propping agents. Dolomite precipitated from slurries partly healed the fractures.

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Lower and Middle Paleozoic Potential of Paradox Basin

Successful oil exploration in the Paradox basin began in 1907 with the discovery of Pennsylvanian oil at Mexican Hat field in San Juan County, Utah. Accelerated exploration began with the discovery of oil in the Pennsylvanian Paradox Formation at Aneth field in 1956 and lasted into the 1960s. Cumulative production at greater Aneth field exceeds 271 million bbl of oil. A second major oil producing zone, the Mississippian Leadville, was established at Lisbon field in 1960. By 1978, its 25 wells had produced 40 million bbl of oil and 310 Bcf of gas. Recently, exploration in the area has been minimal with the exception of the current exploration for carbon dioxide for secondary recovery projects.

The Paradox Formation, the major producing unit in the basin, can be subdivided into both genetic units and facies subzones using sample and mechanical log information. Recognition and mapping of the major facies—hypersaline, penesaline, and marine shelf—for each genetic unit can delineate fairways most favorable for the development of algal mounds in which the best production occurs.

Perhaps the most significant remaining potential is in the Mississippian Leadville formation. Exploration for structural traps within this carbonate unit is difficult owing to the thick overlying Pennsylvanian salt section present over much of the basin. A pilot gravity modeling study in the Lisbon field area has shown that the salt effect can be removed and the underlying structure mapped. Regional gravity modeling of the remaining salt basin may define similar Lisbon-type structures.

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Recent Advances in Helium Analysis as Exploration Tool for Energy "Deposits"

Recent research by the U.S. Geological Survey demonstrates that helium-gas analysis of waters and soils holds great promise as a cost-effective exploration technique for uranium, oil and gas, and geothermal energy sources. The technologic advances include assembling a helium analyzer, almost entirely from commercially available equipment, and packaging the equipment into a mobile laboratory capable of performing as many as 100 analyses a day at a field location. Helium is an attractive indicator element for many exploration programs because of its unique properties: it is highly diffusive, chemically inert, radioactively stable, and not produced or affected by biologic activity. Many associations of helium with uranium have been observed, in which helium is produced by natural radioactive disintegration; with oil and gas, where helium is trapped by structural and stratigraphic features; and with hot-water geothermal systems, in which the cooling and reduced pressure of rising water causes dissolved helium to be released. The following are examples of distinctive helium anomalies found associated with energy "deposits": for uranium, the Ambrosia Lake district, New Mexico; for oil and gas, the Cement oil field, Oklahoma, and the Cliffside gas field, Texas; and for geothermal, the East Mesa known geothermal resource area in the Imperial Valley, California. With respect to an ambient air background of 5.24 ppm helium, the highest observed concentrations of excess helium in soil and soil gas were typically 0.5 ppm for uranium, 10 ppm for oil and gas, and 100 ppm for geothermal; water samples usually had several hundred parts per million helium for all types of energy deposits. Helium analysis can be used as a rapid and inexpensive reconnaissance tool and as complementary support for other geophysical and geochemical prospecting techniques.

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Seabed Characteristics and Sand Dispersal on Bedrock-Dominated Inner Shelf of Southern Labrador

The Labrador Shelf is dissected by the Marginal Trough into a narrow inner rocky shelf, which is the submerged extension of the Precambrian Shield landmass, and an outer shelf zone consisting of broad, flat banks mantled by thick deposits of glacial drift. The inner shelf north of Groswater Bay is 35 km wide, with a highly irregular bedrock-dominated bottom topography. Unconsolidated materials consist of sand, and coarse gravel "pavement" deposits. Sand deposits are less than 1 m thick and limited in areal extent to the flat-bottomed, low-lying areas between bedrock highs. Coarse gravel deposits occur as veneer pavements on the flanks of highs. The sands are underlain either by cohesive muds (early Holocene?) which were deposited in former basinal depressions, or by coarse gravels in local areas marginal to bedrock outcrops. The coarse gravels are probably relict lag deposits formed by the reworking of glacial drift, but the sands are thought to be derived from contemporary nearshore and beach sediments situated about 10 km west of the study area.

The thin and patchy sand distribution suggests that transport mechanisms are more than sufficient to disperse the volume of sand that is being supplied to the inner shelf. Preliminary analysis of near-bottom velocity measurements indicates that the seabed is subjected to a strong southeasterly current (Labrador current) which induces a net southeasterly sand flux across the shelf. The predominantly resistant substrate of the shelf would likely be swept clean of sand, if it were not for the irregular bottom configuration which provides local and temporary sinks for sand deposition.

The most important sediment-transport process on the inner shelf is the southeasterly directed Labrador current. Wave-generated currents are of lesser importance (except in shallow nearshore areas) as a sand-dispersal mechanism, and iceberg-scouring is more effective in redistributing sediment in areas seaward of the inner shelf edge.

