cline) east of the Antler orogenic continental margin. The terrigenous detritus was derived from a rising cordillera composed of Devonian and older oceanic rocks that during the Antler orogeny was first deformed and subsequently obducted eastward onto the outer carbonate shelf as the Roberts Mountains allochthon. Significant amounts of westerly derived detritus in Upper Devonian deposits reflect early Antler orogenic activity along the continental margin. Recurring uplift of the cordillera followed Antler obduction, as shown by chert detritus, derived from the allochthon, in Lower and Upper Mississippian deposits. In Late Mississippian time, clastic sediments filled the foreland basin and spread eastward across the carbonate shelf onto the craton. Volume of detritus diminished in latest Mississippian to Early Pennsylvanian time, as evidenced by widespread carbonate deposition in the Pennsylvanian.

Locally in the early Late Devonian and regionally in the late Late Devonian and Mississippian, western detritus came as a steady influx of mostly clay, silt, and sand debris, and as an irregular influx of conglomeratic debris. Many units exhibit turbidite features—graded bedding, convolute laminae, and sole marks. Some fine-clastic units contain indigenous ichnofossils and displaced fossil invertebrates, fish remains, and terrestrial plant debris; few limestones contain indigenous fossil invertebrates. The sequence and thickness of rocks vary areally, indicating irregular bottom relief which produced a complex system of sediment traps and environments.

PRICE, LEIGH C., Dept. Geol. Sci., Univ. California, Riverside, Riverside, Calif.

SOLUBILITY OF PETROLEUM IN WATER AS FUNCTION OF TEMPERATURE AND SALINITY AND ITS SIGNIFICANCE IN PRIMARY PETROLEUM MIGRATION

The aqueous solubilities of individual hydrocarbons, petroleums, and petroleum fractions increase with increasing temperatures. The rate of solubility increase is uniform from room temperature to about 100°C, after which the rate of increase rises markedly. At temperatures above 150°C, solubilities are high enough to account for the transfer of significant quantities of dissolved hydrocarbons in geologic systems.

Salinities of 350,000 ppm NaCl concentration reduce the aqueous solubilities of individual gasoline-range hydrocarbons to 5-7% of their solubilities in fresh water. A temperature drop from 150 to 25°C reduces the aqueous solubility of a whole petroleum by a factor of 4.5-20.5. Thus, the pronounced decrease in solubility of petroleums at higher salinities and lower temperatures encountered at shallow depths readily serves to release dissolved hydrocarbons during the upward movement of subsurface waters.

Other investigators have shown that 15-20% water, by volume, remains in Gulf Coast argillaceous sediments at depths below 14,000-18,000 ft. This quantity of water is sufficient to account for the primary migration of petroleum from source rocks by molecular solution.

Faults are believed to provide the pathways for vertical movement of water and dissolved hydrocarbons from great depth. Eventually the fluids are focused into sands when the fault becomes impermeable to further fluid movement. Field examples are present in the Gulf Coast and Los Angeles basin. This mechanism is restricted to argillaceous basins containing high concentrations of expandable mixed-layer clays that are buried to a minimal depth of 20,000 ft. It does not apply to carbonates or argillaceous limestones in which primary migration can occur at much shallower depths.

PRYOR, WAYNE A., Dept. Geology, Univ. Cincinnati, Cincinnati, Ohio

PETROLOGY AND SEDIMENTOLOGY OF *OPHIOMORPHA NODOSA* AND MODERN CALLIANASID BURROWS

The trace fossil, *Ophiomorpha nodosa* Lundgren, callianasid burrows, and other similar decapod domichnia exhibit petrographically distinct wall structures that are formed by the mandibular activities of the decapods during construction of their tubular domiciles. These decapod burrows are lined with one or two layers of aggregated sand pellets, 1-10 mm in diameter. The pellets, in turn, are composed of radially oriented, 0.025-0.5-mm subspherical masses of sand grains in a fine-grained, organo-clay matrix.

Callianasid decapods live and construct ophiomorphid burrows in a wide range of marine and brackish-water environments, including estuaries, bays, lagoons, tidal pools and creeks, beaches, shallow-littoral deposits, and in sediments at least 1.5 km offshore at depths of at least 12 m. Ophiomorphid burrows of *Callianasa major* and *C. atlanticus* average only about 5 burrows/sq m in the high-energy, open-marine shore zones and increase to an average of 20 burrows/sq m in 10 m of water, 1 km offshore. The highest concentrations of actively used ophiomorphid burrows, up to 450/sq m, are in the protected, low-energy, tidal pools of the bay and lagoon shores. Contrary to previous reports, callianasid burrows and their ancient equivalents, *Ophiomorpha nodosa* Lundgren, are not indicators of the high-energy, open-marine littoral zone.

