

tion at Cato San Andres field (New Mexico) and Mission Canyon pay at Haas field (North Dakota) reveal no diachronous buildup. As expected these fields demonstrate only a lateral change in velocity within the formation.

Application of stratigraphic-seismic techniques to low-energy carbonate facies can fall into two depositionally controlled divisions. When sediment accretes vertically, traps are mapped solely by lateral changes in velocity. Sedimentary buildup in transgressive or regressive sequences provides angularity, which combined with velocity contrast facilitates seismic detection of the trap.

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Strategy of Exploration for High Temperature Hydrothermal Systems in Basin and Range Province

A 15-phase strategy of exploration for high temperature convective hydrothermal resources in the Basin and Range province features a balanced mix of geologic, geochemical, geophysical, hydrologic, and drilling activities. The strategy is based on a study of data submitted under the Department of Energy's Industry Coupled Case Study Program. Justification for inclusion in or exclusion from the strategy of all pertinent geoscientific methods is given. With continuing research on methods of exploration for and modeling of convective hydrothermal systems, this strategy is expected to change and become more cost-effective with time. Variations on the basic strategy are to be expected where the geology or hydrology requires it. Personal preferences, budgetary constraints, time and land position constraints, and varied experience may cause industrial geothermal exploration managers to differ with our strategy. For those just entering geothermal exploration, the strategy is expected to be particularly useful.

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Middle-Late Permian Paleogeography of Idaho, Nevada, Montana, Utah, and Wyoming

Conodont and brachiopod biostratigraphic zones are used to divide the Phosphoria Formation and related rocks into 7 discrete time intervals of the middle and Late Permian to examine the general sedimentation patterns of the Phosphoria basin. Three depocenters existed in the middle Permian: one in southwestern Montana, one in northeastern Nevada, and one in central-eastern Nevada and adjacent Utah. The sedimentation occurred in two transgressive phases followed by sea level stillstands. A major regression occurred in late Guadalupian time. The conodont and brachiopod faunas indicate that cooler water existed in the area of maximum phosphorite deposition, generally in eastern Idaho and southwestern Montana.

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Permian Conodont Biostratigraphy and Paleogeology

Permian conodont faunas are not diverse but yield a

wealth of information on biostratigraphy and paleoecology. Pennsylvanian faunas carried over into the Early Permian and became extinct in the late Wolfcampian. At this time the rapidly evolving neostreptognathoid and common neogondolellid stocks arose. Predominately, these two stocks are used to subdivide the Permian.

Through most of the Permian, three ecologic faunas can be recognized: (1) a shallow, nearshore fauna dominated by *Hindeodus*, (2) an intermediate fauna dominated by *Neostreptognathodus* or *Merrillina*, and (3) a far-from-shore fauna dominated by *Neogondolella*. Some species of *Neogondolella* varied according to nearness to shore; populations containing higher percentages of individuals with serrated or bumpy margins were nearer to shore, often occurring with *Hindeodus*.

Early Permian *Neogondolella* faunas were cosmopolitan. In the middle Permian three provinces of *Neogondolella* faunas can be recognized: a very endemic west Texas province, a partly endemic Canadian province, and a cosmopolitan Eurasian province. All three provinces consist of stocks that seem to be derived from a common widespread ancestor, *Neogondolella idahoensis*. Only the Eurasian province faunas persisted into the Triassic. It appears that the basins containing the west Texas and Canadian faunal provinces dried up and their respective faunas died out in the Late Permian.

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Multiphase Fluid Movements in Glass Micromodels of Pore Systems

The efficiency with which oil or gas can be displaced by water in the pores of a reservoir rock is affected by the properties of the fluids and the properties of the pore spaces which contain those fluids.

Pore casts provide the most effective way of viewing pore structures and are prepared by impregnating pore systems with resins and subsequently removing the host rock by solution in acid.

Unsteady state relative permeability tests, counter-current imbibition tests, and drainage-imbibition capillary pressure tests can be used to estimate the displacement efficiency for particular fluid conditions in selected cores of reservoir rocks. The results of these tests can be compared with visual observations of pore structure made from pore casts and, in this way, it is possible to suggest which attributes of pore systems in reservoir rocks are critically important in influencing displacement efficiency. These variables include: pore to throat size ratio, the average number of throats connecting with pores, the types, abundance, and arrangement of non-random heterogeneities, and the roughness of surfaces.

However, pore systems in any rock are a complex of variables and, to further understand and define the interaction of fluid and pore variables in trapping oil or gas during displacement, it is necessary to create physical models of pore systems which incorporate the characteristics of real systems but in simplified and controlled forms. The fluid and pore geometric attributes can be varied singly and displacement tests can be viewed under the microscope in transparent micromodels.

dels to gain a better understanding of displacement processes.

