appears to start lower in the section, coincident with the shift to mantle-like 187Os/188Os ratios signaling the onset of massive submarine volcanism. This deviation of results from theoretical expectations possible indicates that the increased flux of hydrothermal Cr was large enough to mask the expected isotopic response of the ocean Cr cycle to increasing anoxia.

IMPLICATION OF PLANETARY BOUNDARY LAYER VARIATION AND METEOROLOGY ON AIR QUALITY IN MEXICO CITY DURING THE DRY SEASON

Osibanjo, Olabosipo O., Bernhard Rappenglueck, Armando Retama, and Monica Jaimes-Palomera

The diurnal evolution of the planetary boundary layer (PBL) is crucial to air quality as it impacts the exchange and distribution of pollutants close to the surface. The emissions of pollutants near the surface contribute to poor air quality during stable atmospheric conditions (calm winds and cool temperature) where the pollutants accumulate near the surface and can rise to unhealthy levels within the PBL. Meteorology (i.e., weather) impacts ozone (O3) concentrations especially during the presence of a high pressure system (associated with calm winds, warm, and clear sky conditions), which enhances the formation of O3 due to strong sunlight and limited atmospheric exchange processes. These conditions frequently occur in Mexico City, in particular during the dry warm season (March to May). These processes are enhanced due to the location of Mexico City in a high altitude basin, which often prevents proper ventilation and favors intense solar radiation for photochemical reactions. This study presents temporally highly resolved PBL heights derived from potential temperature and humidity profiles measured continuously by a MP-3000A microwave radiometer at a monitoring site in Mexico City in conjunction with air quality data for the month of March for the years 2015-2017. The instrument was deployed and maintained for several years by SEDEMA (Secretaría del Medio Ambiente), the Environment Ministry of Mexico City. The month of March is the most representative month for the dry season in Mexico City. In particular, our study focused on March 2016, which showed the most severe smog episode for almost a decade in Mexico City with peak hourly O3 concentrations reaching 200 ppb. The PBL heights were based on various approaches (The results show that peak pollutant concentrations correlate well with the meteorological observations (weak winds, stable PBL) as well as air mass circulation within the Mexico basin.

WHY WAS THERE NO MASS EXTINCTION DURING THE CENOMANIAN-TURONIAN OCEANIC ANOXIC EVENT 2?

Paez-Reyes, Manuel

Most significant ecological disruptions and attendant mass extinctions in Earth history have been associated with widespread anoxia. Recent geochemical data and modeling suggest an expansion of anoxia and euxinia (sulfidic water column) during the Cenomanian-Turonian Oceanic Anoxic Event 2 (OAE2, ~94 Ma). However, the rate of extiction of genera during this event has been estimated to be ~8 times less than at the end of the Permian, even though approximately the same area of seafloor was overlain by anoxic waters during both events. It has been suggested that under sustained euxinic conditions and high temperatures, extinction of marine organisms is more likely to happen. Mass balance modeling of U and Tl isotopes provide evidence for anoxic seafloor conditions ~15 times higher for OAE2 relative to the modern ocean. These two proxies highlight non-sulfidic anoxia and combining with additional proxies can help to delineating non-sulfidic anoxia and euxinia. Quantifying redox-sensitive trace-element (RSTE) concentrations in combination with geochemical modeling will quantify the various types of reducing seafloor area. Specifically, using Fe speciation to describe the local redox conditions enveloping the event which allows for interpretations of various elemental drawdown which is likely responding to the progressive global expansion of reducing to euxinic conditions. Sections of the La Luna Formation in Colombia deposited during OAE2 were compared to a database of RSTEs in other sections. Our results show that the RSTEs are enriched before and after OAE2 and are depleted during the event. This pattern is consistent with other sections around the world suggesting that a drawdown of the RSTE reservoir took place during OAE2 in response to widespread euxinia at the benthic boundary layer. The more-modest extinction rates during OAE2 may have been because the upper part of the water column was better oxygenated and that planktonic organisms could take advantage of this whereas benthic organisms in the Permian could not or due to low diversity prior to 94 Ma because of previous anoxic events.

LOOKING AT SEDIMENT TRANSPORT AND DEPOSITION IN THE SAN LUIS PASS FLOOD TIDAL DELTA

Ramon-Duenas, Carolina

The San Luis Pass tidal delta is an active depositional area on the microtidal Texas coast, located between Galveston and Follets islands. This delta is the main sink for sediments being eroded up-drift, with a sand influx of 10000 m3/yr. The Texas coast is in continuous change due to sea level variations, storms, coast subsidence, and overdevelopment of the coast, with shoreline retreat rates between 1-2 m/yr. Areas of sand accumulation and sequestration reduce the coast erosion vulnerability, and the human risk to rising sea level and storm surges. One hundred and fifty sediment samples have been collected and analyzed for grain size and lithology along the flood tidal delta. Water depth measurements were collected and datum to a mean sea level reference using available information from the NOAA tidal station. Grain size, water depth, distance from the inlet, and water currents are studied to understand flood tidal delta dynamics and control factors for sediment distribution that can be modeled and extrapolated to other modern and paleo- tidal environments. The Texas beach and shoreface are characterized by fine sand. These fine sands, transported by the longshore drift, are the sediment source for the flood tidal delta. In the San Luis Pass area, grain size values vary between clay and fine sand (0.98 to 250 μm), with a mean of fine sand (125-250 μm). Transects of sediment grain size variation (mean, mode, kurtosis, and skewness) along the flood tidal delta show a fining and better sorting trend in a landward direction, indicating that the main control for grain size is distance from the inlet (sediment source) and not water depth. The San Luis Pass flood tidal delta provides a unique setting for the characterization of modern microtidal sediments and provides insight into the understanding of control factors for sediment distribution in tidal environments. The resulting sediment distribution model along with sedimentary structures can be used as an interpretation model for paleo-tidal deposits and other modern deposits.

SEDIMENT SIGNATURE OF WEST ANTARCTIC ICE SHEET DYNAMICS IN THE AMUNDSEN SEA

Robinson, Delaney, Julia Wellner and Expedition 379 science party

IODP Expedition 379 successfully recovered sediment drill cores from two sites on the continental rise in the Amundsen Sea, Antarctica. The cores offer a direct record of glacial history in a drainage basin that currently has the largest negative mass balance of ice anywhere in Antarctica. Both drill sites are located on a large sediment drift deposit identified in seismic, and recovered continuous records of glacially transported sediments. Onboard preliminary scientific assessment of the cores and data collected during the expedition reveal repeated alternations between different facies interpreted to represent cycles of glacial and interglacial periods during the Late Miocene to Quaternary. Dispersed granules and pebble clasts interpreted as ice rafted debris, were identified throughout all time periods at both core sites. This suggests persistent ice rafting and glacial advances onto the Amundsen Sea shelf back to the Late Miocene or earlier. Post expedition research aims to constrain paleo-environments down-core in relation to ice sheet extent and glacial cycles in a distal marine setting. Samples from the cores collected from the Amundsen Sea continental rise of West Antarctica will be analyzed to determine sediment characteristics in relation to depositional processes. Detailed facies investigation will be conducted using grain shape analysis, combined with grain size and grain texture analysis, in addition to detailed thin section analysis of specific sediment structures identified from core sections. Sample analyses will focus on transitions between interglacial and glacial intervals from the Miocene to Middle Pliocene to help implement a standard facies model related to WAIS dynamics.

ASSIMILATION OF MANTLE BY BASALTIC MELT AT HESS DEEP

Sen, Atlanta, Jonathan E. Snow, Christopher J. MacLeod and Johan C. Lissenberg

The study of lower crust is important to understand the enigmatic mechanisms of melt transport and evolution that forms the oceanic crust at mid-ocean ridges. Hess Deep provides a unique window to the lower crustal section of the Earth at the East Pacific Rise. Mantle peridotites are thought to be residues of partial melting, but the mechanism of their evolution is still debated. Although melt-rock reaction is thought to play a significant role, but there is lack of direct evidence from reaction textures or intermediate compositions. The compositional heterogeneity in spinels, (ubiquitous phase in these rocks) helps to quantify the evolutionary processes that these rocks have undergone. The enrichment of TiO2(>1 wt%) in some of the melt-reacted mantle peridotites across different spreading centers is not well explained. We have studied textures and composition of spinels from a melt–reacted hybridized mantle peridotite from the Hess Deep that can help to quantify the process of mantle-melt interaction. Integration of our MELTS model results(mantle assimilation-fractional crystallization, AFC) with the composition from melt-reacted mantle peridotite samples, addresses the mechanism of TiO2 enrichment in spinels, when plagioclase appears in the AFC crystallization trend.

THE INTERPLAY OF TECTONIC ISOLATION AND TRANSCONTINENTAL DRAINAGE IN THE ANCESTRAL ROCKY MOUNTAINS

Smith, Tyson M., Kenny Lambert, Joel Saylor, Tom Lapen, Ryan Leary, Noah Karsky, Crystal Saddah and Lokin Caturi

Exhumation of Ancestral Rocky Mountain (ARM) basement-cored uplifts and attendant drainage reorganization in the late Paleozoic are recorded in adjacent ARM basins. Before ARM deformation, this province of the Laurentian western interior was occupied by a shallow sea and low relief topography. By the late Mississippian a transcontinental fluvial system sourced in the Appalachian Mountains connected the eastern and western margins of North America (modern day reference frame) via sediment transport. However, in the ARM corridor of CO, UT, AZ, and NM sediment sources change along with initiation of a series of flexurally-subsiding, tectonically isolated basins, and bounding uplifts. Immediately prior to ARM deformation, detrital zircon populations in the ARM corridor match those across western Laurentia and feature a multi-modal population consistent with a broad, transcontinental drainage network. With the onset of ARM deformation, detrital zircon populations within the proximal to medial reaches of tectonically-induced basins change to simple populations of only 1–3 age modes reflecting exclusive basement sourcing. Conversely, coeval areas of deposition across much of western Laurentia received variable proportions of local- and continental-sourced sediment. Following ARM deformation in the Triassic, transcontinental drainage was reestablished through the ARM corridor, introducing a multimodal population of detrital zircon ages that match arc and remnant Ouachita-Marathon Mountains sources along the southern margin of North America.
Inverse (non-negative matrix factorization) and forward (mixing model) detrital zircon source analyses present a set of tools that improve our characterization of potential source terranes for receiving basins. We utilize calculated source proportions produced by source analysis, facies distributions, paleogeographic reconstructions, paleocurrent data, and stratigraphic thickness maps to create a series of sediment sourcing maps that illustrate the degree of tectonically-induced basin isolation pre-, syn-, and post-ARM tectonics in North America's western interior.

