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Stratigraphy and Paleontology of Bisti Badlands, San Juan County, New Mexico

Study of 29 stratigraphic sections of the Upper Cretaceous Cliff House Sandstone, Lewis Shale, Pictured Cliffs Sandstone, Fruitland Formation, and Kirtland Shale in the Bisti Badlands of northwestern New Mexico suggest deposition in deltaic environments. Cliff House Sandstone littoral, Lewis Shale prodelta and delta-front, Pictured Cliffs strand-plain, levee, and distributary-channel, Fruitland Formation paludal, estuarine, and delta-plain, and Kirtland Shale flood-plain facies document the transgression and regression of the last epeiric seaway for the San Juan basin.

Littoral and strand-plain paralic facies, respectively, delineate transgressive and regressive sequences, whereas prodelta and delta-front facies reflect deposition in offshore open-marine waters. Late Campanian fossils represented by marine mollusks, sharks and dinoflagellates, pelagic foraminiferids, benthic ostracods, littoral and shallow-neritic *Ophiomorpha* burrows, and terrestrial palynomorphs illustrate that marine conditions prevailed but were contaminated by terrestrial biotas. Deposition of delta-front sandstones 1 km or more from shore is substantiated by the hypopycnal inflow formula.

Terrestrial environments, represented by levee, distributary-channel, paludal, delta-plain, and flood-plain facies, exhibit the deposits of vertically accreted shale, laterally accreted channel sandstones, and coal. Overbanking of distributary channels formed natural levees on the periphery of interdistributary marshes, thereby preserving a coal to shale to sandstone vertical sequence. Local transgression due to channel abandonment and delta-lobe subsidence deposited estuarine shale and upward-coarsening, crevasse-splay sandstones. Delta-plain to flood-plain facies shows the transition from thick commercial coals and shale, to shale and channel sandstones, to shale which contain local coal, bentonite, and channel sandstones. The transition represents, respectively, poorly drained swamps, well-drained delta-top tracts, and riverine with lacustrine regions. Aquatic bivalves and gastropods plus fish, turtle, crocodile, and dinosaur bones occur as lag deposits to channel sandstones. Locally, articulated dinosaur, turtle, and crocodile bones are present in the vertically accreted shale.

Nine hundred million metric tons of coal from four coal seams of the lower Fruitland Formation represent a major energy resource for New Mexico. Western Coal Co., Albuquerque, intends to strip mine 80 million metric tons of coal found within the study area.

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Geology of Espinaso Formation (Oligocene), North-Central New Mexico

In the Hagan basin of north-central New Mexico, Espinaso Ridge contains the largest and least deformed exposures of the Espinaso Formation (Oligocene). The Espinaso primarily consists of 430 m of volcanic detritus eroded from eruptive centers in the Ortiz Mountains and Cerrillos Hills. The Espinaso appears conformable and gradational with the underlying Galisteo Formation and is overlain unconformably by the Santa Fe Group.

Sedimentary structures, facies relations, and upward coarsening sequences indicate that the Espinaso was deposited on prograding alluvial fans by braided streams and laharic flows.

Clasts in the conglomerates range from andesitic near the base of the formation to latitic near the top. A chemical analysis from an interbedded lava flow in the upper half of the section shows a normative composition of nepheline latite. The sandstones are composed mostly of feldspar and lithic fragments. The most distinctive petrologic characteristics of the Espinaso are high P/F ratios, low quartz, lack of any lithic fragments other than volcanic fragments, and high percentages of microlitic volcanic fragments.

The sedimentary record suggests that the commencement of volcanic activity in late Eocene time coincided with deposition of upper Galisteo sandstones. By Espinaso time, significant volcanic activity caused the progradation of coalescing fans over a region of low physiographic relief. The fine grain size of uppermost Espinaso sediments suggests the waning of volcanic activity in the latest Oligocene.

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Effects of Physical and Chemical Diagenesis on Low-Porosity, Low-Permeability Sandstones, Mesaverde Group, Uinta Basin, Utah

Examination of sandstones from core samples spanning a 110-m interval of Upper Cretaceous Mesaverde Group indicates that physical compaction of labile rock fragments and chemical diagenesis greatly modified the original lithology. These modifications reduced porosity (to less than 10%) and permeability (generally to less than 0.5 md at surface conditions). Local silty lamina further reduce vertical permeability.

The sandstones are predominantly feldspathic litharenites composed of monocrystalline and polycrystalline quartz, igneous, metamorphic, and fine-grained sedimentary rock fragments, and small amounts of potassium and plagioclase feldspars. Cementing agents include quartz overgrowths, authigenic low-albite on plagioclase, intergranular calcite and dolomite, and authigenic clays (kaolinite, illite, and minor chlorite). Quartz overgrowths are more common than in the Mesaverde Group sandstones previously examined, and undoubtedly reduce porosity. The overgrowths are sometimes separated from the detrital-quartz host by an iron oxide-stained dust ring or by a thin ($\pm$ 2 μ) film of chlorite. Locally, early formed intergranular calcite occupies as much as 40% of volume and, in addition to virtually eliminating porosity, has largely prevented compaction of labile rock fragments. Chert and fine-grained sedimentary rock fragments are commonly compacted between more competent framework grains. Following compaction and deformation, leaching of feldspars and rock fragments produced secondary porosity, which includes most measured porosity in these sandstones.