Callianasa major and *C. atlanticus* burrows extend down, vertically, to depths of 4.7 m below the sediment surface, where they branch laterally as interconnected, horizontal gallery systems of wide extent. Identical configurations of *Ophiomorpha nodosa* Lundgren are present in the Gulf Coastal Plain Mesozoic and Cenozoic sediments.

RICCI LUCCHI, FRANCO, Univ. Bologna, Bologna, Italy

SEQUENTIAL ANALYSIS OF TURBIDITE BASINS IN NORTH-CENTRAL APENNINES

The Miocene Marnoso-arenacei and Laga Formations form two of the largest outcropping turbidite units of the north-central Apennines, where extensive exposures make facies analysis feasible. Following a more general model proposed by Mutti and Ricci Lucchi (which utilizes bed geometry), sedimentary structures and texture, facies association (slope, submarine fan, basin plain) and sedimentary facies (conglomeratic sandstones, sandstones, sandstones with shale interbeds, shales with sandstone interbeds, chaotic deposits, hemipelagic pelites) were recognized. The value of sequential analysis for comparing stratigraphic subunits within a submarine fan system, and particularly for differentiating between inner fan, mid-fan, outer fan, and basin-plain environments, is emphasized. Recurrent patterns of sedimentation (megasequences or megarhythms, 10-100 m thick) are composed of sets of thick, mostly arenaceous, massive, graded, or crudely laminated layers, with alternate finer grained beds, which are thinly laminated in the lower part. Two main types of "ordered" megasequences are recognized: (A) positive, or thinning upward, interpreted as filling of fan valleys or channels; and (B) negative, or thickening upward, considered to be prograding outer fans along nonchanneled distributaries. Three monotonous, or random, sequences composed of finer grained sediments are also present: (C) slope deposits (thin layers, with a sandstone/shale ratio less than 1); (D) interdistributary fan deposits (thin to medium layers, sand/shale ratio less than 1; and (E) basin-plain deposits (medium to thin layers, with sporadic isolated thick turbidite units, sandstone/shale ratio greater than 1). The vertical association of these subunits, and especially those of the A and B megasequences, show both similarities and differences in the sedimentary history and tectonic control of the Miocene basins. Further application of these criteria to other turbidite basins probably will aid in predicting the location and geometry of sandstone bodies.

RISTVET, BYRON L., FRED T. MACKENZIE, Dept. Geol. Sci., Northwestern Univ., Evanston, Ill., and DONALD C.

THORSTENSON and ROBERT H. LEEPER, Southern Methodist Univ., Dept. Geol. Sci., Dallas, Tex.

PORE-WATER CHEMISTRY AND EARLY DIAGENESIS OF NEARSHORE MARINE SEDIMENTS

Pore-water chemistry and mineralogy of carbonate and terrigenous sediments from Kaneohe Bay, Oahu, Hawaii, were analyzed to determine differences in pore-water compositions, in nature and extent of early diagenetic reactions, and in fluxes of constituents between these sediment types. Pore waters, extracted at *in-situ* temperatures and analyzed for pH and concentrations of Ca^{++}, Mg^{++}, K^+, Na^+, Cl^-, $SO^=_4$, reduced sulfides, SiO_2, NH^+_4, PO_4, NO^-_3, and Sr^{++}, of 23 1-3-m gravity cores show chemical gradients of dissolved species with sediment-burial depth.

The sediment pore waters are anaerobic, exhibiting an increase in reduced sulfides, H^+, and alkalinity and a decrease of $SO^=_4$ with depth. Owing to reactions resulting in the formation of diagenetic ferrous sulfide, the pH's of terrigenous sediment pore waters are higher at an equivalent depth than those of carbonates, whereas reduced sulfides are lower and sulfate reduction is more rapid.

Calcium and Mg^{++} are removed from pore waters with increasing depth as a result of (1) formation of protodolomite, *or* (2) precipitation of calcite and substitution of Mg^{++} for Fe^{++} in clay minerals resulting in formation of ferrous sulfide ("Drever reaction"). Dissolved SiO_2 increases with depth by solution of siliceous plankton or amorphous aluminosilicates, whereas NH^+_4, $PO^{\equiv}_4$, and NO^-_3 increase with depth because of bacterial oxidation of organic matter. Sodium, K^+, and Cl^- vary sympathetically, reflecting the original salinity of the pore waters.

Lateral gradients of dissolved species in bay pore waters reflect the fact that the southern end of the bay is a more efficient trap for organic matter. These gradients imply a lateral component of flux of dissolved constituents.

This study shows that (1) calculations of fluxes in and out of marine sediments must take into account variability of pore-water compositions and fluxes among sediment types, and (2) nutrient regeneration in pore waters can be a significant source of nutrients to overlying waters, whereas reduced sulfide fluxes may be significant enough to inhibit infaunal and epifaunal growth.

