proach, Example from West El Reno Field, Canadian County, Oklahoma

The Frisco Formation is a middle Lower Devonian limestone within the Hunton Group (Upper Ordovician-Lower Devonian). In the Anadarko basin, the Frisco Formation consists of skeletal packstones and grainstones, whose main components are pelmatozoans, brachiopods, and, locally, corals. Depositional intergranular porosity has been mostly obliterated through syntaxial cementation on pelmatozoans, and mechanical and chemical compaction. Only minor intrabryozoan primary porosity remains. Secondary porosity, which formed during subaerial exposure of the Frisco Formation during the late Early and Middle Devonian, occurs locally at the top of the formation in the form of partly leached grains, vugs, and solution channels. This secondary porosity is best developed close to areas where the formation was completely eroded; these areas commonly correspond to Middle Devonian paleostructures.

Hydrocarbon accumulations in the Frisco Formation are mainly in stratigraphic traps situated downdip of the areas where the formation has been severely truncated. The Woodford Shale (Upper Devonian-Lower Mississippian) unconformably overlies the Frisco Formation in the study area and provides a source, trap, and seal for Frisco Formation reservoirs.

Geophysical identification of Frisco Formation porosity is possible using Relative Amplitude (RAM) processing. Mapping of porosity and truncated margins, and identification of potential hydrocarbon traps, are facilitated by using these RAM processed seismic sections. The West El Reno field, Canadian County, Oklahoma, produces gas and condensate from an outlier of the Frisco Formation, and provides a template for this technique.

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Overview of LASL Oil Shale Program

The Los Alamos Scientific Laboratory (LASL) is involved in a broad spectrum of oil shale-related activities for the Department of Energy (DOE), including the bed preparation design of a modified in-situ retort. This aspect of oil shale research has been identified by the DOE as one of the limiting technologies impeding commercial, in-situ development of oil shale.

The retort bed must have uniform particle size, permeability, and void distributions to allow proper retorting and optimum resource recovery. Controlled fracturing using chemical explosives and carefully designed blasting schemes are the only feasible methods to attain this distribution. Our approach to the bed preparation problem is a coordinated research program of explosives characterization, dynamic rock mechanics, predictive computer modeling, and field verification tests.

The program is designed to develop the predictive fracturing capability required for the optimum rubbling of the shale. It takes advantage of the large computing facilities at Los Alamos and the considerable expertise in explosives and computer hydrocodes developed here for other energy and national defense programs. As these codes are developed for oil shale and refined, they are tested with field verification experiments. Tests with up to four boreholes and single-decked charges conducted at the Colony Mine in Colorado in conjunction with ARCO and TOSCO, have demonstrated the ability to predict rock behavior. Larger experiments with more boreholes and decked charges will be done at the Anvil Points Mine near Rifle, Colorado. These field tests will calibrate the fracture modeling codes and confirm their validity to predict explosive fracturing, including the effects of existing joints and fractures in the oil shale. The experiments will also include fluid flow tests to verify the three-dimensional models of multiphase flow that are under development at LASL.

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Mineral Exploration Using Landsat Image Processing and Interpretation Techniques

Custom-processed, enhanced Landsat images were produced to support mineral exploration and resources mapping programs in: (1) the Marfa basin of west Texas, and (2) Puerto Rico. The objective of these projects was to map surface geologic features from the images to aid in geologic analysis of mineral potential.

Contrast-stretched false color images and high-pass filter images ranging in scale from 1:125,000 to 1:250,000 were made for both areas. Through interpretation, a variety of features (linears, curvilinears, drainage patterns, lithology, etc) were successfully mapped. A significant amount of new information was collected (e.g., 30% more linears were mapped in west Texas).

Due to the semi-arid nature of west Texas, techniques that exaggerate spectral differences of the land surface as sensed by the satellite, were used to aid in mapping rock units. A series of ratio images was made to enhance iron oxides, a potential indicator of mineralization in this area. Extensive field work and spectral radiometer studies were used to evaluate initial results and collect data to permit more effective image processing. Ratio images of the visual green and visual red spectral bands proved highly effective for mapping iron oxides.

Due to its synoptic, regional view and effectiveness for mapping a variety of surface geologic features, Landsat image processing and interpretation can provide significant new information that is especially useful in the reconnaissance stages of exploration. When used in conjunction with other data sources and geologic analysis, Landsat can improve exploration programs.

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Paleogeography and Tectonic Implications of Late Cretaceous to Middle Tertiary Rocks of Southern Denver Basin, Colorado

In the southwestern Denver basin, the lower part of the Dawson Formation consists of point-bar sequences composed of andesitic detritus. Eastward, it thickens and becomes predominantly mudstone with subordinate thin point bars. The upper Dawson consists of a basal, eastward-thinning, wedge of feldspathic (braided stream) conglomerates followed by feldspathic or andesitic point-bar deposits, overlain by braided-stream arkoses. Dawson cross-bedding dips eastward. During lower Dawson deposition, the Front Range is interpreted to have only minor topographic expression because andesitic debris came from a source west of the Front Range and was deposited in meandering streams. Early Paleocene erosion of the first Laramide exposure of the Front Range basement produced the lower arkosic unit. Following meandering-stream deposition, a second major arkosic pulse of coarse braided-stream deposits prograded eastward (late Paleocene–early Eocene). Extensive Eocene erosion and stability followed until the Oligocene when the extensive Wall

Mountain Tuff (35 m.y.) was ejected from the southern Sawatch Range and flowed up to 30 km east of the Front Range. The Oligocene Castle Rock Conglomerate forms an elongate, northwest-southeast, discontinuous band across the southern Denver basin. Cross-beds dip east and southeast. Thick tabular cross-beds and large granite boulders derived from the Front Range indicate torrential flood deposition. North to northwesterly dipping bedding, and up to 1,000-m vertical offsets between Front Range Wall Mountain Tuff outcrops and those in the Denver basin suggest significant post-Castle Rock uplifting of the Front Range.

