

with multidirectional trough and planar cross-bedding, *Ophiomorpha* sp., rounded mud clasts, and mud blocks. The tidal channel cuts through tidal-flat deposits, is approximately 40 m wide and 11 m thick, and contains gently dipping accretion beds of fine to very fine sand, including small-scale cross-stratification, and upwardly decreasing sand bed thickness. The lithology and sedimentary structures of facies 3 strongly resemble classic tidal-flat deposits of the Wadden Sea.

The west pit exposes a regressive sequence of (1) tidal-inlet fill, (2) a poorly represented upper shoreface-beach-barrier flat facies, overlain by (3) bay-lagoon deposits. The inlet facies of fine to very fine sand includes large-scale, low-angle planar cross-beds, *Ophiomorpha* sp., bipolar, planar cross-beds, and has a scoured base. Some zones are highly burrowed. Facies 2 consists of trough and planar cross-bedded fine to very fine sand, with low-angle parallel bedding, root traces, and woody fragments near a hummocky upper surface. Facies 3 includes an ashy, burrowed lignite overlain by a massive, burrowed clayey siltstone containing plant debris. Facies 1 and 2, as well as the base of the lignite bed, are uranium bearing.

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Uranium in Volcanic Rocks: Progress

Calc-alkaline rocks of crustal(?) derivation analyzed 0 to 5 ppm uranium in magmatic phases, but hundreds of ppm in epigenetic end-products. Alkaline rocks of mantle(?) derivation analyzed 0 to 22 ppm in magmatic phases, 30 to 45 ppm in deuterically modified phases and hundreds of ppm in final epigenetic modifications. Incompatibility with rock-forming silicates relegates large ions including uranium to residual gas or fluid. Mantle volatiles released during magma generation or crystallization mineralize rocks according to relative chemical reactivity.

In rocks with < 5 ppm U, U-Th were not detected by autoradiography or fluorescence. Uniform weak glow at 10 to 20 ppm U suggests uniform distribution at the eutectic. Selective distribution in more uraniferous rocks favors deuterite or pegmatitic biotite, zircon, complex silicates, and multiple oxides. U-Th uniformly distributed within grains are considered contemporaneous lattice substitutions. Some magmatic minerals in rocks with > 60 ppm U show inclusions variably containing Th, REE, U, Ti, V, Ni, Cr, Cu, Pb, Zn, Ba, and Mn. Halogens, S, and P underscore the volatile role. Inclusion-laden asphaltite is common. Lattice inclusions may represent vapor trapped during crystallization. Those in cleavages, amygdulites, or fractures appear epigenetic. Those lacking Th probably are of relatively low temperature.

Surface tension would inhibit liquid entry into tight textures and lattices, so volatile transport and ionic lattice diffusion are inferred. Inclusions account for most Th-U distribution patterns suggesting dominant epigenetic enrichment of volcanics by residual volatiles.

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Oncolites in Cretaceous Yucca Formation, Presidio County, Texas

Detailed stratigraphic work in the Yucca Formation, Presidio County, Texas, has revealed about 70 ft (21 m) of oncolite-bearing strata. The zone of oncolite occurrence is 180 ft (55 m) above the unconformity separating the Permian and

Cretaceous rocks and 665 ft (203 m) below the initial occurrence of abundant *Orbitolina*. The zone varies both vertically and laterally from oncolite-supported conglomerate with micrite matrix to micrite with less than 10% oncolite content, to algal-encrusted, matrix-supported pebble conglomerate. Oncolites range from less than 0.5 in. (1.25 cm) to approximately 3 in. (7.5 cm) in diameter, and are commonly size sorted within the zone.

The oncolites are most commonly nucleated about a fragmental piece of oncolite material and are classified as type-SS. In the pebble conglomerate facies, algal encrustations occur on very well-rounded, spheroidal clasts of siltstone, micrite, and chert. Very rare encrustations are present on clasts appreciably larger or smaller than the pebble size. Rarely is the algal material nucleated about organic remains such as pelecypod, gastropod, or brachiopod shells.