RAPID FALLING OF A MOON TO ITS PARENT PLANET DUE TO TIDAL-SEISMIC RESONANCE

Tian, Yuan and Yingcai Zheng

Tidal force plays an important role in the evolution of the planet-moon system. The tidal force of a moon can excite seismic waves in the planet it is orbiting. A tidal-seismic resonance is expected when a tidal force frequency matches a free-oscillation frequency of the planet. Here we show that when the moon is close to the planet, the tidal-seismic resonance can cause large-amplitude seismic waves, which can change the shape of the planet and in turn exert a negative torque on the moon to cause it to fall rapidly toward the planet. We postulate that the tidal-seismic resonance may be an important mechanism which can accelerate planet accretion process. On the other hand, tidal-seismic resonance effect can also be used to interrogate planet interior by long term tracking of the orbital change of the moon.

PETROGENETIC MODELING OF PLAGIOGRANITES FROM THE BAY OF ISLANDS OPHIOLITE, NEWFOUNDLAND, CANADA

Yan, Weiyao, John Casey and Yongjun Gao

Early researchers suggested that plagiogranites were predominantly produced by fractional crystallization, but more recent publications have provided new evidences indicating that partial melting is the dominant mechanism (Koepke et al, 2004; Furnes and Dilek, 2017). They have challenged the previous prevailing ideas and, inevitably, invoked the necessity to reevaluate the existing petrogenetic models for worldwide ophiolitic plagiogranites. In this study, I combined geochemical analyses of plagiogranites from the Bay of Islands Ophiolite (BOIC), together with petrogenetic modeling of fractional crystallization by using alphaMELTS and Petrolog, and partial melting by pMELTS, to assess the roles these two models may play during plagiogranite formation. Liquid lines of descent (LLDs) given by fractional crystallization modeling were able to bracket a continuum of basaltic and plagiogranitic rocks, and particularly, after ~60% crystallization, it starts to produce similar trace element variation patterns as plagiogranites from BOIC. But modeling concentrations of zirconium, hafnium and heavy rare earth elements are overall higher than most of our samples, which is probably due to the lack of crystallizing accessory minerals such as zircon. Although the extended partial melting modeling results of different parents can bracket most samples in particular of SiO2, TiO2, Al2O3 and CaO, none of them can be regarded as best-fit LLD to represent the major variation trend. Besides, the modeled FeO* and TiO2 values are significantly lower than those in samples, although their variation trends are similar. Therefore, we still favor that the fractional crystallization is the dominant petrogenetic mechanism of plagiogranites, particularly of those high-silica trondhjemites in BOIC.

BEACH AND DUNE MORPHOLOGY CHANGES INDUCED BY HURRICANE HARVEY FROM REPEAT LIDAR SURVEYS IN THE FREEPORT, TX

Zhou, Xin, Guoquan Wang, Lin Xiong Kuan Wang and Emily England

Catastrophic events, such as Hurricane Harvey in 2017, dramatically change the morphology of the beach and dune in its influenced scopes. Compared to the traditional field surveys and recent rapid developing Airborne LiDAR measure strategy, modern mapping technique like Terrestrial Laser Scanning (TLS) integrated with GPS measures the landscapes with high efficiency as well as prominent spatial and temporal resolutions. To map the changes induced by events like flooding or hurricane under extreme weather, regular seasonal growth and decline, and the recovery process after the destructive force of winds, tides and surges, we collected point clouds dataset by LiDAR (RIEGL VZ200) and GPS (Trimble R10) devices at the same beach and dune region in the Freeport, TX. For each set of point clouds, a Digital Elevation Model (DEM) was built accordingly. Lines of dune ridge, 0.6-m contour (which is the empirical value of Texas shoreline) were extracted from the bare earth DEM. Volume changes were calculated and multiple profiles were cut to evaluate the dynamic erosion patterns along the 7-km Bryan Beach in the Freeport, TX. The maximum shoreline retreat amount is 70 m, which the average value is 24 m; the dune-ridge height changes and seasonal DEM changes display the process of beach recovery in a short term (several months) and long term (4 years, across the full observation period) as well.

UNDERSTANDING TWO-PHASE GULF OF MEXICO OPENING THROUGH DEPOSITIONAL HISTORY, SUBSIDENCE ANALYSIS, AND STRUCTURAL RECONSTRUCTIONS IN THE SOUTHEAST GULF OF MEXICO

Zinecker, Marcus

Most workers now agree that the opening of the Gulf of Mexico (GOM) basin began in a southeastward direction during the Triassic and early Jurassic and is recorded by a broad zone of NE-trending rifts. These Phase 1 rifts are deeply buried and rarely drilled or well imaged along most GOM margins. Phase 1 rifting generated a large post-rift sag basin, subsequently filled by a thick salt layer. A second phase of more north-south directed rifting began in the Late Jurassic as the Yucatan block rotated counterclockwise and formed Phase 2 rifts along with an arcuate area of oceanic crust that separated the salt into two parts: the Louann salt of the northern GOM and the Campeche salt in Mexico. In this study, I focused on testing the two stage and two direction rifting process in the southeast GOM because: 1) two sets of orthogonal rifts are known and are consistent with both southeastward rifting and eastward rifting; and 2) rift structure and stratigraphy can be mapped in detail because the rifts are not deeply buried by thick salt or clastic sedimentary rocks like rifts in the northern GOM. Five tectonostratigraphic sequences were mapped from seismic data and wells and include: 1) early Paleozoic metamorphic basement with Jurassic igneous intrusions, 2) pre-rift dolomite of either Late Paleozoic or Early Jurassic age, 3) syn-rift Late Jurassic arkosic sandstone, conglomerate, and shallow water carbonates, 4) early Cretaceous shallow platform to deep water carbonates, and 5) Late Cretaceous to Cenozoic pelagic carbonate, ooze, chalk, and mud. Four seismic lines were backstripped and structurally restored, and the results show that stretching factors range from 1.07 to 1.24 and are consistent with failed rifts in continental crust worldwide. Analysis of subsidence history shows four main phases of subsidence including: 1) Late Jurassic to Early Cretaceous rapid subsidence associated with Phase 2 rifting; 2) Early to Late Cretaceous thermal subsidence; 3) Latest Cretaceous to Eocene rapid flexural subsidence attributed to the development of the Cuban foreland basin; and 4) Eocene to present day slow subsidence caused by sediment and water loading.

Poster Session

UNDERGRADUATE STUDENTS

ASSESSMENT OF INDUSTRIAL SOURCES FOR HEAVY METALS IN GALVESTON BAY ONSHORE SEDIMENTS USING LEAD ISOTOPES

Arkie, Perry M., Amanda Lopez and Alan Brandon

Galveston Bay is surrounded by industrial areas that potentially produce heavy metals during processing of materials. These heavy metals can then be deposited into the bay via air blown dust and direct input from effluent out of the factories and processing plants. In addition, the Houston ship channel is a heavily used corridor for industrial ships that can also discharge heavy metals into the bay.
This project will assess the impact of and identify these potential sources of industrial pollution on heavy metal biogeochemical cycles in Galveston Bay through analysis of surface sediments for Pb isotopic ratios and heavy metal (As, Cd, Cu, Pb, Hg, Ag, Ni, and Zn) concentrations. Lead isotopes can provide direct fingerprints of the different types of sources of heavy metals in the bay. Heavy metal concentrations have been analyzed by a Thermo Element XR high resolution ICP-MS in collaboration with Dr. Jessica Fitzsimmons at Texas A&M University. Isotopic analysis of 204Pb 206Pb 207Pb and 208Pb was performed using a Neptune Plus high-resolution multi-collector ICP-MS in the New Mexico State University Analytical Geochemistry Research Laboratory in collaboration with Dr. Frank Ramos. Heavy metals are particle reactive and tend to be deposited on the surfaces of sediment grains in marine settings. These can be differentiated from the sources of Pb that are present in the crystal structure of the sediments themselves. Preliminary data comparing onshore samples with samples collected offshore shows variability in the potential sources of contamination. Further investigation will attempt to correlate freshwater inflows with the observed Pb isotopic compositions. Such information will shed light on anthropogenic Pb inputs to the bay.

PALEOGEOGRAPHIC CONTROLS ON THE THICKNESS AND ORGANIC CONTENT OF CRETACEOUS OAE2 BLACK SHALE HORIZONS DOCUMENTED IN WELLS FROM THE GUYANA-SURINAME BASIN AND DEMERARA RISE

Bjelica, Nikola and Paul Mann

Oceanic anoxic events (OAEs) are periods in Earth's history when oceans were depleted in dissolved oxygen. OAE periods during the Cretaceous are characterized by deposition of organic-rich, finely laminated, black, fine-grained sediments and an abrupt increase in the δ13C ratio. The Cenomanian-Turonian OAE2 coincided with a maximum sea level highstand that was probably a response to a global volcano-tectonic event. OAE2 drove organic carbon deposition in distributed basins within Atlantic Ocean under different ocean circulation regimes. Warm climates increased terrestrial weathering and input of fluvial nutrient fluxes, and decreased the levels of oxygen in the atmosphere and oceans. I have compiled the extent and thickness of OAE2 black shales from the Guyana-Suriname basin and Demerara Rise using published well data. OAE2 black shale horizons vary in thickness from 45 m to 200 m with documented TOC values in range from 1% to 36%. The main sources of organic matter in black shales formed during OAE2 are cyanobacteria and lipid compounds including fatty acids (derived from most organisms including bacteria) and sterols (that are never produced by cyanobacteria). Variations in source types explain the observed geochemical differences in TOC values compiled from the Gulf of Mexico, Caribbean and Atlantic passive margins.

NEW U-Pb GEOCHRONOLOGY ON ANDESITE PORPHYRY DIKES, RED LODGE MONTANA; A RECORD OF CRETACEOUS FLAT SLAB SUBDUCTION

French, Logan, Virginia Sisson, Thomas Lapen and Barry Shaulis

This research project focuses on U-Pb geochronology of zircon in andesite porphyry dikes sampled near the Yellowstone Bighorn Research Association (YBRA) field station in Red Lodge, Montana. Much of the geology in and around YBRA has been heavily studied. One exception, however, is research on these dikes is fragmented and from over fifty years ago. It is usually assumed that they were injected in the Paleocene and are younger than the Beartooth Conglomerate created by the Laramide Orogeny. Alternatively, Rouse et al. (1937) posit that they are more likely older than the Beartooth thrust fault and therefore the Beartooth Conglomerate. Recently Barry Shaulis completed a initial U-Pb analysis on one of these dikes which produced a preliminary age of about 93.55 million years old using laser ablation, which reinforces the hypothesis of Rouse et al. (Shaulis, personal communication to Sisson, 2018). There are no other igneous rocks with a similar age in the vicinity. Because of these contradictory theories and lack of study, we found it necessary to further analyze these dikes and continue Shaulis' work. Thin sections were made and observed in reflected light to locate zircon grains both in the andesite porphyry and included basement rock. Over 70 zircon grains were identified across these thin sections. More information will be gathered using the scanning electron microscope (SEM) and LA-ICP-MS lab. We will perform the U-Pb analysis in situ from these thin sections. Over the summer, more samples will be collected and studied to ensure correlation and the results of the preliminary geochronologic data. Our tentative conclusion is that these the dikes are related to the waning stages of Sevier orogeny and possibly related to a pulse of high magmatic flux in the Cascades island arc.

