

submarine fan deposit.

Continuous grain-size plots of the outcropping sands were drafted and distinct turbidite facies were identified using Mutti and Ricci-Lucchi's classification. At the surface, the Williams dips northeast into the valley and contains many rather thin-bedded, usually graded, sandstones and conglomerates, with high porosity and permeability, which are interbedded with siltstone and shale. Thick deposits of shale, commonly cherty, separate large bundles of turbidites that pinch out along strike. The sandstone bundles often form coarsening- and thickening-upward sequences typical of deposition on the smooth suprafan lobes of the midfan. Other sandstones form fining- and thinning-upward sequences diagnostic of deposition on the channelized suprafan, although lack coarse pebbly material. Apparently, the Williams fan continued to prograde until at least midway through its depositional history, when significant lateral shifting of coarse-grained sandstone bodies occurred.

According to petrographic modal analyses, the sands are arkosic, having a clay matrix and occasional carbonate and opal cements. Lithologic descriptions plus petrographic and paleocurrent data suggest the source terrane was only a few miles west-southwest, and most likely was the northern Gabilan Range. The northern Gabilan Range is composed of granitic and metamorphic rock, and is now located 150 mi (240 km) northwest of the outcropping Williams owing to Miocene and post-Miocene strike-slip displacement along the San Andreas fault.

In the subsurface, the Williams is composed primarily of fine to medium-grained sands, which are rather thinly bedded, poorly sorted, and interbedded with thick shales and siltstones characteristic of a lower fan facies. Oil is produced from Williams sands less than 2 mi (3.2 km) north of the study area from the Spellacy and Midway anticlines of the Midway Sunset field. Shales, and occasionally bentonites, separate the producing Williams into different reservoirs.

HALPERN, H. I., and I. R. KAPLAN, Univ. California, Los Angeles, CA

Mineral-Kerogen Interactions in Laboratory Experiments—Significance for Petroleum Genesis

Kerogen from lagoonal mats and from a coastal marine sediment was extracted, mixed with known minerals, and heated in sealed pyrex tubes for periods extending from 1 to 100 hours over a temperature range of 50 to 500°C. The minerals used were calcite, kaolinite, illite, and two different montmorillonites. Methane and carbon dioxide were separated, quantitatively determined, and their $^{13}\text{C}/^{12}\text{C}$ isotope ratio measured. Rock Eval was used on the bulk residual material after pyrolysis to determine amount of hydrocarbon formed and the thermal changes in the kerogen. These results were compared with data obtained from bitumen extraction by organic solvents.

The results suggest that minerals can have either catalytic or inhibitory effects. These effects are displayed at lower temperatures only. At higher temperatures, thermal effects dominate. Calcite and montmorillonite C were found to be inhibitory to production of bitumen, whereas kaolinite, illite, and montmorillonite B were found to be catalytic. The inhibitory effects were interpreted as being due in part to direct interaction between mineral and kerogen, but also to entrapment of bitumen within interlayer spacing and prevention of its escape due to mineral-organic molecular configuration.

HARNETT, TOM, Ventura, CA

Late Pliocene Turbidites, Adams Canyon, California

Late Pliocene deep-water 990 ft (330 m), turbidites of the upper Pico Formation form a well-exposed, nearly complete vertical section in Adams Canyon, California. Approximately 213 ft (700 m) of section were examined in detail, revealing five sections of channel-fill sediments up to 386 ft (117 m) thick, dominated by thick-bedded, coarse to fine-grained sandstones, pebbly sandstones, and conglomerates. A thinning of beds upward was found in all five section, along with an associated decrease in grain size. The channel-fill sediments are separated by tens to hundreds of feet (meters) of finer grained plane-parallel interchannel turbidites. The associations of facies types, along with the cyclic nature of the bed thicknesses, indicate that the entire sequence represents a midfan environment of deposition. A comparison with equivalent age midfan channel sediments exposed in Santa Paula Creek, 1.2 mi (2 km) to the east, indicates more frequent deposition for the midfan sediments of Adams Canyon. This is interpreted to be the result of a decrease in the midfan gradient from east to west causing increased deposition of sediment gravity flows in the Adams Canyon area. Paleocologic studies have indicated an infilling sedimentary basin from early Pliocene time to the beginning of the Pleistocene.

