

line and deformed sedimentary rocks of Mesozoic and older ages. However, the writers' seismic-reflection studies reveal that large areas of the shallow Bering shelf are underlain by intrashelf basins containing several thousand feet of Cenozoic deposits. For example, at least 3,000 ft of sedimentary section overlies basement in western Norton Sound. Nunivak, St. Lawrence, and the Pribilof Islands are basin-bounding structural highs; these may be flanked by oil-bearing Cenozoic deposits.

2. Reflection records reveal that the outer edge of the shallow Bering shelf is underlain by a discontinuous basement high. The basement is composed in part of well-indurated sedimentary rocks of probable Mesozoic age. Cenozoic strata are draped over the shelf-edge basement high and bury the landward-facing flank, which is thought to be the scarp of a normal fault in some areas. The high may be of some interest to petroleum geologists but possible stratigraphic and structural traps within the overlying Cenozoic section are more obvious locations for petroleum prospects.

3. Deep-water drilling techniques ultimately will be required to explore adequately the petroleum possibilities of Umnak Plateau—the borderland which lies at a depth of 6,000 ft in the triangular area formed by the intersection of the Bering continental slope and the Aleutian ridge. The plateau is underlain by at least 5,000 ft of Cenozoic deposits that have accumulated over a differentially downwarped part of the basement platform underlying the shelf. The structure of the plateau is broadly domical, but moderate folding and faulting have deformed its edges; thus the flanks of the plateau may be the best location for future petroleum prospecting.

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#### LARGE-SCALE THRUSTING AND MIGRATING CRETACEOUS FOREDEEPS IN WESTERN BROOKS RANGE AND ADJACENT REGIONS OF NORTHWESTERN ALASKA

Large-scale, low-angle thrust sheets mapped within a 30,000-sq-mi region have been grouped tentatively into five tectonic units, each characterized by multiple northward thrusting of a distinctive rock sequence.

Rock sequences which distinguish the tectonic units in the De Long Mountains are informally designated as follows:

1. *Foothills unit* (northernmost and structurally lowest).—(a) Permian(?), Triassic, and Jurassic chert, shale, and limestone, (b) Early Cretaceous (Valanginian) shale with *Buchia*-bearing coquinoïd limestone, and (c) late Early Cretaceous (early? Albian) graywacke and shale.

2. *Wulik unit*.—(a) Mississippian dark carbonate, chert, and shale, (b) Permian(?), Triassic, and Jurassic(?) varicolored chert, shale, and limestone, (c) Valanginian quartzitic sandstone and shale containing *Buchia*, and (d) early? Albian graywacke and shale.

3. *Kelly unit*.—Subunit A: Devonian and Mississippian detrital rocks; Subunit B: (a) Mississippian light carbonate and terrigenous rocks, (b) Permian(?) and Triassic chert and shale, and (c) earliest Cretaceous (Berriasian and Valanginian) graywacke and shale.

4. *Ipnavik unit*.—(a) Devonian carbonate, (b) Mis-

missippian dark chert, shale, and carbonate intruded by numerous mafic sills (Jurassic?), and (c) Berriasian graywacke and shale.

5. *Misheguk unit*.—(structurally highest): (a) Jurassic(?) tabular, mafic igneous complex several thousand feet thick, and (b) Devonian carbonate.

The five internally thrust tectonic units are juxtaposed and separated by important low-angle thrusts, some of which have a minimum northward displacement of more than 20 mi. Cumulative northward displacement of all thrusts in the region may exceed 150 mi.

The major episode of thrusting was probably Aptian to early(?) Albian; however, three other phases of less intense Cretaceous deformation also are postulated. All four episodes were accompanied by deposition in adjacent foredeeps (exogeosynclines), which are progressively younger northward. The ages of the preserved foredeep rock sequences are: (1) Berriasian and Valanginian; (2) early(?) Albian; (3) later Albian (Nanushuk Group); and (4) Late Cretaceous (Colville Group).

The contrast between the north-trending grains of the Lisburne Peninsula and the southwest-trending structures of the De Long Mountains may have resulted from latest Cretaceous or Tertiary bending of the regional structural grain.

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#### STRATIGRAPHY AND STRUCTURE OF MIDDLE PALEOZOIC SECTION, INDEPENDENCE QUADRANGLE, INYO MOUNTAINS, CALIFORNIA

The middle Paleozoic section in the central Inyo Mountains is represented by slightly more than 2,000 ft of dark-colored hornfels with beds of limestone, impure chert, sandstone, and conglomerate near the base. Four formations have been differentiated: a previously unrecognized Middle Devonian unit, and the Perdido Formation, Chainman Shale, and Hamilton Canyon Formation of probable Late Mississippian age. The Middle Devonian rocks lie unconformably on beds ranging in age from Early Devonian to Middle Ordovician. A second unconformity separates the Middle Devonian section from the Perdido Formation. In the northern half of the Independence quadrangle, the upper part of the Chainman Shale, Hamilton Canyon Formation, and overlying carbonates of the Permo-Pennsylvanian Keeler Canyon Formation are complexly folded, whereas the underlying rocks apparently lack this deformation. This suggests that the upper part of the sequence has been involved in a *décollement*.