SYSTEMATIC ANALYSIS OF THE SEISMIC WAVEFORMS OF DEEP-FOCUS EARTHQUAKES IN TONGA FOR SLAB ANISOTROPY

Given, Paige, Hao Hu, Jiaxuan Li and Yingcai Zheng

Why deep earthquakes, those with a depth from about 60 to 700 kilometers, occur in subducting slabs is still not well understood due to the notion that rocks are expected to be ductile under high-temperature and high-pressure conditions. However, about 25% of global earthquakes are deep earthquakes in subducting slabs. An interesting and well-established observation about deep earthquakes is that they tend to produce non-double-couple (non-DC) radiation patterns. Recent work (Li et al., 2018) showed that non-DC radiation could be caused by strong anisotropy around the earthquake. If this is the case, we should expect the same anisotropy to cause systematic waveform variations with respect to the azimuth and distance of the recording station. Among all subducting slabs, the Tonga slab hosts the greatest number of deep-earthquakes. For this research, we will be focusing on the analysis of seismic waveforms for a group of deep-focus Tonga earthquakes which have unusually large non-DC components. This region is parameterized by a latitude range of 17°S to 25°S, longitude range of 175°E to 185°E, and a depth range of 500 kilometers to 700 kilometers. Seismic waveform data for this research was recorded by global seismometers and collected from the Incorporated Research Institutions for Seismology (IRIS). This raw data was then deconvolved to remove instrument response and set to have consistent reference time parameters for each event. The waveform data was then loaded in the Seismic Analysis Code (SAC) format into the Crazyseismic software where amplitudes of distinct seismic arrivals (P, pP, S, sS) for 51 seismic events were picked and aligned. These picked amplitudes along with their polarities were then compared against synthetic waveforms calculated by spectral element method (SEM), to identify a best-fit source mechanism using a least squares method. Finally, this work will provide important constraints to understand deep earthquake mechanisms and slab anisotropy. The inferred anisotropic slab structures are important boundary conditions for geodynamic modeling of mantle convection and pathways for volatiles such as carbon to be transported into the deep mantle.

IMAGE CLASSIFICATION OF VEGETATION FROM LIDAR DATA USING A NEURAL NETWORK APPROACH

Lee, Jeffrey, Bhavya, Merchant and Chanshik Moon

LiDAR scans of Enchanted Rock, Texas taken from the Summer 2018 Geophysics Field Camp were used to decipher whether vegetation existed on a surface. Pre-processing the data took 5 major steps. Firstly, 2D cross sections were taken from 3D point cloud using Cloud Compare, which were then converted into PNG images. Next, each 480x480 cross section image was split up into 100 48x48 subsections. Then each subsection was manually classified – 1 for vegetation and 0 for no vegetation. Finally, MNIST like data frames were created with the subsections. One set of images had the dimensions 28x28 per image and the other set had 48x48 per image. With these data frames, two neural network models – an Artificial Neural Network (ANN) and a Convolutional Neural Network (CNN) – were created, trained, and tested. The CNN model had an accuracy of 80.3% for the set with 28x28 images and 82.08% for the 48x48 images. The ANN model had an accuracy of 77.46% for the set with 28x28 images and 73.4% for the set with 48x48 images.

PETROGRAPHICAL AND GEOCHEMICAL INVESTIGATION OF BASALTIC EUCRITES: FOCUS ON POTASSIUM FELDSPAR-BEARING EUCRITES

McQuaig, Devin, Justin Simon, David Mittlefehldt and Rosalind Armytage

Basaltic eucrites are mafic meteorites that likely originate from the differentiated asteroid, 4 Vesta. Radiogenic chronometers point to magmatic differentiation on the parent body occurring within 96 and all contain Ba as a minor component. One one side of a boundary in GRO 95533, the K-spar has a BaO content of 0.34 wt%. On the other side of the boundary, the BaO content is 0.66 wt%. The BaO content of HOW 88401 is 1.45 wt%. The SG eucrite, PCA 91179, has the most abundant K-spar grains with an average BaO content of 1.49 wt%. Texturally, K-spars are located in areas of mesostasis or intergrown with plagioclase. Although petrogenesis of the parent body is ambiguous, the petrology and geochemistry of MG and SG eucrites will provide additional insights to the crustal evolution of early-formed planetary bodies.

DETAILED MAPPING OF CENTRAL ATLANTIC FRACTURE ZONES AND CONTINENT-OCEAN BOUNDARIES USING SATELLITE-DERIVED MARINE GRAVITY DATA

Moore, Bryan and Paul Mann

Gravity data released in 2014 provides a global marine gravity model that has twice the resolution of previous models. This higher resolution data is a useful tool for revealing the regional extent of large-scale features such as oceanic fracture zones. The linear basement shear zones that are confidently identifiable and laterally continuous can help define the continent-ocean boundary within oceanic basins like the Central Atlantic. The extent of 25 fracture zones, extending as continuous lineaments over 2,000 km, were traced across the Central Atlantic between its two conjugate rifted margins in northwest Africa and along the east coast of the US. The ends of the fracture zones in areas of less marine sedimentation were used to map the continent-oceanic boundary on both conjugate margins. In areas of thicker marine sediment deposition, where the fracture zones are deeply buried and not visible on the gravity image, determination of the continent-ocean boundary is more challenging. For these areas, previous literature was used to better constrain the COB location. In order to understand why fracture zones formed in those locations, geologic maps of both conjugate margins were compiled to show preexisting basement structure that might have controlled the positions of the fracture zones.

LINKING NAZCA SUBDUCTION RATES AND MAGMATISM ALONG THE ANDES SINCE THE CRETACEOUS

Moore, Mason, Aminat Animashawun, Jonny Wu and Yi-Wei Chen

The Nazca plate has been subducting under the South American plate since Cretaceous times and has been linked to the formation of the Andes Mountains. Using a newly published Nazca-South America plate reconstruction model (Chen et al., 2019), we analyze the movements of the Nazca plate over the past 80 million years and calculate subduction rates and azimuths as it subducts under the South American plate. Magmatic data has been collected in South America at different latitudes and the age of the samples has been determined from previous studies. Using our plate model analysis, we compare the rate of Nazca plate subduction at different latitudes and time with the magmatic samples to see if there is a first-order correlation between subduction and magmatic events.

A SEARCH FOR CONTROLS ON THE DISTRIBUTION OF NATURAL, SUBMARINE OIL SEEPS IN THE MINIBASIN PROVINCES

Pascali, Amanda and Paul Mann

In this research, published literature is used to compile information on 94 submarine oil seeps in the Gulf of Mexico to better understand the factors that control their locations. The majority of Gulf of Mexico submarine, oil seeps are located in the US or Mexico salt provinces which were separated in late Jurassic time by the formation of an arcuate band of oceanic crust that underlies the deep Gulf of Mexico basin. Based on surveys of existing data, nearly no seeps have been identified from the shelves of either the Mexican or US Gulf of Mexico. Of the 57 natural oil seeps in the US Gulf of Mexico, 39 are found along the edges of minibasins, or sub-circular, sedimentary basins bounded on all sides by emergent, salt diapirs. Strata at the edges of mini- basins are usually steeply dipping and faulted along a rotated, normal fault that forms the upper edge of the rising diapir. The steep dip of the bedding and presence of faults provides conduits for the upward rise of oil and the predominance of natural seeps in this setting. Ten seeps were identified in the flat-bottomed centers of the minibasins that are commonly underlain by strata with low dips and fewer conduits for oil to reach the surface. Eight seeps are observed in the deep Gulf of Mexico basin in areas overlying late Jurassic oceanic crust and not overlying a significant salt body. The Mexican salt body however, lacks the high level resolution bathymetric data we have for the US Gulf of Mexico, and for this reason we are not confident that minibasins play the same prominent role in the control of seeps as observed in the US Gulf of Mexico. Of the 37 seeps from the Mexican Gulf of Mexico, nine are on the shelf, ten are on the slope, and 18 are in the deep basin. Research is currently being done on the potential for hydrocarbon exploration in other minibasin provinces such as offshore Angola, which is a passive margin similar to the Gulf of Mexico, with an abundance of natural oil seeps.

DETECTING CHANGE IN ICE PRESENCE WITH CORRELATIONS TO CLIMATIC VARIATIONS IN SVALBARD, NORWAY

Purcell, Connor, Mason Moore, Ozzy Tirmizi and Mario Ballinas

Longyearbyen, the northernmost permanent settlement in the world, sits at the 78 degrees north latitude in the high arctic landscape of Svalbard. The archipelago's proximity to the North Pole places it at the front lines in the battle against climate change and the effects of global warming can be studied in real-time. This unique feature of Svalbard makes it the ideal location to study these effects and gather data at a local scale that is applicable globally. For the past few decades, many research expeditions have been made to Svalbard and remote sensing equipment has been deployed in key field sites to build a continuous data profile of the region. Using the data from these stations, which includes temperature, pressure, precipitation, snow level, glacial ice ablation, water levels, and more, we intend to determine if there are distinct and direct correlations between regional temperatures (air and water) and loss of glacial ice over time.

SIMILARITIES IN ASYMMETRICAL, OCEANIC SPREADING: ICELAND, SOUTH ATLANTIC, NE GULF OF MEXICO, AND MARIANAS BACKARC BASIN

Russell, Trevor and Paul Mann

In the paradigm of plate tectonics, seafloor spreading is viewed as a perfectly symmetrical process - whereby equal areas of new oceanic crust are created on either side of a single, spreading ridge. Asymmetrical seafloor spreading - recorded by unequal areas of oceanic crust present in the North Atlantic, Gulf of Mexico, South Atlantic, Indian Ocean and backarc basins in the western Pacific Ocean has been previously explained by three models: 1) the presence of multiple spreading ridges - formed by "ridge jumps" - would produce wider zones of oceanic crust on the side of the main spreading ridge with the additional ridge or ridges; these earlier extinct ridges can be detected from bathymetry and from maps of magnetic anomalies formed at the spreading ridges; 2) the presence of hotspots are frequently associated with areas of asymmetrical spreading; the wider zone of oceanic crust in this case is found on the side of the spreading ridge opposite from the location of the nearby hotspot; and 3) for backarc basins, like the Marianas basin, one idea is that trenchward slab rollback provides a mechanism to explain asymmetry in a subduction setting. I use Gplates software to create reconstructions of the most asymmetrical areas of seafloor spreading in both continental breakup and subduction settings in order to better understand the role of nearby hotspots on the spreading ridge.