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Contemporaneous Reconstruction and Cementation of Living Lagoonal Patch Reef, Enewetak Atoll, Marshall Islands

A patch reef on the sheltered side of the lagoon at Enewetak, a Pacific oceanic atoll, was sampled from the living coral-algae veneer near the water surface to the lagoon floor at -7 m water depth. The reef was exposed by selective blasting, and samples were studied by slabbed sections, thin sections, and the scanning electron microscope.

The reef is repeatedly and pervasively cemented by crystal aggregates of aragonite and magnesium calcite and by microcrystalline magnesium calcite, and does not show marked preferential control by host mineralogy. Cements (1) fill skeletal cavities, (2) fill borings in both skeletal elements and other early cement, and (3) bind, as mud-sized magnesium calcite, fine-grained bioclastic debris that accumulates in voids of all sizes and origins. The distribution of both cements and cavities is extremely variable, as is cavity size and geometry. Drilled plugs, from the reef core, had porosities of 12.7 to 36.5% and permeabilities of 135 to 32,843 md.

Externally, the reef appears to be a porous boundstone; internally, it changes to wackestone and packstone. Contemporaneous and repeated penetration by micro- and macro-borers continually obliterate original boundstone framework, replacing it with cemented cavities and debris; conversion to wackestone and packstone continues as long as the reef is exposed to seawater.

The diagenetic process results in transformation of the reef from delicate framework to compact limestone, from porous elements to dense rock, and from a large proportion of skeletal aragonite to apparently inorganic aragonite and crystalline and microcrystalline magnesium calcite. It also accounts for the difficulty of identifying the framework core of some fossil reefs.

Despite the effects of pervasive boring, submarine cements and cemented debris maintain and increase the strength of the reef, which has withstood storms, typhoons, and nuclear blasts.

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Source and Time of Generation of Hydrocarbons in Fossil Basin, Western Wyoming Thrust Belt

Oil trapped in Triassic-Jurassic reservoir rocks in fields along the Ryckman Creek-Pineview structural trend on the Absaroka thrust plate was generated in source rocks in the footwall Cretaceous sequence which was overridden by the thrust plate. This conclusion is supported by data from a variety of analytic techniques used to make oil-to-oil and oil-to-source rock correlations. The source of hydrocarbons in Paleozoic reservoirs in the Whitney Canyon-Carter Creek trend on the

Absaroka plate is more difficult to identify with certainty. The accumulations in the Paleozoic rocks are dominantly gas with some condensate, and a significant amount of H₂S is present in contrast to the low-sulfur "sweet" oil and gas in the Ryckman Creek-Pineview trend. The identical sulfur content and chromatographic character of condensate from the Paleozoic and the Triassic-Jurassic reservoirs suggest that both are from the same source.

Reconstruction of the maturation history and measurement of present levels of thermal maturation of source rocks in different structural settings in the Fossil basin demonstrate that peak generation and migration of hydrocarbons from Paleozoic source rocks predated the Absaroka fault which was formed about 75 m.y.B.P. Cretaceous source rocks beneath the Absaroka plate were immature when overridden by the fault and have reached a high level of maturity since that time. Most of the hydrocarbons were generated and expelled from source rocks in the footwall sequence during the last 60 ± m.y., after the hanging-wall structural traps involving both Mesozoic and Paleozoic reservoirs were formed.

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Depositional Environments of Lacustrine Limestones and Their Relation to Major Coal Seams, Upper Pennsylvanian of West Virginia

In the Monongahela Group, lacustrine limestones are intimately associated with important coal deposits as evidenced by (1) their common biogenic origin within embayments between clastic deltaic lobes, (2) the interbedding of thick limestones and minable coal seams, and (3) their paleogeographic proximity. A preliminary study of the lower Monongahela Group in the northern coal basin of West Virginia shows that the seemingly monotonous limestones are actually variable in terms of both paleontology and petrology. Freshwater fossils in these beds include micro- and macro-invertebrates (darwinulid and cypridid ostracodes, mollusks, and abundant *Spirorbis*), vertebrates (fragments of amphibians and fish), and megaplants, and calcareous algae. These rocks are classified as finely laminated micrite, pelmicrite, and intramicrite. Sedimentary structures such as mud cracks, desiccation chips, caliche, and bird's-eye all indicate frequent drying. Water-level fluctuations that commonly affected the lakes, as interpreted from limestones, also affected nearby coal swamps in terms of plant types, water chemistry, and degradation rates. These then determined coal lithotype and ash content. During the periods of subaerial exposure, rare gypsum crystals were precipitated interstitially in the carbonate mud, and the concentration of minerals like gypsum may be one source of sulfur for pyrite in adjacent high-sulfur coals. Hence, the understanding of depositional environments in the lacustrine limestones provides further insights into details of coal formation.

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