Abstracts

New Mexico Geology recognizes the important research of students working in post-graduate M.S. and Ph.D. programs. The following abstracts are from M.S. theses and Ph.D. dissertations completed within the last 12 months that pertain to the geology of New Mexico and neighboring states.

New Mexico Institute of Mining and Technology

WATER ABOVE THE MOUNTAIN FRONT—ASSESSING MOUNTAIN-BLOCK RECHARGE IN SEMIARID REGIONS, by *Huade Guan*, 2005, Ph.D. dissertation, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 441 pp.

Mountains provide as much as 90–100% of the freshwater to surrounding basins in arid and semiarid regions because of their distinctive and complex topography, and the consequent effects on precipitation (P) and evapotranspiration (ET). One of the primary objectives of this dissertation is to estimate mountain-block recharge (MBR), an important component of the mountain contribution to ground water replenishment of surrounding basins, as well as its response to regional climate variability in a semiarid mountain environment of the southwestern U.S. Two major limitations, a lack in understanding hydrologic processes and sparse observation networks, hinder predictive mountain-block hydrologic modeling, and reliable estimation of MBR. Developing approaches to address these limitations is another objective of this dissertation.

A geostatistical algorithm (Auto-Searched Orographic and Atmospheric effects De-trended Kriging, ASOADeK) is first developed for mapping mountain precipitation using sparse gauge data. ASOADeK constructs monthly precipitation maps comparable to PRISM products, and with higher spatial resolution. ASOADeK is also useful for studying reginal climatic settings. In arid and semiarid regions, the dominant water flux out of the mountain block is ET. A Topography- and Vegetation-based surface energy partitioning model for ET modeling (TVET) is developed to include the effects of vegetation and topography on mountain-hillslope energy partitioning. The TVET model can be used to map daily potential evaporation and potential transpiration over mountain terrains. The model is also useful for ecohydrologic studies, for example, evaporation and transpiration partitioning of sparsely vegetated ecosystems.

To understand the factors influencing distributed MBR, both generic and specific two-dimensional hydrologic simulations at the hillslope scale were conducted, using the variably saturated hydrologic modeling code, HYDRUS-2D. The results show that the controlling factors for distributed MBR include bedrock permeability, atmospheric forcing (precipitation, and potential evapotranspiration, or PET), vegetation coverage, and soil cover. Among these, bedrock characteristics are the primary control, affecting both the amount and patterns of mountain-block recharge. For bedrock with permeability above a certain threshold (10^{-15}~10^{-14} m^2, equivalent to saturated hydraulic conductivity of 10^{-8}~10^{-7} m/sec), local climate conditions (regional climate setting + local orographic modification + elevation-and-slope-aspect effects on P and PET), which determine the water availability at the soil-bedrock interface, are the most important controlling factors. Vegetation strongly affects distributed mountain-block recharge by modifying surface energy balance and soil hydraulic properties. Root-zone soil thickness has a significant influence, especially for the matrix-flow-dominant bedrock (e.g., non-welded tuff). A change of vegetation cover in mountains can lead to a significant change in basin-scale ground water balance. These results provide criteria for classifying hydrologically similar response units (HRU) in mountain blocks. A framework for the HRU-based approach for quantifying mountain-block recharge is provided. This framework and related sensitivity studies suggest that future efforts should focus on better characterization of mountain bedrock hydraulic properties and better quantification of high-resolution (both temporally and spatially) mountain precipitation estimates.

A simple point-simulation-based approach is applied to map potential mountain-block recharge in two mountian ranges, northern New Mexico. Assuming uniform bedrock, soil cover, and vegetation coverage, the long-term mean downward water flux across the soil-bedrock interface (upper-bound estimate of distributed MBR) can be statistically associated with long-term mean local climate forcing (i.e., mean PET and P). Similarly, the actual ET flux can be related to mean local climate conditions. With these correlations derived from simulations with recharge-optimal bedrock and soil conditions, maps of upper-bound distributed MBR and water yield (or upper-bound of total MBR, i.e., the difference between precipitation and actual ET) are constructed for two mountain ranges with distinctive bedrocks, the southern part of the Sangre de Cristo Mountains and the Jemez Mountains, both in northern New Mexico. The results show that distributed MBR is restricted to the higher elevations in the Sangre de Cristo Mountains, whereas it is more widely distributed in the Jemez Mountains. The area-weighted average upper-bound distributed MBR is about 35% of the water yield in the Sangre de Cristo Muntains, and 50% in the Jemez Mountains. The results also suggest that previous total MBR estimates (70 mm/yr) for the Sangre de Cristo Mountains are reasonable if the bulk bedrock permeability is close to 1×10^{-14} m^2. For the Jemez Mountains, the results give a total MBR between 70~120 mm/yr, about one-half of previous estimates for the San Juan Mountains.