FLUID INCLUSIONS IN CARBONATES FROM THE GRAND CANYON: MORE EVIDENCE FOR THE OLD-CANYON MODEL

Taylor, Laura, Peter Copeland and Virginia Sisson

One the greatest geological wonder of the world -- the Grand Canyon -- is at the source of great debate in the geoscience community. What is the age of the Grand Canyon? Two prominent theories hold out, one claiming the Grand Canyon was formed 6-5 Ma and the other a much older, 70-50 Ma canyon. This study focuses on the fluids trapped within the Mauv Formation (Cambrian), the Redwall Limestone (Mississippian), the Supai Group (Penn.–Perm.) and the Kaibab Limestone (Permian) from the Grand Canyon. Homogenization temperatures (Th) of secondary fluid inclusions in these rocks range from 110 to 48 °C. These temperatures do not correlate with modern elevation. Previous thermochronlogy from apatites (both U/He and fission track) can be used to estimate the thermal history of our samples; comparison of these T-t curves and our Th values suggest that most of these rocks had fluids trapped within them during the interval 80 to 55 Ma. We interpret the consistency of the apparent timing of fluid trapping to reflect mild deformation of these rocks at this time, consistent with initial uplift associated with the early stages of formation of the Grand Canyon. In other words, these fluid-inclusion data from the Grand Canyon favor the old-canyon model.

M.S. and Early Ph.D. Students

GROUND BASED HYPERSPECTRAL REMOTE SENSING AND GEOCHEMICAL ANALYSIS OF THE WOODFORD SHALE, ARKOMA BASIN, OKLAHOMA

Adigwe, Ekenemolise

Hyperspectral imagery has the ability to determine proportions of minerals in shales, thereby extracting detailed mineralogy of shale rocks (outcrops and drill core) at the millimeter scale. This enables investigators to characterize the composition of seemingly homogenous rocks and complements analysis such as x-ray diffraction analysis and total organic carbon (TOC) analysis, thus providing guidance for detailed sampling.

In this study, this approach was tested on the Woodford Shale of the Arkoma Basin. An outcrop, in the McAlister Shale Pit located in Ardmore Oklahoma as well as drill core samples of Woodford shales the Pittsburg and Hughes counties in Oklahoma were imaged. The hyperspectral data from both outcrops and drill cores were calibrated with measured x-ray diffraction analysis and total organic carbon (TOC). The results show that hyperspectral imagery confirms previously reported mineralogical composition of the Woodford Shale; mostly comprising of clay minerals including illite, some montmorillonite and kaolinite. Dolomite and calcite are present as well as jarosite (an alteration product of pyrite). Kerogen was detected in imagery in areas that coincided with high total organic carbon (TOC) concentration. These results were further calibrated with trace metal concentrations to verify that the Woodford was deposited in a low oxygen reducing environment. Hence, hyperspectral imagery has the ability to highlight shale fabric and to convey mineralogical and geochemical characteristics of hydrocarbon bearing shales. This can further be expanded to determine reservoir properties and thus improve well performance.

INVESTIGATING MODERN SEDIMENT DEPOSITIONAL CHANGES IN GALVESTON BAY, USING CHIRP

Alam, Malik and William Sager

Hurricane Harvey made landfall in Southeast coast of Texas on August 24, 2017, dumping 34 trillion gallons of rainwater. Because of this, the water outflows were strong enough to leave sand deposits along the bayous in Houston. CHIRP and Sidescan sonar data were collected from the total of 4 repeat surveys in Galveston bay's Bolivar Roads. These are the two natural inlets, formed as the sandspit in Holocene (2000 years). The repeat surveys, one of which was conducted couple of weeks prior to the Hurricane documented changes to the inlets and estuary resulting from the rainfall event related to the hurricane. The CHIRP sonar (2-16 kHz) collected data from over 50km of track lines at the Bolivar roads. This data is processed to understand the depositional changes in the estuary and is part of the sedimentation model for the planned coastal barrier to protect Galveston, to be built across Bolivar roads.

EFFECTS OF CONTEMPORANEOUS OROGENESIS ON SEDIMENTATION IN THE LATE CRETACEOUS WESTERN INTERIOR BASIN, NORTHERN UTAH AND SOUTHWESTERN WYOMING

Davis, M. Elizabeth, Joel Saylor and Kurt Rudolph

During the Late Cretaceous, northern Utah and southwestern Wyoming were subject to the effects of tectonic activity from both the Sevier and Laramide orogenies. Deformation from the Sevier Orogeny began in the Jurassic, and resulted in eastward displacement of westward-dipping thrust sheets. Crustal shortening and thickening caused flexural loading and the creation of a foreland basin. Late Cretaceous Laramide tectonism resulted in tectonic partitioning of the Sevier foreland basin by exhumation of basement-cored uplifts. Differential rates of subsidence and uplift throughout the Western Interior Basin are thought to have affected depositional environments and sediment routing patterns. It remains unclear, however, to what extent exhumation and changes in basin geometry played a role in changing sedimentation patterns, and the roles of the Sevier and Laramide orogenies. Furthermore, little work has been done to establish the relationship between the wedgetop conglomerates in the proximal basin and the marginal marine formations in the distal foreland. This work aims to illuminate how tectonics affected provenance, basin geometry, and stratigraphic architecture from proximal to distal locations within the Western Interior Basin from the Coniacian to Maastrichtian (89-66 Ma). Detrital zircon analyses will be used to provide maximum depositional ages for Upper Cretaceous stratigraphy and insights on sediment provenance. Well log correlations integrated with measured sections, detrital zircon ages, and paleocurrent measurements will illuminate spatial and temporal changes in depositional environment and basin geometry. Preliminary and published detrital zircon data indicate varying sediment sources from the proximal to distal parts of the basin. Mixture modeling of samples collected from the western (Coalville, UT) and central (Kemmerer, WY) locations indicate dominant sourcing from Mesozoic Eolianite and U.S. Passive Margin strata exposed in the thrust belt. Samples from the northern distal basin (Rock Springs, WY) are consistent with mixing of a Mesozoic Eolianite source with a Southern Highlands source. Detrital zircon maximum depositional ages, integrated with biostratigraphy, also suggest that the Hams Fork Conglomerate may be younger than the Ericson Formation. This indicates that the hiatus at the Moxa Unconformity continues for several million years younger in the fold belt, with Ericson equivalents onlapping towards the west.

ATMOSPHERIC MERCURY EMISSIONS COLLECTED IN HOUSTON DURING THE ITC CHEMICAL FIRE EVENT

Griggs, Travis and Robert Talbot

Characterizing the sources of atmospheric mercury (Hg) emissions, especially in an industrialized urban and suburban environment, is challenging. This is particularly the case in the Greater Houston area because of its complex meteorology and substantial industry, which includes a sizable petrochemical refining presence. On March 17-20, 2019, there was a fire in the ITC storage facility in Deer Park, TX (southeast of Houston), which contains chemicals used to produce gasoline. Gaseous elemental Hg concentrations were collected at the University of Houston, which is located approximately 15 miles downwind of the plume. There was a detectable increase in gaseous elemental Hg concentrations. Furthermore, the collected Hg emissions correlated with an increase in carbon monoxide, which is an effective short-term combustion tracer. Quantifying the amount of Hg released in an industrial fire event has direct public health implications, as well as possible environmental impacts and public policy considerations.

PRESSURE SURGE EFFECT IN FLUID-FILLED FRACTURE

Jin, Yuesu, Nikolay Dyaur and Yingcai Zheng

Large fluid pressure is required to explain abruptly state changes in hydrogeological system triggered by the passage of dynamic seismic waves. Our previous numerical modeling predicts that this can be possible for a weak-amplitude seismic wave interacting with a fluid-filled fracture, which can magnify the fluid pressure in the fracture by 2 orders compare to incident wave pressure. This phenomenon is called pressure surge effect. Our goal is to verify pressure surge effect in laboratory using ultrasonic experiment.

INTEGRATING MULTI-PHYSICS GEOSCIENTIFIC DATA INTO A COMMON EARTH MODEL THROUGH CROSS-GRADIENT JOINT INVERSION

Kim, Jae Deok and Jiajia Sun

Common Earth model refers to a model of the Earth consistent with all available geoscientific data, and thus, requires the integration of all available geoscientific information in a meaningful way. Joint inversions represent a quantitative method to integrate seemingly disparate datasets. A key issue is to develop a valid coupling strategy that governs the relationship between different physical property models. We assume here that changes in physical parameter values reflect the spatial variations in the underlying geological structure, and thus, different physical property models are expected to have similar structure. One commonly adopted method based on this assumption is that of the cross-gradient constraint. In the cross-gradient method, structural similarity is enforced by keeping the cross-product of the spatial gradients of two models close to zero. We implement cross-gradient joint inversion based upon an open-source geophysical inversion framework, SimPEG. The preliminary results from our work show that cross-gradient joint inversion can improve the structural similarity between different physical property models, and consequently, facilitates the subsequent geological interpretation. We will also apply the joint inversion method to a set of airborne geophysical data from the QUEST project with the goal of building a common Earth model that explains both gravity and magnetic measurements. The stated goal of the QUEST project is to map out mineralized zones and stimulate mineral exploration in an underexplored region of British Columbia.

PETROGENESIS OF GABBRO FROM ULTRASLOW-SPREADING GAKKEL RIDGE

Lee, Yuan Ping, Jonathan Snow and Yongjun Gao

Petrologic evolution under mid-ocean ridges (MORs) has long been a major means to study the complex structure of the oceanic crust. Gakkel Ridge, the Arctic mid-ocean ridge, is especially interesting with its unique “ultraslow” spreading rate. Geochemical studies of Gakkel Ridge basalts and peridotites have shown the primitive magma to be created by a low degree of partial melting and a heterogeneous parental mantle. However, the extremely thin seismic “Layer 3”, correlated generally with gabbro and its properties are not yet known. We studied the geochemistry of gabbros recovered from the AMORE program (Arctic Mid-Ocean Ridge Expidetion, 2001), using Electron Probe Microanalyzer (EPMA) from Rice University and LA-ICP-MS from University of Houston. The results of the CPX Mg# versus anorthite content (An%) of the studied gabbros show the lowest trend in An% compared to global gabbros. MELTS models of isobaric fractional crystallization of average Gakkel primitive basalt indicates that the SLD (solid line of descent) (Mg# CPX vs An% Pl) matches with our results quite well. This implies that the primitive melts creating the upper and the lower oceanic crust in the Gakkel Ridge are quite similar. Such models indicate that both are generated with about 7.5% of partial melting, assuming average DMM composition (Workman & Hart, 2005). Solid line of descent models derived from gabbros can thus be used to predict (or infer) the thickness of the oceanic crust. The crustal thickness calculated by the Gakkel gabbros is about 2 – 4 km in accordance with predictions made with the basalt and the seismic data. Last, SLD derived from crystallizing nearby basalt matches gabbro quite well, and it further implies that Gakkel basalt and gabbro are from similar source, which basalt is the liquid version of gabbro. This makes SLD of gabbro a perfect tools for future MOR studies, especially crustal thickness.