Pebbles and other clast composition indicate the source terrane was Eocene and Miocene sedimentary rocks to the northeast and crystalline basement toward the east. A submarine canyon trending west to southwest is indicated by the paleocurrent data. Flow mechanisms indicated by structures within the section show that sediment was transported by debris, grain, fluidized, and turbulent flows. A rate of 1 mm/year has been estimated as the overall sedimentation rate for the Pliocene sediments in the area.

HOLMES, MARK L., J. D. MACQUEEN, and R. E. SYLWESTER, U.S. Geol. Survey, Seattle, WA

Marine Geophysical Measurements in Central Puget Sound, Washington

Marine seismic refraction (sonobuoy and OBS) and gravity data obtained from the Puget Sound main basin and Lake Washington show a major discontinuity in both seismic velocities and rock densities across a steep (15 mgal/km) gravity gradient striking generally westward through Seattle from the Cascade Range foothills to Hood Canal. North of this gradient is a -129 mgal Bouguer gravity minimum centered over Lake Washington. A least squares inversion analysis of the residual Bouguer gravity field was combined with the refraction velocities to model the subsurface density distribution beneath the central Puget Sound lowland.

The data suggest the existence of a 7 to 8-km deep sedimentary basin beneath the gravity minimum north of the steep gradient. The basin is filled with probable Tertiary and Quaternary rocks having densities ranging from 2.0 to 2.6 g/cc. Modeled rock densities beneath the basin (2.7 to 2.8 g/cc) may indicate the presence of volcanic basement rocks. South of the gravity gradient, Tertiary volcanic and intrusive rocks are overlain by Tertiary and Quaternary sedimentary rocks up to 2 km thick.

The gravity gradient appears to mark a steep fault or faulted flexure forming the southern boundary of the Tertiary basin lying beneath Lake Washington and Seattle. The gravity model suggests that much of the steepness in the gradient across this feature is due to a near-surface density contrast between a west-

trending belt of high density Tertiary igneous rocks and low density tuffs or pyroclastic volcanic and sedimentary rocks along the southern margin of the basin.

INGLE, JAMES C., MARTIN B. LAGOE, and JAVIER HELENES-ESCAMILLA, Stanford Univ., Stanford, CA

Distribution and Depositional History of Neogene Phosphorites Along Pacific Coast of North America

Pelletal and nodular phosphorites occur commonly to abundantly in neritic (shelf) and bathyal (slope) deposits of uppermost Oligocene (25 Ma) to upper Miocene (10 to 7 Ma) age from 23°N on the peninsula of Baja California, Mexico, to 39°N near Point Arena, northern California, encompassing a belt of deposition about 1,430 mi (2,300 km) in length. In addition, pelletal phosphorite sands are commonly present within adjacent middle and lower bathyal deposits of similar age range representing redeposited material in conduits, feeding basins, and submarine fans. In some areas, pelletal phosphorites reach 200 ft (60 m) in thickness. Mining of Miocene phosphorites is now well under way in Baja California. The age of peak formation and accumulation of Pacific Coast phosphorites appears to become younger from south to north implying variations in patterns of upwelling and/or eustatic, climatic, and tectonic control of shelf character and flux of terrigenous clastics to the margin. Later reworking of the Miocene deposits has allowed reconcentration of the phosphorites in adjacent Pliocene, Pleistocene, and Holocene neritic units.

Paleontologic, isotopic, and sedimentologic evidence indicate that the widespread Neogene phosphorites formed under a special set of climatic, oceanographic, eustatic, and tectonic conditions associated or coincident with a major climatic threshold occurring in mid-Miocene (15 Ma) time and commencement of a glacial climatic state. Three key factors were apparently responsible for allowing the unusually prolific formation of Miocene phosphorites as well as simultaneous widespread deposition of diatomaceous sediments in this region including (1) vigorous upwelling of nutrient-rich water and accelerated productivity as a function of deteriorating Neogene climate, (2) associated development of intense oxygen minima impinging against the various slope and shelf areas creating appropriate biogeochemical conditions for phosphorite precipitation, and (3) the absence or severe reduction in delivery of terrigenous clastics to sites of phosphorite precipitation as a function of Neogene eustatic, climatic, and tectonic events.