To understand the response of MBR to climate variability, the teleconnections of seasonal precipitation in the mountains in northern New Mexico with PDO (Pacific Decadal Oscillation) and ENSO (El Niño-Southern Oscillation) are investigated. The results suggest a strong correlation between winter and spring precipitation and ENSO and PDO cycles. The summer precipitation, which is dominated by the North American monsoon, does not have clear correlation with ENSO and PDO cycles. For winter and spring precipitation, PDO effects are more dominant than ENSO effects. Low PDO effects are strongly dampened by El Niño, and slightly enhanced by La Niña. ENSO modulation of high PDO effects is not as strong as for low PDO effects. The high PDO effect on winter precipitation is enhanced by El Niño, but not much affected by La Niña. PDO and ENSO effects on winter precipitation are modified by topography, with larger anomalies at higher elevations for wetter winters, and larger anomalies at lower elevations for drier winters. The effects of PDO and ENSO effects on distributed MBR are examined by the recharge-climate index functions, which are derived from generic hydrologic simulations. The results suggest that ENSO and PDO associated climate variability can typically lead to a 10~20% change in distributed MBR for the two tested mountainous ranges. Because of its multi-decadal period, PDO effects on MBR may influence ground water resources in surrounding basins.

ANALYSIS OF THE DEPOSITIONAL ENVIRONMENT OF THE CRETACEOUS MENEFEE FORMATION—SOUTHEASTERN FLANK OF THE SAN JUAN BASIN, NEW MEXICO, by *Michael A. Iacoboni*, 2005, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 172 pp.

The depositional environment of the Upper Cretaceous Menefee Formation within the San Juan Basin was examined in detail using both outcrop and subsurface data. The Menefee Formation consists of five lithofacies: a thick sandstone lithofacies interpreted to represent channel deposits; a thin-bedded sandstone lithofacies that represents crevasse splay deposits; a gray mudrock lithofacies representing overbank deposits; and coally mudrock lithofacies representing backshore peat swamp deposits. A sixth lithofacies is also described: the flaser-bedded sandstone lithofacies. This lithofacies is part of the Cliffhouse Sandstone and represents a lag bed remnant of the beach facies of a transgressive shoreline system. This lithofacies is included because of its close association with the Menefee Formation depositional system.

The elemental composition of siderite concretions associated with the channel facies indicates an early diagenetic freshwater environment for that lithofacies. In addition, the sulfur content of the Menefee coals is relatively high, which indicates formation in a marine-influenced brackish water environment.

The proposed depositional model for the Menefee Formation is a lagoon and swamp dominated coastal plain that is intersected by an anastomosing fluvial system. This system is interpreted to be situated adjacent to a barrier-island dominated shoreline.

DROUGHT DETECTION AND QUANTIFICATION USING FIELD-BASED SPECTRAL MEASUREMENTS OF VEGETATION IN SEMI-ARID REGIONS, by *Geoffrey S. Marshall*, 2005, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 213 pp.

Drought is a serious climatic condition that affects nearly all climatic zones worldwide. Semi-arid regions are especially susceptible to drought conditions because of their low annual precipitation and high variability of precipitation intensity and timing. Drought severity is normally quantified via drought indices such as the Palmer Drought Severity Index (PDSI) and Standardized Precipitation Index (SPI); however, these indices rely on hydrological and meteorological data from weather stations, which may not be available in many areas. Vegetation response to precipitation may be useful as an