Workman, R. K. & Hart, S. R. (2005). Major and trace element composition of the depleted MORB mantle (DMM). Earth and Planetary Science Letters, 231, 53-72.

BEAM IMAGING OF FRACTURES AROUND A WELLBORE USING SONIC LOGGING DATA

Li, David Z., Xiao Tian, Hao Hu, Xiao-Ming Tang, Xinding, Fang and Yingcai Zheng

Imaging near-wellbore fractures is critical for wellbore integrity monitoring, energy production, and waste disposal. We use a sonic logging tool containing cross-dipole sources and receivers to image structures around the wellbore. We first remove the borehole waves excited by the dipole source. We then apply directional Gaussian beam migration to image fractures around the wellbore. We verify our method using synthetic datasets and validate our method on field data sets collected from fractured natural gas wells. We also find that a low frequency (~1kHz) source is needed to obtain a sharp image of the fracture because high-frequency wavefields can interact with the borehole.

POROSITY PREDICTION USING MULTI-ATTRIBUTE ANALYSIS

Mora Calderon, David

The Daqing field, located in the Songliao basin in northeastern China, is the largest oil field in China. Most of the production in the Daqing field comes from seismically thin sand bodies with thicknesses between 1 and 15 meters. It is thus not usually possible to resolve Daqing reservoirs using only conventional seismic data. Seismic multi-attribute analysis can be used to resolve and make inferences about these thin layers. The multi-attribute analysis utilizes statistical methods or neural networks to find relationships between well data and seismic attributes to predict some physical property of the Earth. The multi-attribute analysis was applied separately to conventional seismic data and seismic data that was spectrally broadened using sparse- layer inversion. Porosity volumes were generated utilizing target porosity logs, conventional seismic attributes, and iso-frequency volumes obtained by spectral decomposition. Resulting resolution, statistical significance, and accuracy in the determination of layer properties were higher for the predictions made using the spectrally broadened volume.

NEOGENE SURFACE UPLIFT OF BOLIVIAN CENTRAL ANDES: INSIGHTS FROM STABLE ISOTOPES OF HYDRATED VOLCANIC GLASS

Nguyen, Geneva N. and Joel Saylor

Constraints on temporal and spatial variations in surface elevations are crucial in understanding the geodynamic processes responsible for large-magnitude uplift of orogenic plateaux. At ~4–6 km elevations, the Central Andean Plateau is the Earth's largest orogenic plateau produced by ocean-continent convergence and inevitably serves as a natural laboratory to study surface uplift mechanisms. Recent paleoaltimetry studies using paleotemperature from sedimentary carbonates point to a Neogene non-uniform pulse of rapid surface uplift across and along the Peruvian Western Cordillera and Bolivian Altiplano, consistent with foundering of mantle lithosphere via Rayleigh-Taylor instability.
In this study, we present the first quantitative paleoelevation reconstruction of the timing and magnitude of surface uplift of the Bolivian Western Cordillera. We reconstruct the isotopic compositions of surface water using hydrogen isotopic composition of hydrated volcanic glass. Glass was isolated fourteen ignimbrites and air-fall tuffs and chronology is based on U-Pb zircon of the same samples. Ten samples exhibit acceptable water content (>1 wt%) and were included in our paleoelevation reconstruction. Paleoelevation is reconstructed based on differences between modern low-elevation δ18O and high-elevation δ18O of meteoric water (Δδ18O) using a one-dimensional thermodynamic Raleigh distillation model. Our data indicates that surface elevation of the Bolivian Western Cordillera was at modern elevation since at least 22.9 Ma, much earlier than previous reconstruction suggested by foliar physiognomy (~ 10 Ma). Two samples show anomalously positive δD values, implying highly evaporative depositional environments. Thus further investigations incorporating measured sections and stratigraphy evaluations are necessary. However, our reconstruction strongly suggests modern elevation of the Bolivian Western Cordillera was established since 22.9 Ma, consistent with Miocene stratigraphic record and provenance data of the Altiplano.

PREDICTING TOTAL MAGNETIZATION DIRECTIONS USING CONVOLUTIONAL NEURAL NETWORKS

Nurindrawati, Felicia D. and Jiajia Sun

Proper interpretation of magnetic data requires an accurate knowledge of total magnetization directions of the source bodies in an area of study. In this study, we examined the use of machine learning, specifically Convolutional Neural Network (CNN), to automatically predict the magnetization direction of a magnetic source body based on a magnetic map. CNN has achieved great success in other applications such as computer vision, but has not been attempted in the realm of magnetics. We simulated magnetic data maps with varying magnetization directions from a cubic source body, all subject to the same inducing field. Two CNNs were trained separately, one for predicting magnetization inclinations and the other for predicting magnetization declinations. We also investigated various CNN architectures and determined the optimal architectures for predicting inclinations and declinations. For the optimal architectures, we achieved 98% and 100% test accuracy for our declination and inclination predictors, respectively. Furthermore, this method was tested on magnetic field data from Black Hill Norite, Australia, with encouraging results. Our study shows that machine learning holds great promise for automatically predicting magnetization directions based on magnetic data maps.

DIAGENETIC STUDIES OF THE MID-TRIASSIC TREDIAN FORMATION IN THE SALT AND TRANS INDUS SURGHAR RANGES, NORTH-WEST HIMALAYAS, PAKISTAN: IMPLICATIONS FOR RESERVOIR CHARACTERIZATION

Qureshi, Kamil A.

Distinguished into two members (namely, the lower Landa Member and the upper Khatkiara Member), the Mid-Triassic Tredian Formation is well exposed in the Nammal Nala section of the Salt Range and the Landa Pasha and Gulakhel Nala sections of the Surghar Ranges. All the three sections were measured, logged and sampled in detail to elucidate the diagenetic changes and assess reservoir potential of the Tredian Formation. Twenty-nine samples were selected for diagenetic investigation, while representative samples were examined with scanning electron microscope (SEM) and energy dispersive X-ray (EDX) analysis to determine their clay mineralogy. The principal lithology is sandstone with some interbedded shale. The Tredian sandstone has undergone intense and complex diagenetic processes. The chemical and mechanical compaction, cementation, replacement, grain fracturing and dissolution are the major diagenetic signatures. Major authigenic cements in the sandstone include calcite (both early and late diagenetic), dolomite, quartz, iron oxide/ hydroxide and clay minerals. The two Members of the Tredian Formation underwent compaction differently. The lower Landa Member shows variable grain contacts (point to long) and early calcite cementation, which stopped mechanical compaction and led to loose packing of grains. However, the upper Khatkiara Member displays tight packing (concavo-convex grain contacts) and significant mechanical compaction. Chemical compaction and pressure induced dissolution of quartz grains provided silica that precipitated as cement thereby reducing inter-granular porosity. This study concludes poor reservoir potential of the lower Landa Member of the Tredian Formation because of the early calcite cementation. Contrarily, the upper Khatkiara Member due to grain fracturing, cement and grain dissolution and inter-crystalline porosity of the chlorite is marked as moderate to good reservoir rock.

DETERMINING BASEMENT TERRANE BOUNDARIES IN THE MODERN CARIBBEAN PLATE AND THEIR IMPACT ON REGIONAL HYDROCARBON SYSTEMS

Romito, Sean

The Caribbean plate is a complex, 3.2 million km2 area of amalgamated and dissimilar basement terranes which I catalogue from an integration of: 1) surface geology; 2) 120,000 km of marine, seismic reflection data; 3) 34 seismic refraction profiles; 4) 51 wells, and their overlying source rocks; 5) reservoir rocks, oil and gas seeps; and 6) areas of commercial hydrocarbons. In decreasing order of their areal extent, the five terranes include: 1) Precambrian/Paleozoic Chortis continental block with average water depths of 1 km, sediment thicknesses of 3 km of pelagic sediments and a recent carbonate platform, and crustal thickness between 25-45 km; 2) Late Triassic/Early Cretaceous Mesquito Composite Oceanic Terranes which lies immediately south of the Chortis with average water depths of 0.3 km, sediment thicknesses of 3 km, and crustal thicknesses between 20-30 km; 3) Early Cretaceous/Recent Great Arc of the Caribbean that surrounds the plate in a relatively narrow band with average water depths of 1.5 km, sediment thicknesses of 2 km of a mixture of siliciclastic and carbonate sediments, and crustal thicknesses of 15-25 km; 4) Cenomanian/Turonian Caribbean Large Igneous Province (CLIP) with average water depths of 4 km, sediment thicknesses of 2 km, and crustal thicknesses between 12-20 km; 5) Late Eocene/Recent Cayman Trough oceanic spreading ridge and pull-apart basin to the north with average water depths of 5.5 km, 1.5 km of pelagic sediments, and crustal thicknesses of 4-8 km; 6) Early Cretaceous extended oceanic crust formed by back-arc extension covering 350,000 km2 to the south and southwest of the CLIP with average water depths of 4 km, sediment thicknesses of 3 km of CLIP comparable sediments, and crustal thickness of 2-6 km; 7) oceanic crust and thinned arc crust of the Grenada basin separating the Aves Ridge and the Lesser Antilles with 3 km water depth, 1.5 km pelagic sediments, and crust from 8-20 km.

SOURCE APPORTIONMENT OF FINE PARTICULATE MATTER NEAR HOUSTON USING AN INTEGRATED FACTOR ANALYSIS

Sadeghi, Bavand, Yunsoo Choi, Sojin Lee, James Flynn and Alexander Kotsakis

Interpretation of large air pollution data sets is a complex task. Factor analysis can be performed to gain a better understanding of the relationships and patterns within data sets. We measured data of fine particulate matter (PM2.5) in West Liberty, a rural area northeast of the Houston metropolitan area, TX between December 2015 and December 2017. The data consist of 233 samples that we individually analyzed for chemical composition. The PM2.5 consists of 38.1% inorganic ions, 28.9% elements, 29.1% organic carbon, and 3.7% elemental carbon and other organic materials. We apply two factor analysis methods (principal component analysis and positive matrix factorization) to the samples categorized into eight similar factors: regional aerosols, biomass burning, gasoline combustion, industry, crustal material, incineration, and marine dust. The first three sources contributed to more than 70% of the total PM2.5 mass. We also show that the receptor models capture the impact of fireworks. To identify the origins of air masses transporting fine particulate matter to the site, we apply the NOAA Hybrid Single-Particle Lagrangian Integrated Trajectory model to carry out a cluster analysis of back trajectories and identify six cluster source regions: the Gulf of Mexico, the Southeast, two Midwestern clusters, the Pacific Northwest, and the Southwest. The results of the analysis show that during the summer months, marine and crustal sources (Saharan dust) were often associated with an onshore flow from the Gulf of Mexico and that four clusters covering 38% of the West Liberty area were strongly influenced by trajectories originating from biomass burning. The results of this study from the dataset should provide decision makers with useful information to determine the sources of ambient air pollution.