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Sedimentology and Tectonic Implications of Oligocene Castle Rock Conglomerate, Southern Denver Basin, Colorado

The Oligocene Castle Rock Conglomerate, 70 m thick, trends northwest-southeast in an elongate discontinuous band (80 km long) across the central Denver basin from near Castle Rock to Calhan, Colorado. The conglomerate was studied to determine the depositional environment and any implications on the tectonic history of the southern Front Range. The Castle Rock Conglomerate is a nonmarine formation with large-scale cross-bedding. It contains angular slump blocks of Wall Mountain Tuff, some exceeding 2 m in length, as well as rounded boulders and cobbles of Front Range basement rocks. It fills valleys, up to 90 m deep, carved into the underlying Oligocene Wall Mountain Tuff and the early Tertiary Dawson Formation. The Castle Rock Conglomerate is interpreted as a deposit of a braided stream, possibly an ancestral South Platte River, which flowed in a broad valley toward the east then southeast.

Several tectonic implications were determined from this study: (1) the Front Range, after being eroded to a low plain in the Eocene, was regenerated after the middle Oligocene, as shown by structural offset of the Castle Rock at the edge of the Front Range, and by its interpretation as a restricted fluvial deposit rather than a broad fanglomerate; (2) the fluvial interpretation supports other suggestions that this formation resulted from the eastward diversion of the Rio Grande headwaters by the Thirtynine Mile volcanic field across the area which is presently the Front Range; and (3) north to northwesterly dipping beds, opposite to paleocurrents, indicate post-Castle Rock rotation of the Denver basin.

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Storm-Surge Ebb Deposits of Early Cambrian Shelf: Andrews Mountain Member, Campito Formation, Eastern California

The Andrews Mountain Member of the Campito Formation consists of complexly interbedded fine sands, siltstones, and mudstones that accumulated in an offshore, shallow-shelf setting. Deposition of these units was punctuated by short duration, high-energy flows that deposited crudely graded, hummocky cross-stratified sand beds. These flows are inferred to be the product of the ebb of large storm surges. The sedimentology of these units indicates a five-stage scenario for their formation. (1) Initial erosion and suspension of muddy fairweather substrates occur in response to long-period storm waves. (2) As an intense low-pressure system moves onshore, a sediment-charged return bottom flow is generated by a storm-surge ebb. This flow moves across the shelf and further erodes and entrains material. (3) As the competence and capacity of the flow are exceeded, fine sand is deposited as parallel laminated and hummocky cross-stratified units. (4) Rapid attenuation of the flow then leads to low-flow regime deposition of climbing ripples and small-current ripples. Where deposition occurs within storm wave base, upper parts of the beds are reworked into complex wave-current ripples and flaser bedding. (5) Soft-bodied, benthic communities recolonize muddy substrates with the resumption of fairweather conditions.

Rather than depositing sand sheets over extensive areas, multiple storm-surge flows are inferred to have incrementally moved sand across the shelf. In addition, thinning/fining-upward and thickening/coarsening-upward stratigraphic sequences may reflect changes in both the intensity of the flows and the proximity of a local sand source.

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Sedimentologic Aspects of Bioturbation in Abyssal Atlantic Ocean

Relations between bioturbation features and sedimentologic aspects of abyssal pelagic ooze and clay were investigated in 26 box cores collected in 1,400 to 5,700 m of water in the central and southern Atlantic Ocean. Sediment composition, texture, and core stratigraphy were compared with the occurrences of biogenic structures and other aspects of bioturbation to determine the sedimentologic factors that most affect burrow preservation and biologic mixing of abyssal sediment.

Box core surfaces typically exhibited a heterogeneous microtopography of mounds, lumps, trails, agglutinated tubes, and open holes. Benthic protists (foraminifera and xenophyophorids) and fecal strings of larger organisms were common. Remnants of shallow infaunal tunnel systems sometimes were evident on slightly washed box core surfaces. For example, *Paleodictyon* occurred in carbonate-rich ooze; *Cosmorhaphe* occurred in deposits containing 20 to 30% coarse fraction; and *Spirorhaphe* appeared to be cosmopolitan with respect to sediment type.

Sediments of the mixed layer (upper 5 to 8 cm) and underlying Holocene transition layer were compared with respect to carbonate, organic carbon, and coarse fraction ($>62\mu m$) percentages. Transition layer sediments, which contained the most visible burrows, were much more heterogeneous in terms of carbonate content than mixed layer deposits. However, the heterogeneity of organic carbon and coarse fraction concentrations were roughly equivalent in the two horizons.

Visibility of specific burrows was highest in cores with low carbonate contents ($<30\%$ $CaCO_3$) and also in cores from the Sierra Leone Rise, where sedimentation patterns appear to have changed following the last glacial stage. Burrow visibility was poorest in cores with high carbonate contents ($>70\%$ $CaCO_3$) throughout the entire core.

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Anatomy of Modern Open-Ocean Windward Carbonate Slope: Northern Little Bahama Bank

The modern carbonate slopes in the northern Bahamas are classified as windward or leeward types along open oceans, open seaways, or closed seaways.

Morphologically the open-ocean windward carbonate slope,