indicator of drought stress and drought quantification, and although this response has been studied by satellite sensor analysis of vegetation indices in many regions, there has not been much research using field-based spectral measurements of specific vegetation response to these stresses as a means of drought quantification. Reflectance measurements of rain-sheltered and control creosote shrubs and black gramma grass along with irrigated and control shrubs were taken between January 2003 and October 2004 in the Sevilleta National Wildlife Refuge and processed to give twelve vegetation indices for each one of the vegetation conditions. Each index was correlated to SPI calculated at various timescales from the 5-Points weather station precipitation record between 1999 and 2004 at varying lag intervals, as well as to PDSI data obtained from the National Climatic Data Center to identify which vegetation index had the strongest correlation with the calculated SPI values at which timescale. T-test comparisons were also made between the control vegetation and both the drought-stressed and irrigated vegetation index data. The results show a strong linear correlation between the Normalized Difference Vegetation Index (NDVI), Atmospherically Resistant Vegetation Index (ARVI), Vegetation Index Number (VIN), Soil-adjusted Vegetation Index (SAVI) and Modified Soil-Adjusted Index (MSAI), and the 17-Week SPI for shrub and 14-Week SPI for grass with no time lag. When time lag was taken into account, the SPI timescale of largest correlation decreased in sync with the considered time lag. For the PDI, the greatest correlation was with the Water Band Index (WBI). This implies that the NDVI, ARVI, VIN, SAVI, and MSAVI are potentially excellent indicators of drought severity, and can be used as proxy indicators of drought stress due to precipitation scarcity and/or variation when calculated from field measurements. Also, 11 of the 12 vegetation indices showed statistical differences between the drought-stressed grass and control grass as well as the irrigated and control shrub, but only six of the vegetation indices showed a difference between the drought-stressed and control shrub. The most significant regression equations between vegetation index and SPI for creosote shrub and grass derived from these field-based measurements were applied to satellite images. To overcome the issue of spectral mixing of grass, shrub, and soil within a single pixel when upscaling from point measurements to ASTER satellite data is performed, the linear unmixing spectral analysis technique was implemented to obtain an estimated fraction of each type of surface (grass, soil, and shrub) within a pixel using field-based averages of shrub, grass, and soil reflectance and vegetation indices as end members. The unmixed results were generally representative of the actual land cover classification, but the actual percentages at some pixels were not quite accurate due to the underestimation and overestimation for soil and grass end members respectively. After linear spectral unmixing analysis, the ASTER spectral reflectance images were converted to SPI images. Comparison with SPI data from the National Drought Mitigation Center (NDMC) shows that:

(1) ASTER SPI images have a higher spatial resolution (15 m) than NDMC SPI images (>100 km, on the scale of the climatic division), making it hard to upscale accurately.
(2) SPI prediction results varied according to the unmixing method used and were inconclusive.

As the spatial resolution of NDMC SPI images is very low, validation of the present algorithm for SPI mapping using high-resolution satellite data with other data sets should be continued in the future. Application of further land cover remote sensing research should be considered for future work as well.

MICROMETEOROLOGICAL MODELING OF AN IDEALIZED CAVE AND APPLICATION TO CARLSBAD CAVERN, NEW MEXICO, by *Setsuko Shindo*, 2005, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 244 pp.

Air-filled caves are subsurface, semi-closed systems with their own poorly understood internal micrometeorology. Cave micrometeorological processes may contribute to the formation and subsequent enlargement of caves and control some of the details of secondary mineral deposition. In this work, we consider some aspects of the internal fluid-thermal dynamics of caves, especially buoyancy and natural convection due to geothermal heating, characterized by a Rayleigh number defined for cave conditions. Two-dimensional steady state computer models of idealized caves were created using FEMLAB multiphysics computer software. The thermal properties of limestone and air, and geothermal flux were incorporated into the models. Limestone was considered an impermeable material. The models couple the incompressible Navier–Stokes equations (air phase only) with the thermal energy convection and conduction equation using the finite element method.

Although the constructed models are limited in scale and have highly simplified geometries compared to real caves, they have identified some important factors that influence internal cave dynamics. Air-filled caves act as insulators. Geothermal heat produces convection cells in the deeper parts of caves, where there is less influence from the surface. These internal dynamics can induce the flow of surface air into caves largely due to thermally induced buoyancy forces, the conservation of mass of essentially incompressible air, and cave geometries (e.g., the presence of multiple entrances).