A DEEP LEARNING MODEL TO IMPROVE WRF FORECASTS: A CASE STUDY OF TEMPERATURE, RELATIVE HUMIDITY, AND WIND SPEED ACROSS SOUTH KOREA

Sayeed, Alqamah, Yunsoo Choi, Ebrahim Eslami and Jia Jung

The advancements in numerical weather prediction (NWP) model has accelerated with better understanding of physical phenomenon pertaining to dynamics of weather and better computing resources. Despite these advancements, these models have some inherent biases, which lead to reduced accuracy. In this work, we investigate the use of a computationally-efficient fast deep learning method, called convolutional neural network (CNN), as a post-processing technique in order to improve mesoscale WRF outputs. More precisely, one day ahead (with a 1-hour temporal resolution), several meteorological parameters calculated by the WRF model were bias-corrected through the use of a CNN for the entire 2017. A three-year history (2014-2016) were used to train the CNN model in order to reduce the bias of the WRF forecasts for relative humidity (RH), surface wind speed, and surface temperature. The WRF data (with 27 km spatial resolution) were processed by the Meteorology-Chemistry Interface Processor (MCIP). The ground observation data were obtained from the Korean Meteorological Administration (KMA) station network for total 30 weather station locations. The results indicated that the WRF forecasts can be notably improved for all station locations. The annual average correlation coefficient (r) for temperature, RH and WS were 0.98 (WRF: r=0.96), 0.81 (WRF: r=0.67) and 0.67(WRF: r=0.57) respectively for all stations. The annual r increments were ranged 0.0071-0.020 for temperature, 0-0.210 for RH, and 0.015-0.229 for wind speed. While this study focused on South Korea, the proposed approach can be applied for any measured weather parameters in a mesoscale resolution.

APPLICATION OF Re-Os GEOCHRONOLOGY TO HYDROCARBON GENERATION IN OFFSHORE CALIFORNIA BASINS

Silva, Leiser G., Alan Brandon, Joe Curiale, John Casey and Yongjun Gao

The rhenium-osmium (Re-Os) system has been used with geochronological applications in the dating of igneous rocks, and in constraining the Earth's geochemical evolution. However, various sources of Os contribute to the ocean and ultimately become sequestered in organic rich sediments, these sediments will reflect the 187Os/188Os signature of seawater at the time of their deposition. The Re-Os system is therefore a reliable tracer and dating tool in organic rich sediments that act as excellent source rocks for petroleum. Oil generation and migration is thought to reset the initial 187Os/188Os of oil, reflecting the 187Os/188Os of the source rock at the time of generation. This resetting of the Re-Os geochronometer implies that a Re-Os age from a suite of oils should reflect the timing of generation and migration unless post-emplacement alteration has taken place. This study set out to determine the Re-Os isotopic compositions of 16 oil samples that originate from the offshore Santa Maria basin (Field 395 oils) and the northwestern Santa Barbara Channel (Bonito and Santa Maria field oils). The age determined for the Bonito and Santa Maria field oils was 30 + 3.1 Ma and determined that these oils are more than likely sourced from the Monterey Formation, but have undergone alteration by a mantle-derived fluid that has overprinted the original 187Os/188Os isotopic signature. The age of 30 + 3.1 Ma aligns perfectly with the shift from subduction tectonics to transform and oblique subduction between the Farallon-Pacific plate and the California margin that may have initiated hydrocarbon generation in Eocene source rocks, provided these oils are not sourced from the Monterey Formation. There is significant scatter among the data in Field 395 oils interpreted as an overprint caused by mantle-derived fluid interactions facilitated by nearby faults or alteration by thermochemical or bacterial sulfate reduction that is taking place presently. This study and Barnette (2015), the only Re-Os studies published in the California area, show the viability of acquiring essential generative information of an oil field using only Re-Os geochemical techniques in the absence of additional geochemical data, and confirm the results of previous Re-Os studies regarding oil-fluid interactions.

HURRICANE HARVEY SEDIMENTATION PATTERNS IN BUFFALO BAYOU, TEXAS

Stearns, Andrew I.

Hurricane Harvey produced an extreme precipitation event over Houston, Texas from August 25-30, 2017. Harvey stalled out Southwest of the Houston area from August 26-28 with many areas experiencing greater than 750 mm 3dy-1 or the 1000-year event return period. The resulting 11.1 x 109 m3 of runoff caused mobilization of large sediment volumes which has implications for future flood control in bayous and rivers. As of Spring 2019, roughly 102,000 m3 of sediment has been removed along Buffalo Bayou, although most of the 1-3 m high sand bar flood deposits downstream of Addicks and Barker reservoirs remain untouched. Thick flood deposits from large storms decrease the bankfull volume capacity of rivers and bayous causing them to be more susceptible to flooding. Using pre and post Harvey satellite imagery and high-resolution digital elevation models, we determine areas of relative erosion and deposition along Buffalo Bayou from Addicks and Barker reservoirs to downtown Houston. Flood deposit sediment samples were collected from the Addicks and Barker dams to downtown Houston. These samples were then analyzed using a laser particle analyzer to investigate vertical and lateral grain size variations. By determining the first-order depositional patterns in Buffalo Bayou, we can determine sedimentation behavior downstream of Addicks and Barker reservoirs.

ASSESSING THE HETEROGENEITY OF THE TISSINT SHERGOTTITE STREWNFIELD USING RB-SR, SM-ND and LU-HF ISOTOPE SYSTEMATICS

Suarez, Stephanie E., Thomas J. Lapen, Minako Righter, Brian L. Beard and Anthony J. Irving

Tissint, the 5th witnessed Martian meteorite fall occurred on July 18, 2011 near Oued Drâa valley, east of Tata, Morocco. While most studies of Tissint converge to a consensus that it is a shergottite relatively depleted in lithophile incompatible trace elements, crystallization age determinations have been variable. Currently, there is a discrepancy in crystallization age determination amongst three separate labs using combinations of Lu-Hf, Sm-Nd, and Rb-Sr analyses. Each lab tested one single fragment from the entire Tissint meteorite strewn-field, which included samples (UWB1), (ASU#1744), (UNM#645). Sm-Nd analyses were performed in all three studies and produced two different dates. Analyses from two of the three studies, UH and Lawrence Livermore National Lab, are in agreement and give a combined Sm-Nd age of 593±25 Ma. Analysis at NASA-JSC provided a date of 472±36 Ma (ASU#1744). This is approximately a 120 Ma difference in crystallization ages for separate samples analyzed from the strewn field. A heterogeneous Tissint meteorite strewn field hypothesis might explain the different ages where launch-paired volcanic strata fell to Earth together. Tissint, along with at least 11 other depleted olivine-phyric shergottites, have an ejection age of 1.1 Ma and exhibit a range of crystallization ages from 347 Ma to 2403 Ma. These 11 depleted shergottites are believed to be ejected from Mars surface by single impact event. The two different ages for Tissint could, in theory, represent two lava flows of differing ages that became co-mingled during the ejection. These fragments from different flows would have been launched and travel paired because they fell as one observed fall. This hypothesis was assessed by Rb-Sr, Sm-Nd and Lu-Hf isotopic investigations of separately collected fragments from the Tissint strewn-field, including the sample analyzed at the JSC (UNM#645). The Rb-Sr isotopic systematics of Tissint fragment residues, including the UNM#645 sample dated at 495 ± 35 Ma by (Shih et al. 2014), are isotopically indistinguishable with data from LLNL that indicates an age of 559 ± 39 Ma. The implications of these data are that all fragments analyzed so far are cogenetic and that the Tissint strewn-field appears to be homogeneous.

ANALYSIS OF FRACTURE CLUSTERS ON SEISMIC REFLECTORS

Walker, Joanna M. and Yincai Zheng

I will utilize borehole resistivity images from a lateral well in West Texas to identify and characterize fractures. The fractures will be characterized as conductive, resistive or mixed (both conductive and resistive) based on the resistivity contrast to the rest of the borehole image. I will then analyze the presence of the fractures and the proximity to one another. This proximity will determine cluster groups for the identified fractures. The statistical information collected from the borehole image analysis will be plugged into algorithms that are designed to generate the appearance of seismic reflectors based on predetermined variables. I expect that the fracture clusters will influence the seismic reflectors and in the future this effect can be used to identify fracture clusters before drilling, enhancing drilling performance and improving packer spacing for fracking.

JOINT INVERSION OF MULTIPLE GEOPHYSICAL DATASETS BASED ON A NEW STRUCTURAL SIMILARITY MEASURE

Wei, Xiaolong and Jiajia Sun

Joint inversion simultaneously inverts multiple geophysical data sets collected over the same area in a unified mathematical framework, and aims to recover a common Earth model that can explain all available geophysical data sets. Joint inversion, therefore, holds great promise for integrating multi-physics geoscience data sets, for reducing uncertainty in the resulting models, and for maximizing values in the measurements. A key issue when implementing joint inversion is to design a coupling strategy that links one physical property model to another based on either physical parameter relationships or structural similarities. In our work, we focus on the structure-based joint inversion. We designed a new structural similarity measure using logistic functions. The logistic functions convert a physical property model to a binary image with zeros corresponding to regions of no significant structures and ones corresponding to regions of significant structures. We apply logistic functions to two different physical property models and then measure their structural similarity by simply calculating the spatial coincidence between zeros and ones in the two binary images. We use a simple example to illustrate the validity of this new structural similarity measure. We will also discuss the numerical strategies that we have developed to solve the joint inverse problem, as well as the field data sets that we are going to use in our future work.

INTEGRATION OF GRAVITY MODELING, SEDIMENTARY FACIES AND SUBSIDENCE ANALYSIS TO UNDERSTAND THE TECTONIC STAGES OF PALEOZOIC TO RECENT PERMIAN BASIN, WEST TEXAS

Zhang, Hualing and Paul Mann

The Permian Basin (PB) of West Texas and southeast New Mexico is one of the most prolific oil-producing basins in the western hemisphere. During late Paleozoic collision of North and South America, the PB underwent complex faulting and fracturing that coincided with two areas of extreme (30-42 m/my) subsidence A regional gravity map shows that the PB forms a western extension of a 650-km-long gravity low that has been previously inferred to represent a batholith of Early Mesoproterozoic age. A preliminary 2D gravity model for a regional, north-south line was generated, incorporating density and lithological controls from well logs which reached the Ellenburger formation and from previously published gravity models. This elongate batholith appears to have act as a zone of weakness that focused subsidence as a result of north-south, interpolate compression. Subsidence history based on eight representative well logs throughout the Permian Basin and integrated with facies information from deep wells define five tectonic phases that controlled the patterns of basin sedimentation:1) Pre-collisional, passive margin phase from the Late Precambrian to Late Mississippian (850-320 Ma) with deposition of shallow-marine facies at an average subsidence rate of 8 m/my; units are tabular with no evidence for syn-tectonic wedging 2) Main collisional phase from the Late Mississippian to Mid Permian (320-265 Ma) with deposition of mixed, siliciclastic-carbonate deep-marine facies at an average subsidence rate of 42 m/my; tectonic wedges up to 2.4 km thick are verified on deep wells to consist of sandstone, shale, and detrital limestone; 3) Post-collisional phase from Mid Permian to Late Triassic (265-230 Ma) with deposition of tabular, shallow-marine, carbonate facies at an average sedimentation rate of 30 m/my; 4) Passive margin phase from Late Triassic to Late Cretaceous (230-80 Ma) with deposition of shallow-marine, carbonate facies at an average sedimentation rate of 4 m/my; and 5) Basin reactivation phase from Late Cretaceous to Early Eocene (80-0 Ma) related to the Laramide orogeny followed by the Basin and Range extensional event.

