Exploration for Tertiary accumulations is carried out by: (1) mapping source rocks in basins with proper depth for maturity, (2) establishing presence of reservoir rocks, and (3) delineation of traps by photogeologic-geomorphic techniques, gravity surveys, and seismic shooting.

Numerous shows of oil and gas have been recorded in wells drilled in various basins, both in Paleozoic and Tertiary rocks. Other oil and gas indications include the Bruffey oil and gas seeps (Pine Valley, Nevada), the Wells oil seep (west of Wells, Nevada), an asphaltite dike in Mississippian sediments (Piñon Range, east of Pine Valley), the West Brigham City and Farmington gas areas (east of Great Salt Lake, Utah), and the Fallon gas area (Carson Sink, Nevada). Oil source units include Cretaceous to Tertiary lake deposits (Sheep Pass Formation, Elko Shale, Kinsey Canyon Formation, Newark Canyon Formation, and King Lear Formation), Mississippian Chainman Shale, Devonian Pilot Shale, and Ordovician Vinnini Shale.

Several Paleozoic plays exist in Nevada, including the Mississippian Diamond Peak (Illipah, Scotty Wash) sandstone pinch-outs. Reef buildups may be present in the Silurian and Devonian section.

Exploration in the Basin and Range province should result in significant discoveries of oil and gas in the future.

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Smectite-Illite Transformation—Role in Generating and Maintaining Geopressure

Mixed layer smectite-illite clays comprise a significant fraction of fine-grained clastic sediments in many basins around the world. Abnormally high fluid pressure (geopressure) is associated with parts of these basins. The presence of smectite-illite is a necessary but not sufficient criterion for the existence of geopressure.

Smectite reacts with potassium feldspar producing illite, silica, sodium-calcium feldspar, and releasing loosely bound water. Observations in the northern Gulf of Mexico support an equilibrium model for the reaction, the shift in the logarithm of the equilibrium coefficient with depth being proportional to the product of the reaction enthalpy and the geothermal gradient. Reaction enthalpies range from 2,000 to 26,000 cal/mole, highest reaction enthalpies occurring along the south Texas coast, lowest in the Mississippi delta. Abrupt diagenesis-depth profiles are associated with geopressure, gradual reaction with depth associated with near hydrostatic fluid pressure gradients.

Sediments compact over intervals where the effective pressure increases. Geopressure is associated with porosity increase and effective pressure decrease with depth. The top of the zone of sediment under-compaction coincides with change in sign of the effective pressure gradient from positive to negative. In this interval, fluid pressure increases with depth faster than does the overburden pressure. Very high fluid-pressure gradients are associated with the combination of low shale permeability, high shale porosity, and rapid basement subsidence. Because of the close connection between high fluid-pressure gradient and abrupt conversion of smectite to illite, we conclude that this reaction is responsible for abnormal loss of permeability, probably a result of the finely divided silica that is produced.

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Application of Inversion Processing to Exploration for Point-Bar Sandstones

West Moorcroft field, Crook County, Wyoming, produces from a point-bar sandstone of the Fall River formation of Cretaceous age. New Bielau field, Colorado County, Texas, is productive from an Eocene age, Wilcox formation point-bar sandstone. Although both reservoir sandstones were deposited in a similar "meander belt" facies, the expressed geometry of the trap as defined from the Seislog® traces is unique to each field.

In West Moorcroft field, at 4,800 ft (1,463 m) hydrocarbons are trapped by the arcuate shape of channel-filling shale that forms a seal for approximately 40 ft (12 m) of sandstone. Analysis of bandpass filtered sonic logs suggests that the frequency content of conventional seismic data is likely inadequate to uniquely separate porous sandstone from shale. Inversion of the seismic data facilitated identification of a higher velocity event, which although not discretely sandstone could be related to the productive unit. Updip, the channel-filling shale, the real trap, does form a mappable stratigraphic unit.

The producing point-bar sandstone at New Bielau is both deeper (8,700 ft; 2,652 m) and thicker (65 ft; 20 m) than at West Moorcroft. As predicted by bandpass filtered sonic logs, the sandstone is not uniquely resolved on inverted seismic data.

In this example, a high velocity marker beneath the productive interval clearly illustrates the concave morphology of the channel and serves to define the trap. Although poorly defined, the shale in the channel fill is recognizable.

In a comparative sense, the two fields illustrate the ability of inversion processing to identify very subtle stratigraphic units that can then be related to a reasonable geologic model. The expression of this stratigraphy on the conventional seismic section reminds us just how subtle those indicators really are.

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Controls of Zeolite Cementation in Upper Jurassic Sandstones, Lower Cook Inlet, Alaska

Field and petrographic studies indicate that the major factors controlling zeolite cementation in Upper Jurassic sandstones of Lower Cook Inlet were provenance, depositional environment, and igneous activity. The Jurassic strata record the unroofing of a Mesozoic volcanic-plutonic arc complex related to subduction and plate accretion beginning at least by Triassic time. Petrologic-stratigraphic trends show a striking increase in the ratio of quartz to volcanic rock fragments from Lower Jurassic to Upper Jurassic sedimentary rocks, reflecting increasing depth of erosion of the arc complex. Superimposed on these trends are local variations in mineralogy related to differences in depositional environment. For example, shallow-marine, tidal sandstones of the Upper Jurassic Staniukovich Formation contain an average of $Q_{48}F_{42}L_{10}$ whereas the underlying Upper Jurassic Naknek, a deep marine deposit, averages $Q_4F_{58}L_{38}$. The Naknek was tightly cemented with heulandite during shallow burial as unstable volcanic material altered. Only minor heulandite is found in the Staniukovich which was mineralogically much more stable. Subsequently, however, laumontite cement destroyed much porosity in the Staniukovich. Laumontite clearly postdates heulandite cement and present evidence suggests that laumontite cementation was a late event, perhaps related to Tertiary intrusion and volcanism. Depth of burial was not a major factor in zeolite cementation.