ROSS, CHARLES A., Dept. Geology, Western Washington State College, Bellingham, Wash.

SEDIMENTARY ENVIRONMENTS, PENNSYLVANIAN AND EARLY PERMIAN, SOUTHEASTERN ARIZONA

In southeastern Arizona, Pennsylvanian and Early Permian strata have 15 complex transgressive and regressive cycles. Sedimentary environments were influenced primarily by a stable central Arizona shelf (divisible into Papago inner shelf, San Pedro outer shelf, and Mogollon inner shelf) and an unstable Pedregosa basin on the southeast.

Morrowan and earliest Derryan deposits (Black Prince Limestone) have a basal red clastic unit overlain by thin, sheetlike carbonate units. During late Derryan and early and middle Desmoinesian deposition (lower part of Horquilla Limestone), successive carbonate banks separated the 3 parts of the central Arizona shelf, but there was little differentiation of sediments on the San Pedro outer shelf and in the Pedregosa basin. During the latter part of the Desmoinesian, a clastic influx from the north initiated carbonate-poor depositional cycles.

Missourian and Virgilian deposition (upper part of Horquilla Limestone) produced more clearly differentiated carbonate-bank margins around the Pedregosa basin and San Pedro outer shelf. Northward, these strata become dominantly clastic and pass into interdistributary bay and lagoonal deposits and supratidal, deltaic redbeds and conglomerates of the Supai Formation.

Wolfcampian depositional environments (part of Supai and Earp Formations) shifted southeast with time. On the Mogollon inner shelf, supratidal deltas and gypsiferous lagoonal deposits form this part of the Supai Formation; and on the San Pedro outer shelf, shallow-shelf sandstones, siltstones and shales intertongue with a few thin limestones. Massive, lenticular carbonate banks enclosed the Pedrogosa basin, and within the basin, dark fetid clastics and carbonates suggest restricted environments. Latest Wolfcampian or early Leonardian sediments (part of Supai and Earp Formations) are sandy dolostones and siltstones with impoverished faunas that suggest a series of poorly aerated lagoons.

RUSSELL, KENNETH L., Cities Service Oil Co., Exploration and Production Research, Tulsa, Okla.

INTERSTITIAL WATERS, MINERALOGY, AND DIAGENESIS OF SHALES, DARE COUNTY, NORTH CAROLINA

The Atlantic coastal plain of North Carolina contains a complex stratigraphic sequence of Mesozoic and younger rocks. Sidewall cores were taken in the shale sequences of 2 closely spaced wells for analysis of their mineralogy and interstitial waters. In both wells, interstitial waters from all shales are less saline than sea water—even in those shales that are distinctly marine. Typical samples from the first well are mostly NaCl; sulfate is commonly high—around 4,000 ppm or more, and calcium also is above its seawater concentration. The waters in the adjacent sands, which are calculated from logs and assumed to be NaCl, have salinities that range from 30,000 to 40,000 ppm. There is no regular relation between salinities in shales versus the associated sands.

In the second well, interstitial waters in corresponding shales are of equal or lower salinities, in some only half as saline as in the first well, and contain more nearly pure NaCl. However, the salinity in the adjacent sands is always greater than 40,000 ppm and increases with depth to over 100,000 ppm. Thus, the correlative shale and sand beds in these 2 wells contain very different interstitial waters. There is no obvious geologic explanation for the different diagenetic history. The mineralogy of all shales is similar, with kaolinite, montmorillonite, and quartz predominant, illite always present, and calcite sparingly present. Neither salt nor gypsum was present in the second well, although many samples in the first well are nearly saturated with gypsum. Temperatures are not especially high, and there is no evidence for extensive mineral diagenesis.

SABINS, FLOYD F., JR., Chevron Research Co., La Habra, Calif.

GEOLOGIC INTERPRETATION OF RADAR AND SPACE IMAGERY OF CALIFORNIA

Side-looking airborne radar (SLAR) imagery in California is interpreted in terms of geologic structure and rock type. Field checks and comparison with published geologic maps indicate some revisions of existing maps. In particular, linears on the radar imagery point to previously unmapped faults. In outcrops where surface texture is related to bedrock lithology, the radar signature may indicate rock type.

The unmanned Earth Resources Technology Satellite (ERTS) telemeters multispectral-scanner imagery that is reconstituted into reflected-infrared-color imagery. With respect to radar imagery, the ERTS imagery has poorer spatial resolution and smaller scale; nevertheless, useful regional patterns may be interpreted. Repetition of ERTS imagery on an 18-day cycle should enable us to determine the season for obtaining maximum geologic information.

SANDERS, J. E., Dept. Geology, Barnard College, New York, N.Y.

MAP OF PARTS OF FLOOR OF SANTA BARBARA