chanoid dune deposition. Facies C is characterized by tabular-planar cross-beds, 3 to 4 m thick, interlayered with flat laminated fluvial arenites. It probably formed by migration of solitary transverse dunes across emergent parts of the braidplain. Paleocurrents in all facies are unimodal and parallel to the paleoslope, but commonly show a strong mode perpendicular to the paleoslope. The lack of duricrusts, silcretes, and ephemeral lake deposits suggests a semi-arid to humid paleoclimate.

The eolianites are distinguished from fluvial sediments by: (1) tabular-planar and trough cross-beds bounded by low-angle to horizontal planar surfaces, the cross-beds being composed internally of wedge-shaped intrasets that dip in the direction of the megaset foresets; (2) ripple cross-lamination perpendicular to the megaset foreset dip; and (3) large-scale cross-beds. An eolian origin is substantiated by association with braided river facies, dissimilarity of cross stratification compared to established fluvial facies models, and the tectonic setting.

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Reflection Seismic Surveys for Basin and Range Geothermal Areas—An Assessment

Several state-of-the-art reflection seismic surveys have been completed in high-temperature geothermal areas of the northern Basin and Range province. The survey data have been made public through the Department of Energy/Division of Geothermal Energy Industry Coupled and Exploration Technology programs. Data were studied for the Stillwater, Dixie Valley, Beowawe, San Emidio, and Soda Lake resource areas.

Reflection quality, and hence usefulness of the reflection method, can be highly variable in the complex basin and range environment. Certainly survey design and proper processing are required to enhance the quality of the data. The most severe geologic condition appears to be the presence of surface, or near surface, layered volcanic rocks. These result in strong early reflections, substantial ringing and poor energy penetration to depth, as at Beowawe. In areas of thick alluvial cover, or Tertiary gravels and lake bed sedimentation (San Emidio, Soda Lake, Stillwater), data quality is often sufficient to map basin border faults and major displacements on volcanic or bedrock surfaces beneath 2,000 to 4,000 ft (609 to 1,219 m) of cover. Faulting is indicated primarily by the systematic termination of coherent reflections. Diffraction patterns are sometimes recognized but commonly obscured by the complex faulting and lithologic variations. The identification of a given reflector across major structures and accurate time-to-depth conversion are difficult interpretational problems. Excellent data quality at Stillwater and Dixie Valley should contribute to the development of these resources.

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Roosevelt Hot Springs, Utah Geothermal Resource —Integrated Case Study

The Roosevelt Hot Springs geothermal resource is located along the western margin of the Mineral Mountains, approximately 19 km northeast of Milford, in southwestern Utah. To date, seven producing wells have been drilled by Phillips Petroleum Co. and Thermal Power Co. Construction will soon begin on the first stage of a 120-megawatt power plant.

Detailed geologic mapping and the study of well logs and drill cuttings indicate that the geothermal reservoir is a fracture-controlled, liquid-dominated system. The host rocks of the reservoir are Precambrian metamorphic rocks and various Tertiary intrusives. The reservoir is mainly localized between the range front and an alluvial covered horst block, along which fluids have migrated to the surface forming an elongate north-trending dome of siliceous sinter. The reservoir is an area of high heat flow (over 1,000 mW/sq mi) and low near-surface electrical resistivity (less than 10 ohm-m). Aeromagnetic, gravity, and reflection seismic data help define the geologic structure within and around the alluvium covered reservoir. Trace element geochemistry shows that arsenic, lithium, and mercury are enriched along fluid pathways of the geothermal system. Mercury concentrations greater than 20 ppb occur only at temperatures less than 225°C and reflect the present thermal configuration of the field.

The system was efficiently explored using detailed geologic mapping in combination with thermal gradient studies and dipole-dipole resistivity.

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Biostratigraphy of Monterey Formation, Palos Verde Hills, Southern California

Three members comprise the Monterey Formation in the Palos Verdes Hills: the Altamira Shale, The Valmonte Diatomite, and the Malaga Mudstone. Following the diatom zonation of Barron (in press), the middle to upper Altamira Shale ranges from Subzone b of the *Denticulopsis lauta* Zone through Subzone b of the *Denticulopsis hustedtii-D. lauta* Zone (14.5 to 12 m.y.B.P.), the Valmonte Diatomite ranges from Subzone b of the *D. hustedtii-D. lauta* Zone into the lower *Thalassiosira antiqua* Zone (13 to 8 m.y.B.P.), and the Malaga Mudstone ranges from the lower *T. antiqua* Zone into the lower *Thalassiosira oestrupii* Zone (8 to 4 m.y.B.P.), transgressing the Miocene-Pliocene boundary (5 m.y.B.P.). The overlap of up to one million years along the Altamira-Valmonte contact is not surprising since this contact is characterized by a diagenetic change of Opal-A to Opal-CT at most sites.

The age distribution of outcrops reflects northwest-southeast-trending anticlinorium structure of the Palos Verdes Hills, but local sections are discontinuous and deformed due to slumping, folding, and faulting during Pliocene uplift of the hills. This is best seen at Malaga Cove where folds, faults, and slumps are visible along the sea cliffs, and a short hiatus marks the Valmonte-Malaga contact.

The siliceous biostratigraphy of the Palos Verdes Hills correlates to that of the Monterey Formation at Newport Bay. However, the correlation of the siliceous zonation to the benthic foraminiferal stages (assigned by Woodring et al, and Warren) differs for the two areas.

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Dune Size in Paleodeserts of Colorado Plateau

Where dunes migrate during deposition, they move upward (climb) with respect to the generalized depositional surface. Sediment deposited on each lee slope and not eroded during passage of a following trough is left behind as a cross-stratified bed. Because sediment is thus transferred from dunes to underlying strata, bed forms must decrease in cross-sectional area or in number, or both, unless sediment lost from dunes during deposition is replaced with sediment transported from outside the depositional area.