Advanced Ph.D. Students

STRUCTURAL EVOLUTION OF PORT ISABEL PASSIVE MARGIN FOLDBELT, NORTHWEST GULF OF MEXICO: RESULTS FROM KINEMATICS RESTORATIONS

Bugti, Muhammad Nawaz

This study evaluates possible mechanisms of deformation that caused the evolution of the Port Isabel passive margin foldbelt. The updip extensional part of the passive margin is characterized by the Corsair normal fault trend, which is the 80 km wide and 400 km long running along the western Texas coast. The downdip shortening areas are the Port Isabel and Perdido passive margin fold belts in the deepwater GOM. Seismic interpretation of six key seismic horizons carried out in the study area, and kinematic restoration is performed on western parts of three northwest-to-southeast-striking lines ranging in length from 200 to 300 km to understand the sequence of deformation. StructuralSolver software is utilized for structural restoration using the vertical simple shear model. Two decollement surfaces of Eocene-Oligocene and Middle Jurassic age can be observed in the seismic data. Perdido foldbelt lies at the compressional part of the passive margin foldbelt. Anticlines in Perdido are salt-cored on the lower detachment, while extension occurred, towards the west, along the Corsair trend, occurs at the upper detachment. Logically, the extension has, somehow, to transfer from the updip upper detachment to the downdip lower detachment. Three different mechanisms of transfer of deformation from upper to lower detachment are evaluated. 2D seismic data supports the collapsing paleo salt wall model. As initial set up, a salt wall existed in the Jurassic-Eocene section; an updip salt canopy was emplaced to the hinterland, and an updip extension is marked by listric normal faulting. During Oligocene, the salt wall starts to expand and collapse, creating an accommodation space; simultaneously salt inflows in the detachment basin from an updip canopy, and growth sedimentation occurs along the fault(s) that sole in the collapsing salt wall. During Upper Oligocene, the extension is transferred from the shallow sections to deep section (Middle Jurassic- Eocene). An absence of shallow extension leads to A. abnormal growth in the shallower (Oligocene-younger) section, B. additional extension in the deeper section, and salt diapirism, of allochthonous salt infilled from the updip canopy, within the detachment basin.

DYNAMIC TOPOGRAPHY OF A GRAVITY-CONSTRAINED CRUSTAL MODEL ACROSS THE CARIBBEAN REGION

Chen, Yi-Wei, Lorenzo Colli, Dale Bird and Jonny Wu

Most of Earth's topography is isostatically compensated. However, viscous stress induced by mantle convection can warp the Earth's surface over long wavelengths (10^2-10^4 km), with amplitudes of several hundred meters, producing so-called dynamic topography. A detailed analysis of dynamic topography can thus shed some light on the direction and intensity of mantle flow. One way to estimate dynamic topography consists of calculating the isostatically compensated topography and subtracting it from the observed, total topography. This requires constraining the thickness and densities of sediment, crust and lithosphere. Recent studies have shown a global-scale dynamic topography over oceanic plate that was induced by mantle convection. However, areas of complex crustal structure, such as the continental lithosphere and over-thickened oceanic lithosphere have not yet been fully analyzed due to the lack of well constrained basement and Moho relief.

The Caribbean region has been proposed as a candidate for outflow of asthenospheric mantle, from a shrinking Pacific region to an expanding Atlantic region. This flow would produce a potentially observable dynamic topography gradient across the region. However, the dynamic topography across the Caribbean region remains unclear due to the complexities of the Caribbean crust, which is thicker than average oceanic crust of 7 km, and the lack of comprehensive and highly-resolved basement and Moho information.

We conducted a 3D structural invertion of the Moho using free air gravity anomalies with prescribed surface relief and basement relief. Published global grids of Gtopo 30 and TerrainBase were used for topography and bathymetry, respectively. The basement relief was derived by subtracting the published sediment thickness from the total surface relief. Sedimentary density was derived from empirical relations of sediment depth vs density. Lithospheric mantle density of oceanic plates was derived from relations of lithospheric age vs density. Moho depths and basement relief can be tested against independent seismic refraction and receiver function data. Discrepancies exist possibly due to uncertainty in sediment thickness. Here, we show and compare Moho depths and basement depths from our inversion, the interpolation of high-quality refraction data, and the depths from previous studies.

DEPTH TO THE TOP OF OVERPRESSURE IN THE DEEPWATER GULF OF MEXICO: GARDEN BANKS, GREEN CANYON, KEATHLEY CANYON, AND WALKER RIDGE

Cornelius, Sharon

For the Gulf of Mexico, overpressure is defined as the point below the seafloor at which the geopressure gradient reaches 0.70 psi/ft, or a 13.5 ppg drilling mud weight (Bebout et al., 1982 and Rabinovich, 2011). The geopressure gradient was calculated from 150 wells using the bottom-hole mud weights converted to psi and then subtracting the hydrostatic pressure of the water column. The depth at which the remaining sediment (pore) pressure would reach 0.70 psi/ft was then calculated using the geopressure gradient. There are twelve contributing factors to the formation of overpressure in the study area but the only one correlating over the whole region is water depth. Disequilibrium compaction is widespread due to high sedimentation rates during the Cenozoic; but numerically it does not contribute greatly. Other more significant
contributors are hydrocarbon generation, smectite to illite transformation, and sandstone diagenesis. Location factors include seafloor topographic highs or lows, presence of salt bodies, salt movement, proximity to faults, geothermal gradients, and thickness of clastic lithological units.

WHAT DRIVES EROSION IN THE HIMALAYAS

Johnston, Shelby N., Matt Canon and Peter Copeland

To better understand the cause of modern erosion in Central Nepal, we have compared modern detrital muscovite $^{40}Ar/^{39}Ar$ data to bedrock data from the Narayani river catchment, creating a map of preferential erosion. Our erosion pattern is in agreement with previous patterns derived from various methods (river incision, cosmogenic dating, sediment flux) and doesn't show a correlation with mean annual rainfall data, MHT coupling, or ksn values. All modern erosion patterns show preferential erosion above the location of the MHT deep ramp. We assert that modern erosion is thus driven by material bulging over the deep ramp. Because preferential erosion occurs in areas with the lowest $^{40}Ar/^{39}Ar$ ages, we believe that this process has been driving erosion for the past few million years.

THE IMPACT OF THE DIRECT EFFECT OF AEROSOLS ON METEOROLOGY AND AIR QUALITY USING AEROSOL OPTICAL DEPTH ASSIMILATION DURING THE KORUS-AQ PERIOD

Jung, Jia, Amir Souri, David Wong, Sojin Lee, Wonbae Jeon, Jhoon Kim and Yunsoo Choi

To quantify the impact of the direct aerosol effect accurately, this study incorporated the Geostationary Ocean Color Imager (GOCI) aerosol optical depth (AOD) into a coupled meteorology-chemistry model. We designed three model simulations to observe the impact of AOD assimilation and aerosol feedback during the KORUS-AQ period (May – June 2016). By assimilating the GOCI AOD with high temporal and spatial resolutions, we improve the statistics from the comparison AOD and AERONET data (RMSE: 0.12, R: 0.77, IOA: 0.69, MAE: 0.08). The inclusion of the direct effect of aerosols produces the best model performance (RMSE: 0.10, R: 0.86, IOA: 0.72, MAE: 0.07). AOD values were increased as much as 0.15, which is associated with an average reduction in solar radiation of -31.39 W/m^2, a planetary boundary layer height (-104.70 m), an air temperature (-0.58 ℃), and a surface wind speed (-0.07 m/s) over land. In addition, concentrations of major gaseous and particulate pollutants at the surface (SO2, NO2, NH3, SO_4^(2-), NO_3^-, NH_4^+, PM2.5) increase by 7.87 – 34% while OH concentration decreases by -4.58 %. Changes in meteorology and air quality appear to be more significant in high-aerosol loading areas. The integrated process rate analysis shows decelerated vertical transport, resulting in an accumulation of air pollutants near the surface and the amount of nitrate, which is higher than that of sulfate because of its response to reduced temperature. We conclude that constraining aerosol concentrations using geostationary satellite data is a prerequisite for quantifying the impact of aerosols on meteorology and air quality.

MACHINE LEARNING IDENTIFICATION OF DISCRETE FRACTURES FROM DOUBLE BEAM IMAGES

Li, Jiaxuan, Hao Hu and Yingcai Zheng

Reservoir natural fracture detection is of critical importance in unconventional resource and geothermal resource development and production. Previously, we proposed a double-beam interference method to characterize irregularly distributed fractures, including multiple coexisted fractures with random spacings and azimuths. This method is target-oriented and it outputs complex-valued interference patterns for reservoir fracture target, which contain information about local fracture orientation, density, and fracture compliance. Previously, only amplitude spectral information of the double-beam image was interpreted and the phase spectrum was ignored. In this study, we take advantage of machine learning technique to perform high-resolution interpretation of the double-beam images to directly obtain discrete fractures.

SALT IMAGING BY JOINT INVERSION OF SEISMIC FULL WAVEFORM AND GRAVITY GRADIOMETRY DATA

Li, Xinyan and Jiajia Sun

Salt imaging in geologically complicated areas can be challenging. Indeed, the quality of seismic imaging of the salt bodies largely depends upon whether reflections from the salt boundaries are recorded by the surface receivers or not. However, depending on the shapes of the salt body as well as the geometrical layout of the seismic receivers, reflections might be missing for certain parts of the salt boundaries. In such cases, complementary geophysical data, such as gravity gradiometry data, could provide useful information for better imaging of the salt body because gravity gradiometry data are sensitive to density contrast between the salt body and the sedimentary background. Another motivation for complementing full-waveform seismic data with gravity gradiometry data stems from the fact that low frequency information, which is critical for the success of seismic full-waveform inversion, is usually missing, but gravity gradiometry data can fill the gap in the spectrum contents. In this study, we investigate and develop various numerical strategies for integrating full-waveform seismic and gravity gradiometry data in the context of joint inversion. We use the 3D SEG/EAGE salt model to simulate different scenarios and to test our numerical algorithms.