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Deep Terrestrial Heat-Flow Studies in Southwestern United States

Deep geothermal gradient measurements yielding good heat-flow data are necessary to accurately predict lithospheric and asthenospheric temperatures and relate thermal conditions in the lithosphere and asthenosphere to fundamental tectonic processes such as vertical movements in the earth. Many heat-flow measurements are calculated from temperature gradients taken at depths less than 1 km. In some places, groundwater perturbation of these temperature gradients precludes basic appreciation of regional lithospheric or local geothermal conditions. Previous heat-flow data suggest the Colorado Plateau is an area of low heat flow (~1.2 HFU) whereas new deeper heat-flow measurements show the Colorado Plateau has intermediate heat flow (~1.6 HFU). These new data are in keeping with other geophysical measurements. As such, the gradual uplift component of vertical movement over the western United States since the Eocene may relate to lithospheric reheating (thermal expansion) as North America drifted over hotter asthenosphere. New deep data in the southern Basin and Range province indicate regional heat flow of 1.95 HFU suggesting 0.3 to 0.4 HFU difference between the Basin and Range and Colorado Plateau. Different lithospheric responses to asthenospheric anomalies may allow widespread magma intrusion in the Basin and Range with only modest intrusion in the Colorado Plateau. Both large scale and local geothermal anomalies are also significantly perturbed by groundwater movement, e.g., the Rio Grande rift and the San Francisco Mountains. High quality heat-flow data extending along profiles from mountainous areas will allow appreciation of thermal conditions in mountain blocks and magma bodies, such as profiles from the southern Rockies and the San Juan Mountains.

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Conodont Animal—Hypotheses and Speculations

More than a century after their discovery, conodonts remain biologic orphans. These skeletal constituents of some as yet unspecified marine organisms have been assigned by various workers to: vertebrates (from ancestral to advanced), arthropods, several kinds of worms, several classes of mollusks, lophophorates, separate classes (or a phylum) all their own, and even algae and vascular plants. Functional interpretations of conodonts include: stem, gill, or tentacular supports; dermal spines and scales; radulae; digestive tract stirrers and sieves; jaws, teeth, or "superteeth;" and copulatory graspers. Each conodontophorid bore up to at least two dozen, commonly very differently shaped, conodont elements in an apparatus. The existence and makeup of these multi-element apparatuses are known from naturally occurring assemblages of elements that are interpreted as coprolitic, gut contents, in-situ burials, fused clusters, or empirical reconstructions based on numerical (clustering) techniques.

Current hypotheses about the form and function of the apparatuses, and hence the nature of the organism itself, center on whether some elements functioned as fused units for grasping or as members of an array of food-gathering and/or sieving digits and pectinate units, possibly in a lophophore. Bearing on these hypotheses are the questions. (1) Were all conodont elements always enveloped by soft tissue during life? (2) Do the fused clusters owe their fusion to biologic processes or to postmortem diagenetic mineralization? The question of biological affinity remains unresolved. However, recently discovered fused clusters suggest that fusion was diagenetic.

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History of Sulfidization of South Texas Roll-Type Uranium Deposit

Studies of the mineralogy, sulfur isotope geochemistry, and uranium-lead isotope geochronology of a roll-type orebody in the Felder deposit, south Texas, have indicated important constraints on the genesis of this deposit. Post-mineralization sulfidization of the host Oakville Sandstone (Miocene) resulted in precipitation of pyrite and marcasite in the altered tongue that differ in relative abundance and in isotopic composition from pyrite and marcasite elsewhere in the host rock. The altered tongue is characterized by a predominance of pyrite over marcasite and by heavy $\delta^{34}S$ values (-5.2 to $+20.6$ per mil), whereas reduced-barren and mineralized rock is characterized by abundant ore-stage marcasite and by light $\delta^{34}S$ values (-29.9 to -47.7 per mil). In reduced-barren and mineralized rock, two generations of pyrite are present: (1) pre-ore pyrite grains that are commonly enclosed by ore-stage marcasite; and (2) post-ore pyrite that is genetically equivalent to pyrite in the altered tongue. Resulfidization of the deposit by hydrogen sulfide-bearing solutions introduced along one or more nearby faults is indicated by the similarity in isotopic compositions of pyrite in the altered tongue to that of sour gas in the underlying Edwards Limestone (Cretaceous). The time of this resulfidization is probably indicated by the unusually precise $^{207}Pb/^{204}Pb$–$^{235}U/^{204}Pb$ isochron age of 5.09 ± 0.11 m.y. The lack of significant scatter of the points on the isochron diagram must reflect the immobility of uranium and lead over the last 5 m.y. due to the continued presence of hydrogen sulfide. The 5-m.y. isochron age indicates that no significant roll-forming processes have occurred in the Felder deposit since this time.

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Upper Cretaceous Mosby Sandstone, Central Montana—Example of Thin, Widespread Storm-Generated Sandstone Cycles

The Mosby Sandstone Member of the Greenhorn Formation is composed of thin (less than 6 ft or 1.8 m), very fine-grained to fine-grained sandstone cycles separated by shale. The sandstones occur either as individual beds, generally less than 1 ft (9.3 m) thick and separated by interbeds of shale, or as amalgamated beds. The base of each cycle is a planar to undulating ero-