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Hydrology of Strippable Coal Deposits, San Juan Basin

Commercial coal deposits of the San Juan basin are associated with intertonguing Cretaceous marine and nonmarine deposits. Sandstone units in this stratigraphic sequence act as ground-water aquifers that may be affected by mining operations. Sandstone aquifers can be classified as areally extensive with significant potential for ground-water development, or as discontinuous aquifers of limited potential.

Coal deposits in the lower part of the stratigraphic sequence generally are associated with areally extensive sandstones.

These include the Dilco coal which rests on the Dalton Sandstone, and the Cleary coal which overlies the widely distributed Point Look Sandstone. Menefee and Kirtland-Fruitland coals are commonly associated with discontinuous sandstones of limited ground-water potential.

Much of the natural ground water associated with the coal deposits of the San Juan basin does not meet the water-quality standards of the Public Health Service or the Office of Surface Mining. However, to prevent further degradation, stripping and reclamation practices should be based on the regional hydrologic system and on the hydrologic characteristics of the coal-associated aquifers.

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Response of Rio Grande River to Dam Construction

Data in sufficient detail to support a qualitative assessment of the geomorphic response of the Rio Grande to the construction of main-stem dams are available for two reaches in New Mexico: below Elephant Butte Dam and below Cochiti Dam. Documentation of channel adjustments below Elephant Butte Dam during 1917-32 provides a set of interpretive keys to support a detailed analysis of the response of the Rio Grande to the construction of Cochiti Dam in 1973. A comparison of cross-section, planform, and profile data develops a time-sequenced picture of geomorphic change during 1970-80 in the 50-mi (80 km) reach of the Rio Grande below Cochiti. When correlated with the hydrologic records, hydraulic data, and the history of engineering activity in the reach this analysis provides a qualitative assessment, in terms of trends, of the response of a semiarid zone alluvial river to dam construction.

Regulation of discharge and alternation of sediment load following closure of Cochiti Dam required major adjustments in the alluvial system below the dam. In the upper reaches, gravel armor and base-level control by the volume and size of sediment in arroyo and tributary deltas restricted change in the vertical dimension. Correlative adjustment in river planform was strongly influenced by channelization activities. In the lower reaches, adjustment has been through significant shifts in longitudinal profile with relatively little change in planform. Degradation was limited by gravel armor and arroyo control in the upper reaches, but became the dominant process in the middle reaches. In the lower reaches, an initial period of degradation was followed by aggradation as the heavy sediment load derived from upstream scour encountered a slightly reduced gradient and depletion of main channel flow by successive irrigation diversions. Available hydrologic data also permit evaluation of the impact of an extended period of regulated low flow and a sustained period of high flow on system stability.

A qualitative analysis, alone, yields meaningful results, and also supports a more precise assessment of river response as well as the predictive capability that can be derived from physical-process computer modeling.

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Environment of Deposition and Uranium Host Rock Potential of Jurassic Morrison Formation, Northeastern New Mexico

A stratigraphic examination of the Morrison Formation in northeastern New Mexico indicates that its sediments were deposited in either a semiarid or arid environment when the area was located below 30°N lat. and was under the influence of the Northeast Trades. The dry environment and the prevailing northeasterly flow adversely affected the chance of commercial quantities of uranium from being incorporated into Morrison sediments.

Dinosaurs that lived in the area were adapted to living in a dry and hot habitat.

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Preliminary Basin Analysis of El Rito Formation (Eocene), North-Central New Mexico

The Eocene El Rito Formation of north-central New Mexico is the basal Tertiary unit of the Chama basin and the northwestern Espanola basin. Deposition of the El Rito occurred in the final stages of the Laramide orogeny. The formation is an alluvial-fan deposit, showing two principal facies, quartzite conglomerate and quartzose sandstone. Paleocurrent directions determined from imbricated clasts, cross-bedding, and parting lineations indicate that the primary sources for the sediment were in the north and northeast.

The clasts of the early, conglomeratic facies were derived from the reworking of sediments eroded from the Precambrian crystalline highlands of northern New Mexico early in the Laramide orogeny. The conglomerates represent debris-flow, sieve and high-energy, braided-stream gravel deposits. The immature, sand-sized particles were derived from proximal sources in the Brazos uplift during the final stages of the Laramide orogeny. The sandstone units represent sheet-flow sediments deposited from lower energy, braided streams with more easterly sources than the sources for the conglomerates.

Point counts of thin sections of four sandstone samples show high QFL% quartz and QpLvmLsm% metamorphic lithics. These results are consistent with a provenance in the Precambrian metamorphic core of the Brazos uplift. Extensive diagenetic effects typical of Cenozoic desert alluvium include calcite, zeolite, and hematite pore-filling and replacement of grains, alteration of feldspars, and removal of heavy minerals.

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Historical Geology as Framework for Synthesis and Management of Data from Environmental Impact Studies in New Mexico

Development of New Mexico's energy resources and concomitant utilization of other resources produce unavoidable impacts on the environment. Although areas involved in specific projects are comparatively small, the cumulative extent of impacted areas is substantial. Currently, required studies of impacts produce inventories and descriptions of discrete subjects (e.g., climate, water quality, soils, biota, archeology, paleontology, etc) without relating the subjects to a larger system, or more completely analyzing their scientific potential in the context of natural systems. Historical geology provides a framework for a unified study of the dynamics of the predevelopment environment. This synthetic approach indicates which data are redundant and what further data are needed, provides a long-term baseline for evaluating impacts of development, and provides insights for mitigation of adverse impacts. Because historical geology considers the chronology of changing landscapes and their ecology, the environmental context of data is essential for reconstructing the