Humidity is an important factor frequently cited as influencing cave features. However, Rayleigh number and instability analyses indicate that humidity has less impact on flow dynamics in moderate cave meteorological conditions (e.g., cave air temperature of 20° C); on the contrary, humidity may be affected by fluid flows. Future studies on subjects such as latent heat transport, evaporation, and condensation will be required.

Unlike our steady state models, real cave systems could be transient and, thus, the rate of escaping air could be different from the rate of incoming air. Because cave air moves in order to conserve air mass, if caves temporarily have excess air mass, a high air pressure area may be created locally, triggering the movement of this air to areas of lower pressure. As a result, if a cave entrance is large enough, inflow and outflow components can be observed at a single entrance. The models were applied to help explain several observed phenomena within Carlsbad Cavern, New Mexico. This cave is an extremely large and geometrically complex cave; however, the simple models constructed in this study help to shed light on the interpretation of observations.

To our knowledge, this modeling effort is the first attempt to capture the behavior of such cave micrometeorological systems in a quantitatively rigorous manner. We believe that computer modeling can be very useful to assist understanding of the dynamics of cave interiors and possible effects on the enlargement and subsequent mineralogical decoration of caves. Modeling combined with detailed and continuous site monitoring in real caves, and attempts to include the vertical variations of humidity, cave pressure fluctuations, and salient aspects of cave geometries will be especially fruitful.

University of New Mexico

TECTONIC AND METAMORPHIC IMPLICATIONS OF HIGH CHLORINE CONTENTS IN SERPENTINITES, by *Jaime D. Barnes*, 2006, Ph.D. dissertation, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 161 pp.

Serpentinites contain significant amounts of chlorine (up to 1 wt% Cl), as well as 13 wt% H_2O, and are stable to depths of 150–200 km in subduction zones, thereby making serpentinites a major carrier of chlorine and water into the deep mantle. Incorporation of chlorine from the serpentinite into the slab-derived fluid will alter the resulting fluid chemistry by generating a high-salinity fluid with a low water activity. Serpentinite dehydration is likely responsible for intermediate to deep-focus earthquakes, and serpentinite-derived high-salinity fluid can drastically alter the trace element transport efficiency from slab-derived fluids to the mantle wedge, ultimately affecting metasomatic properties and water activities in metamorphic systems. Not only does serpentinite chemistry affect geodynamics, subduction zone geochemistry, and continental metasomatism, but is also a major component in the global chlorine cycle, potentially balancing the cycle.

This dissertation comprises six chapters, each investigating the role of serpentinite-hosted chlorine on subduction zone geochemistry, metasomatism, tectonics, and the global chlorine cycle. Serpentinites are shown to host Cl within multiple sites, including water-soluble salts, iowaite, fine-grained amorphous serpentine along bastite and relict olivine-serpentine mesh interfaces, and within bastite lamellae and chrysotile tubes. Chlorine concentration and chlorine isotope composition analyses on both water-soluble and structurally bound Cl serpentinites from a series of ODP/DSDP seafloor serpentinites and obducted serpentinites from Italy and Costa Rica show that $\delta^{37}Cl$ values in serpentinites are a sensitive indicator of the source of the serpentinizing fluid and can be used to decipher tectonic processes involved in serpentinization. The chlorine isotope and concentration data from serpentinites, as well as the additional $\delta^{37}Cl$ measurements from meteorites, mantle-derived materials, and early Earth evaporites, are then used to model the secular global chlorine cycle. Serpentinites are shown to be a major contributor of Cl to the mantle, but isotopic work on volcanic gases is necessary to fully evaluate the model.

EXAMINING WATER-ROCK INTERACTION AT IDAHO NATIONAL LABORATORY AND SALINIZATION OF THE RIO GRANDE USING URANIUM AND

STRONTIUM ISOTOPES AS NATURAL ENVIRONMENTAL TRACERS, by *Elizabeth M. Nichols*, 2006, M.S. thesis, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 217 pp.