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Shale Mineralogy of General Crude Oil and Department of Energy 1 Pleasant Bayou Geopressured-Geothermal Test Well, Brazoria County, Texas

Thirty-three shale samples, ranging in depth from 2,185 to 15,592 ft (666 to 4,752 m), were examined by X-ray diffraction methods to determine changes in a mineralogy with depth. Quartz is present in all samples and averages 15 wt. %. Above 7,800 ft (2,377 m), calcite content varies due to fossil fragments. Below 7,800 ft (2,377 m), calcite content varies from 0 to 9 wt. %. Potassium feldspar and plagioclase contents are essentially constant at an average of 3 and 4 wt. %, respectively. Total clay content, combining kaolinite, illite, mixed-layer illite-montmorillonite (I/M), and traces of chlorite, is essentially constant, averaging 65 wt. %. Individual clay minerals have quite variable contents from sample to sample, but distinct trends are noted: (1) kaolinite content is constant at an average of 25% total clay; (2) illite content initially averaged 35% total clay, decreases with depth, and is zero in 10 of the 14 samples below 10,000 ft (3,048 m); and (3) mixed-layer I/M averages 40% total clay in shallow samples and 70% in deeper samples. The top of the geopressured zone, occurring at a pore fluid pressure gradient of 0.465 psi/ft and equilibrium temperature of approximately 190°F (88°C), is marked by a definite increase of illite in mixed-layer I/M at approximately 8,500 ft (2,591 m). A major change in illite content from 40% at 11,210 ft (3,417 m), to 84% at 11.750 ft (3,581 m), corresponds to a pore fluid pressure gradient of 0.7 psi/ft, and equilibrium temperature of approximately 250°F (122°C). In addition, the arrangement of the I/M layers changes from random interstratification in samples from 11,540 ft (3,517 m), and shallower, to an ordered layering from 11,750 ft (3,581 m) and deeper.

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Uniformitarianism and Tertiary Reef Paleoecology

Successful application of knowledge about modern reef ecosystems to Tertiary reef paleoecocystems depends greatly upon the scale at which it is applied.

The present is clearly an imperfect key to the past in the comparison of the biogeography and regional ecology of modern reefs with those of the Tertiary. This is largely because the Holocene and Pleistocene ecologic and biogeographic distribution of reef-building scleractinian corals, octocorals, and other key members of the reef community is a relatively recent phenomenon and is not representative of most of the Tertiary. Major changes in reef-coral paleobiogeography and evolution occurred in the late Eocene, at the end of the Oligocene, in the middle Miocene and at the end of the Pliocene. A worldwide change in the ecology of shallow-reef communities occurred in the early Pleistocene with the great diversification and growth luxuriance of predominantly branching species of reef-corals with light, rapidly growing skeletons accompanied by the proliferation of the hydrozoan *Millepora.* Most of these corals belong to the families Acroporidae, Poritidae, and Seriatoporidae.

Other more detailed paleoecologic relations may, however, be reconstructed only by strict uniformitarian comparison to living-reef examples because the evidence needed to derive them is not preserved or is incompletely preserved in the fossil record. Some of these include: (a) quantitative estimation for an ancient reef of the standing crop biomass volume and productivity. Many of the biotic components of the benthic reef ecosystem, such as seagrasses, sponges, and octocorals, have little preservation potential; (b) an estimation of the amounts and pathways of energy cycled through the benthic reef paleoecosystems; (c) the presence of symbiotic relations, such as the vital link between hermatypic corals and zooxanthellae; (d) mutualistic and antibiotic relations among encrusters; (e) sediment-rejection potential, especially that of reef corals, octocorals, and sponges; and (f) interspecific aggression among reef corals, although some overgrowth relations may be deduced from the fossil record.

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Eolian-Fluviatile (Continental) Origin of Ancient Stratigraphic Trap for Petroleum in Weber Formation, Rangely Oil Field, Colorado

An ancient stratigraphic trap for petroleum exists in continental deposits at Rangely oil field where the eolian Weber Sandstone (Pennsylvanian-Permian) intertongues with the fluvial Maroon Formation. The stratigraphic trap developed as a result of the progradation of eolian dunes toward the ancient Uncompahgre uplift. Layers of fine silt and conglomeratic material that formed along the margins of the dune field created a permeable barrier, owing to diagenetic cementation and their intrinsic textural properties. The conditions which created the stratigraphic trap at Rangely may have developed in other areas along the margins of ancient Pennsylvanian uplifts in Colorado, Wyoming, and Utah.

Analysis of core indicates that porosity and permeability within the oil-producing sandstone are affected by diagenetic processes. Burrowed and contorted intervals are more intensely cemented and have reduced porosity and permeability values relative to undisturbed intervals.

Evidence for eolian origin of the Weber Sandstone