JENDEN, PETER D., and I. R. KAPLAN, Univ. California, Los Angeles, CA

Diagenetic Relationships Between Inorganic Matrix and Kerogen in Wilcox Group, Southwest Texas

Eighteen core samples of shale from the Eocene Wilcox formation in the Gulf Coast of Texas were extracted in organic solvents and digested in hydrofluoric acid in order to examine the bitumen and kerogen fractions. The kerogen was found to be largely terrigenous in origin with stable carbon isotope values ranging between -26 and -29 ppt (PDB). Smectite dehydration in the area begins at less than 1 km depth (60°C). At the depths of initial petroleum generation (1.5 km and 85°C), expandable layers comprise only 30% of the illite-smectite clays. It therefore does not seem likely that water expelled during smectite dehydration can mobilize significant amounts of hydrocarbons.

Geopressuring of pore fluids occurs toward the end of the main stage of petroleum generation, below 3 km. In the gas zone, hydrocarbon concentrations increase between 3.6 and 4.6 km from a low of 7 mg/gC to 15 mg/gC. Two samples in this region showed anomalously high concentrations of hydrocarbons (100 mg/gC). These observations may indicate subsurface migration of hydrocarbons, perhaps in a methane and carbon dioxide-rich fluid phase. In addition to facilitating hydrocarbon migration, carbon dioxide generated from kerogen may also be involved in the precipitation of ankerite cement in sandstones below 2.5 km.

JORDAN, J. M., J. I. PRITCHARD, H. RENICK, and R. C. WEST, Indesco Inc.

Exploring for Subtle Sandstone Channels By Use of Electrical Geophysics

Electrical methods can be used directly as a resistivity tool which not only defines structure but also provides information, such as rock type, fluid content, and porosity, necessary to resolve lithologic and stratigraphic problems.

To help meet the challenge of today's petroleum exploration problems, a multi-methodology electrical resistivity system has been developed. This system uses various source-receiver arrays and multiple source and receiver types.

Seismic roll-along cables and an eight-channel digital recording system are used to achieve rapid field coverage. Measurements are made in profile every 220 ft (67 m).

Five decades of frequency can be covered to produce soundings from the surface to a maximum of 30,000 ft (9,100 m) in depth. A powerful transmitter is used to obtain near-zone (late time) and far-zone (early time) electromagnetic soundings as well as DC soundings. Magnetotelluric measurements are used to reach depths below 20,000 ft (6,100 m) if necessary.

The data are displayed as profiles of closely spaced pseudo E-logs and induction logs that are correlatable to existing well logs.

Two case histories of exploration for subtle sand traps include one located in the D J basin of Colorado. The other describes the detection of a 30 ft (9 m) sand sequence at a depth of 2,500 ft (760 m) on the eastern shelf of the Permian basin in west Texas. The approaches used in these case histories have direct application to many problems of the central valleys of California.

KELLER, MARGARET A., U.S. Geol. Survey, Menlo Park, CA

Lithostratigraphy and Diagenesis of Monterey Formation near Ojai, California

Lithostratigraphy and diagenesis of the middle Miocene Monterey Formation were studied at seven localities parallel with the axial trend of the Miocene Santa Barbara basin between Goleta and the North Sulphur Mountain area of the Ojai oil field in Santa Barbara and Ventura Counties, California. The lithologic sequence of the Monterey Formation does not change markedly within the area except for the addition of discrete sand layers, as much as 1.6 ft (0.5 m) thick, in the east near the Ojai oil field. The most complete, accessible, and representative section studied is 1.2 mi (2 km) south of Oakview, where the formation can be divided into five units, which correlate well to C. M. Isaacs' five informal members along the Santa Barbara coast. At the base of the Monterey, distinctive,