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#### MOVEMENT ALONG FAULTS IN CENTRAL INYO MOUNTAINS, EASTERN CALIFORNIA

A large anticline and syncline located near the mouth of Mazourka Canyon and formed during the early Mesozoic are broken by several faults of Tertiary age. These faults are almost parallel with the scarp formed at the time of the 1872 Owens Valley earthquake. Reconstruction of folds indicates that the best-exposed fault is normal and that vertical movement east of Kearsarge has exceeded 10,000 ft. Little

if any strike-slip movement has taken place on this or closely associated faults.

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#### NONEXPLOSIVE ENERGY SOURCES

(No abstract submitted)

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#### STRUCTURAL INTERPRETATION OF COMPUTER PROCESSED GEOFRACTURE DATA

(No abstract submitted)

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#### SUBSURFACE CROSS SECTIONS IN CARRIZO PLAIN SEGMENT OF SAN ANDREAS FAULT, CALIFORNIA

The Carrizo Plain segment of the San Andreas fault system includes an area of about 3,000 sq mi. The segment extends a distance of about 80 mi along the San Andreas fault between Cholame Valley on the north and Cuyama Valley on the south and is about 40 mi wide (20 mi on each side of the fault). Subsurface data from about 500 exploratory wells drilled in this area have been incorporated into a set of cross sections that carry into the subsurface the stratigraphic units and structures mapped and compiled by T. W. Dibblee, Jr., at the surface. Paleontologic data and electric-log correlations have been utilized to determine facies variations in Tertiary units on both sides of the fault. Strikingly different stratigraphy within the Tertiary sequence in closely spaced wells is interpreted as resulting from the effects of (1) gross lateral facies changes in rocks of the same age, (2) moderate erosion beneath local unconformities, and (3) lateral and/or thrust faulting that has brought rocks of the same age but different geologic environment into juxtaposition.

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#### GEOHERMAL ENERGY RESERVOIRS

The potential of a geothermal area is dependent primarily on volume and temperature of the reservoir and adequacy of fluid supply. Inadequate fluid supply may be a more common limiting factor than inadequate heat supply. Except in very porous reservoirs, most of the heat is stored in rocks rather than in pore fluids.

Geothermal fields can be classified as hot-spring systems or as deep insulated reservoirs with little surface expression; gradations also exist. Hot-spring systems have high near-surface permeability, at least locally, on faults and fractures, permitting fluids to escape at high rates. Deep reservoirs with little surface expression require the presence of permeable reservoir rocks capped by insulating rocks of low permeability.

Liquid water is generally the dominant fluid, but steam can form by boiling as hot water rises to levels of lower pressure. Dry steam areas probably are rare. About 30 areas in the United States have been explored for geothermal energy, but the existence of dry

steam has been proved only at "The Geysers." Extensive utilization of geothermal energy therefore must depend largely on steam "flashed" from hot water with decrease in pressure.

Problems that confront broad utilization of geothermal energy include: (1) discovery of reservoirs with adequate supply of energy and natural fluids; (2) deposition of  $\text{CaCO}_3$  or  $\text{SiO}_2$ ; (3) chemical corrosion; (4) objectionable chemicals in some effluents; and (5) inapplicability of existing public laws.

The optimum environment for a geothermal reservoir includes (1) potent source of heat, such as a magma chamber; such heat sources are most likely to occur in regions of late Cenozoic volcanism; (2) reservoirs of adequate volume, permeability, and porosity; and (3) capping of rock of low permeability that inhibits convective loss of both fluids and heat. A deep well-insulated reservoir may have at least 10 times the energy content of an otherwise similar, shallow, uninsulated reservoir.

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#### DISTRIBUTION OF CALCAREOUS NANNOPLANKTON FROM MIDDLE TERTIARY CIPERO FORMATION OF TRINIDAD, W.I.

A zonation of the middle Tertiary Ciperio section of Trinidad, W.I., based on the distribution of calcareous nannoplankton is presented, and some correlations with strata elsewhere, using these zones, are suggested.

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#### GEOLOGY OF AUGILA AREA, LIBYA

Reservoirs of the Augila oil field, Libya, are a carbonate and clastic unit as well as the underlying fractured and weathered granitic basement rock.

The Upper Cretaceous sedimentary reservoir rocks were deposited above the crest of a paleohigh composed of early Paleozoic or late Precambrian granitic rocks. The regional high extended across an area greater than 1,000 sq mi, had more than 2,000 ft of topographic relief, and was intensely fractured and weathered prior to burial.

A diachronous basal clastic unit, composed of basement-derived material deposited as the sea advanced across the high, grades upward and laterally into carbonates, forming a single sedimentary reservoir.

Petrographic and ecologic studies indicate that porosity and permeability in the sedimentary reservoir are the result of the environments of deposition and diagenesis. The Augila field is divided into the following environmental sectors: (a) low energy, well protected from the open sea; (b) low to moderate energy, shallow marine, slightly protected; (c) low to moderate energy, shallow open-marine shelf; and, (d) low energy, open marine.

These depositional environments were controlled by granitic ridges along the crest of the regional uplift and formed barrier islands during deposition of the sedimentary reservoir.

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#### LINDSEY SLOUGH GAS FIELD, CALIFORNIA