ples from numerous surface sections measured in considerable detail from localities throughout the east-west outcrop band of the Nanushuk are also being studied.

The results thus far are preliminary. Distinctive relations among assemblages are emerging, suggesting correlations from the surface to subsurface and delineating ages of middle Albian to early Cenomanian for the units studied. This palynologic work represents a pioneering effort in North Slope biostratigraphy. One interesting aspect of the overall Nanushuk Group project is that the same samples used for paleontology are also used for sedimentologic and other analyses, making possible multidisciplinary studies on a sample-to-sample basis.

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Diagenetic Alteration in Eocene Alluvial-Plain Deposits, Sierra Nevada Foothills, California

Cobbles in Eocene alluvial-plain deposits of California indicate that major changes have occurred in these first-cycle sediments. Migrating pore water has caused diagenetic alteration in the upper parts and authigenic iron sulfide growth in the lower parts of these braided-river gravels. Analysis of thin sections and X-ray diffraction patterns reveals that mica, amphibole, and feldspar in cobbles of various compositions are replaced predominantly by kaolinite. Original minerals found in fresh cores of some cobbles are replaced completely in altered rims by hematite and limonite. Sand samples from the upper parts of the gravels contain abundant quartz with kaolinite pseudomorphs of biotite and feldspar and hematite pseudomorphs of iron sulfide. The heavy-mineral suite consists of chemically stable minerals including zircon, ilmenite, tourmaline, and the alteration products anatase and leucoxene. Sand in the basal Eocene gravels contains abundant detrital iron-bearing silicates and authigenic sulfides. Cobbles in the lower unit show little evidence of alteration. Apparently, decomposition of trapped organic matter and pyritic slate clasts reduced the pH and Eh of the pore water percolating through the gravels, causing the hydrolysis of silicate minerals. Some constituent ions migrated in solution away from reaction sites, and iron was precipitated as sulfides as it reached saturation. At some later time, lowering of the water table permitted oxidation of the sulfides in the upper parts of the gravels. This interpretation suggests that the subtropical alluvial-plain environment is ideal for elimination of chemically unstable minerals and rock fragments from sediment being transported through the river system.

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Shell Borings in Upper Miocene–Pliocene Tamiami Formation, Collier County, Florida

Borings of common marine organisms such as algae, bivalves, polychaetes, and echinoids are potentially useful in sedimentologic and paleoecologic studies. A variety of spectacular shell borings is preserved in the upper Miocene–Pliocene Tamiami Formation exposed in Collier County, Florida. Paleontology of the richly fossiliferous Tamiami Limestone is difficult to study because leaching has selectively removed aragonitic shells. However, this selective shell removal has revealed excellently preserved shell borings as mud-filled molds. Characteristic, interconnecting, subspherical galleries of clionid sponges are the most common borings. The ichnogenus *Entobia* is applied to fossil borings similar to modern clionid sponges. Essentially all of the thick-shelled bivalves, as well as many of the thinner shelled species show evidence of sponge borings. Borings of two polychaete worms are also abundant in Tamiami fossils. Excavations similar to those produced by the genus *Polydora* are the most common, and the second appears unlike modern forms and is tentatively placed in the ichnogenus *Meandropolydora.* Most thick shells contain distinctive borings of two species of bivalves. These borings have a calcareous lining, and are similar in form to borings of the modern mytilid genus *Lithophaga.* The Tamiami Limestone has been described as of shallow-water origin, because of the contained oysters, pectens, and echinoderms. Information derived from the abundant shell borings is consistent with this interpretation, indicating a shallow, warm, low-energy environment.

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In-Situ Formation of Botryoidal Aragonite on Permian Seafloor

Botryoidal masses of (former) aragonite make up the core facies of some Lower Permian phylloid algal mounds in the Sacramento Mountains of New Mexico. These mounds were deposited along a shelf edge in shallow, gently current-swept environments. The aragonite appears to have been precipitated inorganically as in-situ seafloor growths, with individual vertical relief as much as 5.0 cm above the substrate. As such, they represent the first reported occurrence of marine aragonite formation at the sediment/water interface. The lateral and vertical coalescence of botryoids created a three-dimensional network of interbotryoid and internal cavities that were simultaneously filled with fossiliferous marine sediment and/or aragonite-fan cements. The volume of marine aragonite in these inorganic boundstones is as high as 85% in some samples.

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Petrology of Miocene Catahoula Formation, Central Texas Coastal Plain

In the central Texas coastal plain, the Catahoula Formation consists of a basal Chita Sandstone Member (fluvial-channel facies) and an overlying and/or laterally contiguous Onalaska Clay Member (flood-plain and levee facies). The basal unit of the Chita Sandstone is typically a channel deposit of ash-gray, conglomeratic, medium to coarse-grained sandstone in graded to poorly laminated beds containing silicified wood chips. Fining-upward sequences of moderately sorted sandstone units consist of (McBride classification): sublitharenite (42%), quartz-arenite (29%), subarkose (16%),

and litharenite (13%). Modal analyses of 41 thin sections show that framework grains consist of quartz (80%), rock fragments (15%), feldspar (5%), and trace amounts of micas and heavy minerals. Porosity of Chita Sandstone units ranges from 0 to 35%; mean percent of cement (mostly chalcedony, cristobalite, and opal) is 12.8%.