Using equations that relate the amount of sediment lost by dunes to the amount gained by sets of cross-strata, we calculate that the dunes which deposited the De Chelly (Permian), Navajo (Triassic? and Jurassic), and Entrada (Jurassic) Sandstones had mean heights with lower and upper limits of 16 and 450 m, respectively. Although these calculated dune heights are surprisingly large, two kinds of field obsevations support the hypothesis that the dunes that deposited 10-m thick sets of cross-strata common in eolian sandstones may have been 100 m high or higher—comparable in size to large modern dunes or draas. First, many sets of eolian cross-strata are primarily bottomset beds; they rarely contain dune-crest deposits or convex-upward cross-strata deposited on lupper lee slopes, and some sets contain sand-flow toes that pinch out near the top of the set. Second, the sand-flow layers in these eolian sandstones are thicker and laterally more extensive than in modern 10-m high dunes. The hypothesis that large dunes deposit relatively thin sets of cross-strata explains the absence in the geologic record of sets of eolian cross-strata comparable in thickness to the height of large modern dunes.

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Model of Transgressive Barrier Island Stratigraphy

Cape Romain, South Carolina, is a large cuspate foreland, 50 km north of Charleston. Geomorphically, it is a barrier-marsh-lagoon complex in a state of rapid transgression. Historically, the shoreline has retreated more than a kilometer; the present retreat rate averages 10 m/year. A detailed coring program was undertaken to determine the Pleistocene-Holocene stratigraphy of the cape. The resulting depositional model has been correlated to the Cretaceous of Wyoming and the Carboniferous of Alabama.

Unconsolidated Pleistocene and Holocene sediments lie unconformably over Oligocene marls. These late Pleistocene facies consist of shallow embayment sand shoals. Silty highly protected lagoon fills and shell storm lags are found laterally. During the Wisconsin lowstand of sea level, the area was emergent, and a freshwater swamp developed forming a 1.8 m thick peat. The swamp existed for about 7,000 years, until the leading edge of the Holocene transgression overtopped it. Rapidly rising sea level exceeded sediment supply resulting in the deposition of laminated silts. A barrier island probably had already developed offshore, affording protection for the lagoon. As the rate of sea level rise slowed, the lagoon filled with a coarsening-upward sequence of flasered sands and silts, overlain by a silty sand tidal-flat facies. The lagoonal facies were capped by the barrier island and its associated marshes and tidal creeks. These barrier-related deposits consist of silty marshes and clean sand and shell washovers, inlet fills, and spit platforms. As the system moves landward, much of the lagoonal sequence is truncated at the shoreface, forming a ravinement surface overlain by an offshore sand; however, the Pleistocene deposits and the peat will be preserved below wave base.

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Mineralogic and Chemical Composition of Antrim Shale, Michigan

The Antrim Shale is the Michigan basin equivalent of Devonian-Mississippian black shales of the eastern United States. The Dow Chemical Co., with DOE funding, has investigated the possibility of in-situ gas production from the Antrim by underground combustion. This paper summarizes some results obtained in the shale characterization program that was a part of that study.

Antrim Shale is rather uniform in composition and contains about 30% Si, 8% Al, 4% Fe, 2% Mg, 3% Ca, 2% S, and 5% organic carbon. Mineralogically, Antrim Shale consists of 50 to 60% quartz, 20 to 35% illite, 5 to 10% kaolinite, 0 to 5% chlorite, and up to 5% pyrite. Calcite and dolomite, when present, occur as limestone nodules, lenses, and interbeds up to 5 ft (2 m) thick in the lower half of the Antrim. Bedford Shale, which overlies the Antrim in eastern Michigan, contains more total clays, illite and kaolinite, and less quartz. Ellsworth Shale, which interfingers with the upper part of the Antrim in western Michigan, contains up to 25% dolomite.

Antrim Shale contains up to 12.8% organic material, as measured by low-temperature ashing. Bitumen contents range from 0.2 to 0.8%. Average molecular weights of bitumen components are 360 to 370. Deeper drill holes have higher bitumen contents. Kerogen, which makes up the rest of organic material, is of low functionality, about 1 functional group per 25 carbon atoms. Hydroxyl (1 group/50 C atoms) and alkene double bonds (1 group/50 C atoms) are the most common groups present.

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Bridges to *What* Future?

The theme title of this annual meeting demands an answer to the question: what will be the principal energy source for mankind in 50 years? In 100 years? When our petroleum supplies are gone or so reduced as to be unimportant, what will be the alternatives? Geothermal and other minor sources will help, but the major possibilities are our other fossil fuels (oil shale, tar sands, and especially coal), nuclear energy, and solar energy. Because the other fossil fuels are also nonrenewable resources, they can only serve as a bridge to the ultimate major source: nuclear or solar. An examination of these in terms of adequacy, effects on man's environment, and the quality of human life, indicates that solar energy is the logical choice. It is not true that solar power is inadequate; recent studies indicate that solar energy could provide liquid and gaseous fuel and electricity, not only for the present world population of about 4 billion, but for the 10 billion forecast by the demographers by 2080, if adequate planning and development are started now. Present policies seem to be locking us into a nuclear future, with all of the major problems and dangers it entails. Rational, realistic decisions are needed, and we geologists can provide valuable advice to the policy makers.

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Influence of Pore Geometry on Future Enhanced Recovery in Ordovician (Red River) Carbonate Reservoirs at Cabin Creek Field, Montana

This study related the distribution of pore geometry to enhanced recovery within the Upper Ordovician Red River