$^{87}Sr/^{86}Sr$, $\delta^{234}U$, and U and Sr concentrations of perched water and core leachates from the Vadose Zone Research Park (VZRP) at the Idaho National Laboratory (INL) have been measured to examine water-rock interaction in order to directly correlate the behavior of natural U and Sr at the VZRP to actinide and ^{90}Sr contamination on other laboratory property. $^{87}Sr/^{86}Sr$ vs. $\delta^{234}U$ for all samples give a reaction path between two end members, the outfall water and another member at depth. Water samples taken from one well depth over a period of two months during a Br-tracer test show decreasing $\delta^{234}U$, and no change in concentration, that corresponds with Br-breakthrough. The Br-tracer test coincided with a change in the location of the outfall discharge; thus the decreasing $\delta^{234}U$ is a result of interaction with newly wetted vadose zone materials. Isotopic analysis of leachates of core material from have determined that uranium from the pore water, exchangeable, and carbonate material in the surficial sediment is readily available to initially infiltrating water. Exchange with lower $\delta^{234}U$ uranium affects perched water compositions for months after initial wetting. $^{87}Sr/^{86}Sr$ ratios of perched water are lowered briefly during wetting, but similarities between the outfall and extractions limit Sr interpretations. However, this study should help predict behavior of Sr and U at contaminated sites.

$\delta^{234}U$ and U concentration of samples from the Rio Grande and agricultural drains have been analyzed to examine salinization of the Rio Grande from the headwaters in Colorado to the U.S.–Mexico border at Ft. Quitman, Texas. U concentrations increase at locations downstream of basin termini that are associated with increases in salinity (Mills 2003). Data show a net decrease in $\delta^{234}U$ with distance from the headwaters, corresponding to increases in river U concentrations. This indicates that there is addition of U to the Rio Grande from water with $\delta^{234}U$ values closer to secular equilibrium. Uranium data support recent studies, which determined that addition of 1–10% of sedimentary brine from ground water can account for the observed increases in salinity of the Rio Grande (Hogan et al. in preparation; Mills 2003).

SIGNIFICANCE AND IMPLICATIONS OF HOLOCENE LACUSTRINE AND ALLUVIAL DEPOSITS, LAGUNA EL FRESNAL BASIN, NORTHERN CHIHUAHUA, MEXICO, by *Jeffrey S. Parker*, 2005, M.S. thesis, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 105 pp.

In the Laguna El Fresnal basin the timing and magnitudes of latest Pleistocene and Holocene climate changes are bracketed using stratigraphic and geomorphic evidence from the distal alluvial fan environment, which is used to interpret the local geomorphic responses.

The latest Pleistocene highstand (BR I) at 1,210 m has a minimum age of ~11 ka. Sometime during the Pleistocene–Holocene transition the basin may have completely desiccated. The BR I deposits were deeply incised before lake reoccupation in the early Holocene (BR II) to 1,202 m. Then, desiccation occurred until the middle Holocene highstand (BR IIIa) at ~1,192 m. Evidence of BR IIa is absent from described stratigraphic sections due to local scouring. In the early Neoglacial a lake (BR IIIb) reoccupied the Laguna El Fresnal basin to ~1,192 m for ~600 yrs. Following this highstand the climate became drier and the basin desiccated. A subsequent period of pedogenesis and stability lasted less than ~1,000 yrs. In the late Holocene before 2,600 cal yr B.P. aggradation resumed as an inset back filling probably until ~1,000 cal yr B.P. Although there is no geomorphic evidence for a beach ridge, aquatic molluska (*Physa* sp.) found suggest an effectively wetter period. Then there is a short interval of pedogenesis and stability followed by aggradation associated with the Little Ice Age (LIA) lake (BR IV) at 1,188 m ~500 cal yr B.P. The LIA lake had a duration of ~200 yrs, a ~10% smaller surface area, and a ~30 to 50% smaller volume than the early Neoglacial lake. After LIA lake desiccation incision began across the BR IV berm, which was infilled by coarse gravels. Near the turn of the century, the modern channel was incised to two-thirds of its present depth.

In the Laguna El Fresnal basin during effectively wetter intervals high lake levels and reduced gradient may have assisted distal fan aggradation by decreasing stream power. During effectively drier intervals or transitional periods increased gradient and possibly short intervals of high magnitude discharges may trigger incision and encourage soil development.