The presence of this oncolite zone within an otherwise unfossiliferous section provides some control for interpreting depositional environments within the Yucca Formation. However, oncolites have been reported from several aquatic depositional environments both in the geologic record and as forming today. These environments include: lacustrine, fluvial; shallow, nearshore marine; and marginal marine brackish water systems. Local sedimentary features and broader stratigraphic relations effectively eliminate lacustrine and fluvial interpretation.

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Geology of Sierra Pena Blanca Region, Chihuahua, Mexico

The Sierra Pena Blanca is a fault-block mountain range, extending 100 km in a north-south direction, and being up to 15 km wide. Paleozoic eugeosynclinal sediments constitute the southernmost part, and rocks are progressively younger to the north. Cretaceous basinal and reef carbonate facies are present, and are succeeded northward by lower Tertiary conglomerates, ash-flow tuffs, and volcanoclastics, ranging in age from 44 to 35 m.y. The area is at the boundary of the Chihuahua trough on the east and the Aldama platform on the west. Internally, the range has a repetition of significant northwest-trending, down-to-the-northeast faults. The Tertiary units show some variation in thickness and facies throughout the area. They illustrate an outflow environment, and some units suggest a caldera source on the west or southwest.

Significant uranium deposits occur near the base of the ignimbrite pile. The largest volume of ore is stratigraphically controlled at the base of a welded ash-flow tuff, the Nopal Formation. The Margarita deposit and northern El Curvo zone are examples of this type. Additional mineralization occurs in fractures and faults, as at Nopal 1 and 3. Some mineralization is also present in the underlying Cretaceous carbonate rocks, as at Domatilla, and Sierra Gomez.

Data were collected from drill holes in the Margarita deposits. To define the geochemical indicators a principal factor analysis was performed on the data, which consists of 30 samples with 28 chemical elements. Factor analysis reduced this data set to 8 latent variables or factors. The factors can be interpreted from the association of variables which have the highest factor loadings.

An eight-factor solution to the analysis indicated that certain trace elements, as well as some important major elements, could be used as possible geochemical indicators for this type of deposit. The positive trace elements defined are: MnO, Hg, B, Y As, Mo, F, and Cu. The multiple correlation coefficient

for these variables is as great as 0.9, but, individually, the correlation between uranium and the variables was no greater than 0.3. These elements individually have little significance but, taken as a suite, they are related to the uranium mineralization. Major and minor elements which are also related are MgO, CaO, CO₂, Fe, and S. The deposit is interpreted as having been deposited from uraniferous ground waters between 100 and 200°C, migrating toward paleotopographic lows on the east. The uranium is believed to have been derived from the leaching of tuffs.

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Magnetotelluric Exploration—Update

Exploration for oil, gas, and geothermal resources through the use of magnetotellurics has reached an all-time high. Geophysical exploration in poor or nonseismic areas, coupled with increased interpretational capabilities, has made magnetotelluric exploration a practical tool. The explorationist now has an increased capability to explore in areas where geophysical data were previously impossible to obtain. Interpretation of magnetotelluric data is greatly enhanced through the use of new modeling techniques. Case studies demonstrate magnetotelluric exploration applications.

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Facies Patterns and Depositional Models of Permian Sabkha Complex—Red Cave Formation, Texas Panhandle

The Red Cave Formation (Permian, Leonard Series) in the Texas Panhandle consists of cyclic, red-bed clastic and carbonate-evaporite members that were deposited in an extensive coastal sabkha, desert wadi plain, and a carbonate inner shelf which bordered the northern Midland basin. Evaporite members were deposited in carbonate-evaporite crustal sabkhas and clastic members were deposited in mud-rich coastal to continental sabkhas.