The Catahoula Formation is unique in that it records the last significant influx of volcanic detritus supplied to Gulf Coast sediments. Volcanic contributions include (1) abundant volcanic quartz (22% of total quartz); (2) rock fragments consisting mostly of silicic shards, felsite clasts, and tuffaceous clay clasts; (3) fresh sanidine (sanidine/orthoclase ratio = 1.2); and (4) a heavy mineral suite dominated by euhedral, elongated zircons. Onalaska Clay consists of mudstone and clay-ball lithoarenite beds composed mostly of montmorillonite, volcanic ash, and quartz silt. Volcanic ash in the Onalaska Clay is a likely source of most of the uranium mineralization in contiguous sandstone units. Silica leached from volcanic ash in the Onalaska Clay has been redeposited as pore-filling sequences of chalcedony (length slow and length fast), cristobalite, and opal cement in Chita Sandstone units.

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Creation and Application of Variable Density Grids to Oil Exploration Data

A significant problem in automatic interpolation procedures is that of honoring data points exactly. When maps of subsurface structures are made by computer, contours can pass on the wrong side of well data points or, where the well log depth is the same as the contour, not pass through them. They will be misplaced a varying amount depending on the grid size employed during interpolation. Honoring the data points can be guaranteed only if the rectangular or triangular grid base has as some proportion of its nodes the wells themselves. Therefore, the concept of a variable size grid is introduced using either rectangles or triangles, with the cell size decreasing in areas of closely clustered boreholes. By using locally defined functions it is possible to maintain a continuous surface over the whole map area and create a faithful representation of the structures in the map. FELIX, a minicomputer mapping and analysis system, is one system used to interpolate the subsurface structure of an oil field where the wells are distributed unevenly over the test area. In the triangular case in this system, it seems likely that little time need be spent searching for optimal triangular networks and a relatively simple algorithm is substituted.

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Paleoecologic Evaluation of Late Eocene Zonations of West Coast

Investigations of the late Eocene benthic forams along the West Coast indicate that the current zonal schemes can be modified to accommodate the constraints imposed on the organisms by ecologic conditions and thus become less provincial. The benthic foraminiferal assemblages of northwestern Oregon and southwestern Washington are used to develop a series of ecologic facies indicative of bathymetry and/or water mass. Upper depth limits, trends, clines, and morphologic variations of this group provide tools for determining ecology. The faunas of the type sections of the California and Washington stages, zones, and subzones, when analyzed in terms of this ecologic model illustrate some of the deficiencies inherent in these schemes. The late Eocene zones of California have a strong association with depth; that is, Narizian zones are lower or middle bathyal whereas Refugian zones are outer neritic or upper bathyal. The late Eocene zones of Washington are diagnostic of middle bathyal depths with considerable transport; as a result partial rather than total ranges are used in the development of these zones.

Although no new zones are proposed, it is possible to revise the existing zones to recognize the total ranges and bathymetric or other ecologic controls. The late Narizian Stage encompasses a bathyal and neritic facies. The bathyal facies is correlative with a modified *Bulimina corrugata* Zone of California and the *Uvigerina* cf. *U. yazooensis* Zone of Washington. The neritic late Narizian facies corresponds to a modified *Bulimina schencki–Plectofrondicularia* cf. *P. jenkinsi* Zone of Washington and a modified *Amphimorphina jenkinsi* Zone of California. The Refugian Stage can also be divided into a neritic and bathyal facies. However, the early and late subdivision of this stage is weak. The Refugian is equivalent to the modified versions of the *Cibicides haydoni* Subzone, *Uvigerina atwilli* Subzone, and the *Uvigerina vicksburgensis* Zone of California and a modified *Sigmomorphina schencki* Zone of Washington. The *Cibicides haydoni* Subzone is the neritic facies of the Refugian whereas the faunas of the *Uvigerina atwilli* Subzone, *Uvigerina vicksburgensis* Zone, and *Sigmomorphina schencki* Zone represent the bathyal Refugian facies.

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Computer Drafting—Its Application in Petroleum Exploration

Conventional or manual drafting of exploration data has been used since the early 1900s. Within the past 4 or 5 years, the use of small computer and digitizing equipment to supplement proved methods has saved time, improved accuracy, and simplified modifications.

Maps, charts, cross sections, etc, can be captured, edited, and drawn by plotters in half the time of conventional methods. Once in digital form, documents can be edited and easily combined with other graphics. Maps with different scales and projections can be transformed to common projections and scales.

Phillips Petroleum Co. uses a Bendix 100/101 digitizing-drafting system which consists of a Nova 100 computer with tape drive and disk pack, a Bendix cursor and table, and a Tektronix 4014-1 CRT. Output can be generated for both a Calcomp 748 plotter and/or a Versatec 42-in. electrostatic plotter. This type of system is not a replacement for manual drafting, but is a supple-