HYDRAULIC FRACTURE SIZE DETECTION USING RESONANCE

Lin, Rongrong and Yingcai Zheng

Hydraulic fracturing is commonly used in unconventional reservoir explorations. The size of the hydraulic fracture is a very important parameter for estimating the ultimate recovery and planning the later fracturing. In this study we proposed a new method of estimating the size of the fracture using resonance.

TESTING PROTO-SOUTH CHINA SEA PLATE RECONSTRUCTIONS BY DATA ASSIMILATION INTO TERRA GLOBAL MANTLE CONVECTION MODELS

Lin, Yi-An, Lorenzo Colli and Jonny Wu

The South China Sea lies at a key junction between major plates (i.e. Pacific, Eurasian and Indo-Australian) within one of the most tectonically complex regions in the world. A great diversity of plate reconstructions has been proposed for the South China Sea area since the Cenozoic. One class of 'conventional' proto-South China Sea plate models suggests that South China Sea opening was accommodated by one-sided, southward Proto-South China Sea subduction beneath Borneo during the Eocene and Early Miocene (e.g. Hall and Breitfield, 2017; Holloway, 1982; Taylor and Hayes, 1983). In contrast, an 'alternative' model proposed double-sided Proto South China Sea subduction within the same time period (Wu and Suppe, 2018). The alternative model was proposed to explain the origin of a slab-like, sub-horizontal fast tomographic anomaly below the present South China Sea at 500 to 700 km depths that exceed 1000 km in N-S and E-W extent (Wu and Suppe, 2018). This study assimilates these two end-member plate models into the numerical model TERRA (Bunge et al., 1998). The computational domain is discretized on a regular grid based on the icosahedron, for a total of ~80 million grid points and a resolution of ~25 km, allowing us to simulate convection in the same regime as the real Earth. We implemented the plate models as a set of continuously closing plates in order to generate a global self-consistent velocity field to be assimilated into the convection models. We explicitly tested the viability of the two plate models against tomography following Schuberth et al. (2009) by converting the resulting temperature field to seismic velocities and applying a resolution filter from S40RTS (Ritsema et al., 2011). Our results show that the two plate models produce fast anomalies under the present-day South China Sea that are distinguishable, even within the coarser-scale S40RTS resolution filter. The alternative model produces more slab-related cold anomalies under present-day South China Sea. We will discuss a next set of thermochemical model results that were designed to increase realism by incorporating possible oceanic and continental compositional differences.

TECTONIC GEOMORPHOLOGY REVEALS AREAS OF ACTIVE TRANSPRESSION ON THE ISLAND OF HISPANIOLA (HAITI AND THE DOMINICAN REPUBLIC)

Sun, Lei

The island of Hispaniola is shared between the country of Haiti occupying the western third of the island and the Dominican Republic occupying the eastern two-thirds. Late Miocene to recent deformation is related to a 250 km-wide zone of active, left-lateral, seismogenic transpression between two major east-west strike-slip zones: the Septentrional-Oriente fault zone along the northern edge of the island and the Enriquillo-Plantain Garden fault zone (EPGFZ) along its southern edge. To better understand how active deformation is partitioned on strike-slip faults and large, en echelon folds across the 75,260 km2 island, we used ArcGIS software and a high-resolution (30m) ASTER GDEM to: 1) construct river longitudinal profiles of all major rivers on the island; 2) calculate both normalized steepness index (ksn) and stream length-gradient index (SL) along the rivers; and 3) to calculate relative surface roughness (SR) and hypsometric integral (HI) from the topography. The extracted knickpoints as well as high-ksn, high-SL segments reveal several areas where Neogene to recent uplifting is occurring as a result of transpressional folds: Chaine des Matheux-Sierra de Neiba and Sierra de Bahoruco-Massif de Selle. Low surface roughness and high HI values were also indicative of young landforms that were poorly incised resulted from recent uplifting. In contrast, the topographically-lower area of eastern Hispaniola shows much lower ksn and SL values that is consistent with less shortening and uplift. We interpret the abrupt variations in geomorphological indices to reflect the kinematic variation and along-strike transition from oblique subduction with little strain partitioning in the eastern Hispaniola to oblique subduction-collision with strain partitioning in the western Hispaniola.

EARTHQUAKE STRESS DROP FOR A CIRCULAR CRACK IN AN ANISOTROPIC MEDIUM

Tang, Shuhang, Yingcai Zheng, Hua-Wei Zhou, Hao Hu, Jiaxuan Li and Yuandi Gan

The circular-crack model has been widely used in seismology to infer earthquake stress drop. A common assumption is that the background medium is isotropic, although many earthquakes occur in geologically anisotropic settings. In this paper, we study the effect of anisotropy on stress drop for a circular crack model and present explicit formalism in both static and kinematic cases. In the static case, we obtain the relationship between stress drop and slip for a circular crack model in an arbitrarily anisotropic medium. Special attention is given to the transversely isotropic (TI) medium. The static formalism is useful in understanding stress drop but not all quantities are observables. Therefore, we resort to the kinematic case, where we can infer stress drop using recorded far-field body waves. In the kinematic case, we assume that the crack ruptures circularly and reaches the final displacement determined by the static solutions. The far-field waveforms and their spectra will be used to infer stress drop. Finally, we calculate the stress drops for cracks in both isotropic and anisotropic media. We find that in an isotropic medium, only shear stress acting on the crack surface contributes to shear slip. On the other hand, in a TI medium, if the anisotropy symmetry axis is not perpendicular to the crack surface, a normal stress (normal to the crack surface) can produce a shear slip. In calculating stress drop for an earthquake in an anisotropic medium using far-field body waves, a large error may be introduced if we ignore the possible anisotropy information in the inversion. For a TI medium with about 18% anisotropy, the misfit of inferred stress drop could be up to 16%.

RADIALLY ANISOTROPIC SHEAR WAVE VELOCITY STRUCTURE BENEATH EASTERN NORTH AMERICA FROM SURFACE WAVE TOMOGRAPHY

Tao, Zhongmin and Aibing Li

The eastern North American continent consists of the Grenville Province, the Appalachian Orogen, and the Atlantic margin. Even though it has been stable since the opening of the Atlantic Ocean, mantle upwelling beneath New England is inferred from seismic velocity models, which reveal a broad low velocity anomaly in the upper mantle. To better constrain mantle dynamics beneath eastern North America, we construct a 3-D radially anisotropic shear wave velocity model using Rayleigh and Love wave tomography. Fundamental modes of surface waves are extracted from 114 earthquakes recorded at 220 USArray Transportable Array stations at periods of 20 to 167 s for Rayleigh wave and 35 to 167 s for Love wave. We develop 3-D Vsv, Vsh, and radial anisotropy models from obtained Rayleigh and Love wave phase velocities. Low velocities are mostly imaged beneath the Atlantic margin, where a sharp Vsv decrease is observed at a depth range of 60 to 80 km, consistent with the lithosphere and asthenosphere boundary (LAB) from receiver functions. The Grenville Province is characterized by a thick, high-velocity lithosphere without a sharp LAB. The mid-crust of the Grenville Province and the Appalachian Mountains is imaged with a substantial radial anisotropy of Vsv>Vsh, reflecting crustal shortening from the Grenville and Appalachian orogenies. The New England slow anomaly extends westward as a narrow band at the depths of 100-160 km and correlates with positive radial anisotropy, implying a dominant horizontal asthenospheric flow against mantle upwelling. The slow anomaly is likely caused by westward migration of hot oceanic asthenosphere through a weak channel that could be resulted from previous tectonic and hotspot activities in eastern North America.

IMPLICATIONS OF UPDATED MAGNETIC ANOMALIES FOR THE TECTONIC EVOLUTION OF WALVIS RIDGE

Thoram, Sriharsha and William Sager

Walvis Ridge (WR) is a NE trending submarine ridge on the African plate in the South Atlantic extending from Namibia to the islands of Tristan Cunha and Gough. WR is a hotspot trail thought to be formed by the interaction of a hotspot with the Mid-Atlantic Ridge. WR morphology is complex, starting as narrow ridge near the continental margin, converting to a plateau (Valdivia Bank) at right angles, forming en-echelon ridges and splitting into three seamount chains (Guyot Province), two of which end in active volcanic islands of Tristan and Gough. Many hypotheses based on simple hotspot models have been put forth to explain the tectonic evolution of WR - multiple hotspots, moving hotspots, ridge-hotspot interactions - none of which satisfactorily explain the complex geomorphology. In this study, we investigate the tectonic evolution of WR during 84-68 Ma by interpreting magnetic anomalies C34-C30 near the ridge. We model newly obtained magnetic data around WR and re-interpret old magnetic data available from NCEI and JAMSTEC databases. Our focus is C34-C30 because it is an anomalous time in the formation of WR and coincides with the formation of the Rio Grande Rise on the South American plate. During this period, a major plate reorganization occurred in the South Atlantic, WR evolved from an ocean plateau (Valdivia Bank) to en-echelon ridges and then to a series of seamount chains. Coincidently, there was a reduction of spreading rate from 70mm/yr (end of 34n) to about 40mm/yr (end of 30n) and several new fracture zones formed between WR and Rio Grande Rise. This study for the first time has successfully tracked chrons C33n to C34n along the length of WR, where previously no magnetic anomalies were identified. The updated magnetic anomalies will provide better constraints and help understand the tectonic evolution of WR in greater detail. Our analysis of the magnetic anomalies suggests that WR should not be treated as a simple hotspot trail and that complex tectonic processes, including microplate formation, were involved in dictating the overall geomorphology.

EVALUATION OF A RAPID TLS SURVEYING METHOD FOR COASTAL EROSION MONITORING: A CASE STUDY AT FREEPORT, TEXAS

Xiong, Lin, Guoquan Wang, Yan Bao, Xin Zhou, Xiaohan Sun and Ruibin Zhao

Terrestrial Laser Scanning (TLS) has become a powerful acquisition technique for high-resolution high-accuracy topographic mapping. To reduce surveying time and simplify operational tasks, we have developed a rapid TLS surveying method that requires only one reflector in the field. The method allows direct georeferencing of point clouds from individual scans to a stable regional geodetic reference frame. The seven-parameter Helmert transformation is employed to transform positional coordinates within the scanner's own coordinate system to a regional geodetic East-North-Height (ENH) coordinate system. These seven parameters are derived from measurements of two onboard inclination sensors and two GPS units mounted on the scanner and reflector. TLS datasets collected at a segment of the beach-dune-wetland area in Freeport, Texas are used to evaluate the performance of the rapid surveying method by comparison with kinematic GPS mapping. According to this study, the rapid TLS surveying method can achieve a coordinate accuracy (root-mean-square error) below 5 cm on point clouds, both in plane and height, at an object distance up to about 300 m in the field. The proposed method would particularly benefit researchers who need to map morphological changes in coastal regions where strong wind and soft sand prohibit reflectors from remaining strictly stable for a long period.