LATE HOLOCENE CLIMATE VARIABILITY IN THE SOUTHWESTERN UNITED STATES FROM HIGH-RESOLUTION SPELEOTHEM DATA, by *Jessica B. T. Rasmussen*, 2006, Ph.D. dissertation, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 199 pp.

A long-term, high-resolution moisture record based on annual stalagmite banding from southeastern New Mexico is used to investigate the relationship between local climate variability and larger ocean-atmospheric oscillations, and to characterize how these relationships have modulated climate variability over the late Holocene. Two years of cave drip rate, pressure, temperature, and humidity data show a fast response of the cave environment to surface variability, and seasonal changes in drip rate and drip water chemistry that correspond to seasonal precipitation variability. The fast cave response supports the use of speleothems as annually resolved proxies for regional moisture variability. A complete, annually resolved moisture record for the last 3,245 yrs, based on multiple stalagmites, shows dramatic shifts from pluvial to drought conditions between 2,700–2,100, 1,800–1,500, and 700–300 yrs B.P. that coincide with important cultural transitions in the Southwest.

Statistical analyses suggest that late Holocene precipitation variability in the Southwest has been caused by changes in the Pacific Ocean, indicating large shifts from pluvial to drought conditions alternating with periods of dampened, near-average precipitation over the last 3,000 yrs. Significant spectral peaks at decadal-scale frequencies likely correspond to modern frequencies of the Pacific Decadal Oscillation, and are dominant during episodes of large precipitation shifts. Correlation between modern precipitation in Asia and the study region further supports Pacific modulation of late Holocene drought cycles. Stalagmite growth suggests an onset of wetter conditions around 3,000 yr B.P. relative to the middle Holocene, likely driven by cooler temperatures and changes in PDO/ENSO variability. The record suggests overall conditions have become increasingly drier over the last 1,500 yrs, with modern climate conditions comparable to other periods of major drought during the late Holocene.

This study provides unprecedented insight to the long-term effects of the PDO/ENSO system on precipitation variability in the Southwest. Severe droughts that punctuated wetter than normal periods of the late Holocene may have challenged emerging agrarian ancestral American communities; given the evidence for such dramatic precipitation variability and the late Holocene trend toward increased aridity, the modern effects of increased global surface temperatures on the PDO/ENSO system should be cause for great concern.

LATE CRETACEOUS SELACHIAN BIOSTRATIGRAPHY IN NEW MEXICO, by *Sally C. Williams*, 2005, M.S. thesis, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 117 pp.

New Mexico has an extensive fossil record of Late Cretaceous sharks that provides a basis for understanding their biostratigraphy, evolution, and paleoecology. Seven biostratigraphically distinctive assemblages of selachians can be recognized for the Late Cretaceous Western Interior Seaway in New Mexico: (1) middle Cenomanian–middle Turonian *Ptychodus anonymus* zone; (2) middle Turonian *Ptychodus anonymus–Ptychodus whipplei* zone; (3) middle Turonian–middle Coniacian *Ptychodus whipplei–Squalicorax falcatus* zone; (4) middle Coniacian *Ptychodus mortoni–Squalicorax falcatus* zone; (5) middle Coniacian–late Santonian *Ptychodus mortoni–Squalicorax kaupi* zone; (6) early Campanian–middle Campanian *Squalicorax kaupi–Squalicorax pristodontus* zone; and (7) middle–late Campanian *Squalicorax pristodontus–Cretodus* zone. The primary species that define these zones belong to the genera *Ptychodus* and *Squalicorax* because they have the most complete fossil record of the selachian species found in the New Mexican Upper Cretaceous. Each *Ptychodus* species has an average species duration of 4.1 million years, whereas *Squalicorax* species have an average duration of 11 million years. The evolutionary turnover of species of these genera correlate to marine regressions. There are three assemblages that are examined for paleoecology. The middle Turonian Atarque Sandstone–Semilla Sandstone–Juana Lopez system provides a group of nearly time-correlative localities of both nearshore and offshore localities, and show that nearshore localities are much more diverse and the fossils more abundant. The El Vado Sandstone provides a look at an unusually pelagic fauna where the assemblage is not dominated by one single species of grasping dention lamniform shark. The third assemblage is the Dalton–Hosta system. This allows us to compare the effects of taphonomy on the abundances of species present.