North to south, red-bed wadi-plain facies pass into coastal sabkha facies and inner-shelf dolomite facies. In a Randall County core, vertical sequences commonly include slightly fossiliferous, faintly laminated to burrowed dolomitic mudstone and pellet wackestone overlain by cross-laminated oolitic or pellet packstone to grainstone, followed by algal-laminated dolomitic mudstone and nodular anhydrite in dolomite matrix. A progradational carbonate shoreline is inferred, with supratidal or sabkha evaporite to intertidal algal-mat and sand-flat environments passing seaward into a shallow, muddy subtidal inner shelf. Mud-rich sabkha sequences culminate with red to green mudstone and anhydrite above shoreline carbonates. Carbonate and evaporite facies pinch out generally toward the northwest and northeast into wadi-plain red beds. These facies include ripple-drift cross-laminated siltstone and sandstone deposited in braided fluvial channels, adhesion-rippled siltstone, and red to green mudstone deposited in mud-flat and interchannel environments. Desiccation features, intraclasts, root zones, and paleosol horizons attest to subaerial exposure and probable nonmarine conditions.

Large-scale cyclicity of red-bed clastic and carbonate-evaporite members probably was controlled by the relative supply or fluctuating input of clastics to sabkhas by way of fluvial systems rather than by absolute sea-level changes.

Partial modern analogs to Red Cave sabkha depositional models are the coastal mud flats and alluvial fans in the north-

western Gulf of California, tidal flats and an ephemeral stream delta (Wooramel delta) in Gladstone Embayment, Shark Bay, Australia, and the Trucial Coast sabkhas in the Persian Gulf. Each setting has certain facets that are remarkably similar to interpreted paleoenvironments and lithofacies of the Red Cave Formation.

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Geothermal Research and Exploration in New Mexico

A Department of Energy (DOE)-sponsored evaluation of the hydrologic characteristics of New Mexico's low-temperature geothermal sites is being conducted. Over 40 areas have been designated for possible low-temperature geothermal application. There are nine areas with estimated temperatures of between 100 and 105°C, and three areas with estimated temperatures $\geq 150^\circ\text{C}$. Eight prospective high-temperature geothermal resource areas, where public knowledge of successful drilling is lacking, were designated for DOE by New Mexico researchers.

Drilling on state and private lands is concentrated in the Lightning Dock and Radium Springs KGRA vicinities, west of Socorro, east of Las Cruces, east of the Jemez River, and in the Baca Loc. 1 KGRA. Drilling on federal land is concentrated in the Baca Loc. 1, Kilbourne Hole, Radium Springs, and Socorro Peak KGRAs.

Geothermal research at Sandia Laboratories includes: (1) successful testing of a high-temperature borehole temperature-logging instrument, (2) development of an efficient continuous chain bit, and (3) continuation of the Magma Energy Research Project, which was recently involved in drilling into the Kilauea Iki lava lake.

NMIMT has mapped a large, deep magma body and several shallow magma bodies in the crust of the Rio Grande rift near Socorro.

The LASL Hot Dry Rock Geothermal Energy Project has yielded promising technical results; researchers are studying two out-of-state areas for possible hot dry rock demonstration sites: Stumpy Point-Wallops Island in Maryland, and the western Snake River Plain in Idaho.

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Uranium in Diagenesis of Pruett, Duff, and Tascotal Formations, Trans-Pecos, Texas

The Pruett, Duff, and Tascotal Formations (Eocene-Oligocene) form a 1-km thick sequence of tuffaceous sediment composed, prior to diagenesis, of rock and mineral fragments and volcanic glass. Ground-water diagenesis dissolved glass and some mineral fragments to produce the following mineral assemblages from top to bottom: (1) hydrated glass, (2) clinoptilolite-opal, (3) clinoptilolite-quartz, and (4) analcime-quartz. Calcite and montmorillonite formed early and are present throughout the section. The presence of minor uranium mineralization in underlying Cretaceous rocks and in channel sandstones and lacustrine deposits in tuffaceous sediments and the presence of uranium concentrations up to 100 ppb in present ground water in tuffaceous sediments confirm that some uranium mobilization has occurred.

Average uranium concentration increases down section reflecting either (1) greater primary abundance in older sediment due either to greater abundance of glass or more U-rich