preferentially preserved in finer grained and muddy layers. However, even in some muddy sandstones, rock fragments, feldspars, and matrix were dissolved, creating secondary porosity.

The probable paragenetic sequence of major diagenetic events was: (1) hematite-clay coatings (red-bed units only); (2) quartz-overgrowth; (3) local clay, carbonate, and sulfate cementation; (4) compaction (ductile grains deformed); (5) leaching of non-quartz grains, cement, and matrix; (6) crystallization of authigenic kaolinite and minor illite and halloysite in some secondary pores; (8) minor dolomite cementation and replacement. Hydrocarbons migrated after kaolinite had partly occluded some pores. The products of diagenesis vary according to original composition, porosity, and permeability.

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Provenance of Middle Tertiary Nonmarine Deposits, Santa Maria Basin and Vicinity, California

Rocks of the middle Tertiary (mostly Oligocene) Sespe and Lospe Formations crop out in the Santa Maria basin and vicinity. Lithofacies are typical of alluvial fan/plain deposits: clast- and matrix-supported conglomerates interbedded with planar to crossbedded sandstones are commonly overlain by sandstone-shale sequences.

Although Lospe deposits near San Simeon, in northwestern San Luis Obispo County, and at Point Sal, near Santa Maria in Santa Barbara County, are presently more than 90 km apart on opposite sides of the San Simeon-Hosgri fault zone, they were derived from the same western source consisting partly of silica-carbonate rock and ophiolite terranes. Proximal fan lithofacies near San Simeon and medial to distal facies at Point Sal indicate an easterly draining system in which San Simeon was closer to the source. Point Sal sandstone clasts containing more than 5% detrital potassium-feldspar were probably derived from an Upper Cretaceous-Paleogene sedimentary terrane to the southwest.

The middle Tertiary paleogeology of the Santa Maria basin was dominated by an easterly draining, aggrading alluvial fan complex near Point Sal. Displacement along a proto-Hosgri fault probably initially uplifted the highlands west of the fan complex. Lospe alluvial deposition at Point Sal was separate from Sespe-Lospe deposition to the south, southeast and north, with the possible exception of an area 3 km northeast of Santa Maria.

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Sedimentation on Antarctic Sea Floor

The most common sediment type cored on the continental shelf is relict diamicton. Sediments were deposited by grounded ice (basal tills) through lodgement processes or from floating ice. The seaward limit of basal tills is the shelf edge. Glacial marine sediments derived from floating ice are probably deposited near the grounding line of ice shelves. Several criteria distinguish basal tills from glacial marine sediments.

Sedimentation on exposed Antarctic continental shelf is predominantly marine rather than glacial. Antarctica generally lacks a wave dominated coastal zone and the continental shelf is unusually deep (average 500 m). Therefore, waves and wind-generated currents have little influence on bottom sediments. Tidal and thermohaline currents are apparently too weak to erode the cohesive basal tills and glacial marine sediments. Mass-flow processes are the important factors in shelf sedimentation today. Turbidites, consisting of well sorted quartz sands, are widespread on the continental margin and abyssal floor. These sands are commonly interbedded with poorly sorted glacial marine sediments. Calcareous turbidites have also been cored in the Ross Sea. Laminated siliceous oozes, which are almost devoid of ice-rafted debris, fill many shelf depressions.

At the shelf edge and upper slope, geostrophic currents erode the bottom and transport sands by traction, while silts and clays are suspended and transported parallel to the slope. These currents are disrupted only in areas where shelf waters are sufficiently dense to displace and mix with circumpolar waters (thermohaline mixing). This mixed bottom water flows downslope at velocities of only a few centimeters per second, depositing laminated silts along the flow path. Ice-rafting diminishes sharply seaward of the present ice front, and ice-rafted debris comprises a minor component of slope and rise deposits.

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Seismic Investigation of Gas Hydrate Reflectors, Blake Outer Ridge Area Off Southeastern United States

Gas hydrates are known to exist at several deep ocean-floor locations across the continental margin of the eastern United States. Hydrates are stable in sediments having sufficient gas saturations at suitable pressures and temperatures. These conditions usually confine the hydrate to the uppermost few hundred meters of sediment below the sea floor. At greater depths and increased temperatures, free gas occurs and is probably trapped by the overlying hydrate zone. The transition boundary between the hydrate zone and free-gas zone is a relatively large impedance contrast to seismic sound waves and, hence, produced a high-amplitude reflection on multichannel seismic data.

Regional multichannel seismic reflection profiles have been collected by the U.S. Geological Survey along the continental shelf from Cape Hatteras to the Blake Outer Ridge area. These profiles reveal several major and several minor seismic-amplitude anomalies that parallel the sea floor. Depth maps of the high-amplitude reflections were constructed to determine whether free gas is trapped by an impermeable gas hydrate layer, or by local structural or stratigraphic traps. In some places, derivation of interval velocities has produced abnormally low velocities for the free gas layer. Investigation of the high-amplitude reflectors shows that they are not distinct, but consist of several interfering phases which complicate the selection of correct velocities.

Two-dimensional seismic modeling was used as an aid for determining the proper velocity estimating technique. Depth maps of the high amplitude reflections demonstrate the distribution of these anomalous features and strongly suggest the formation of gas hydrates.

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Resolution, Bandwidth, and Money

Our preoccupation with big structure is over. Today the geophysicist and geologist, together, must establish small-scale stratigraphy and faulting, delineate the limits of reservoirs, and compute rock properties. Critical to these efforts is resolution—the ability to see small features.

Resolution, both vertical and horizontal, depends on the seismic bandwidth. Obviously, this requires high frequencies. There is also value in the low frequencies, particularly to the geologist using pseudo-logs or searching for gradual transitions of rock properties.

First steps to improve the bandwidth involve deconvolution in association with good field technique, good field discipline, and additional processing. These improvements are inexpensive, but limited. Thereafter, we depend on improvements in the source; these improvements begin to increase the cost significantly.

In explosive work, improvements can be made by manipulating the charge size, the depth, and the ghost reflection; many small charges and a few large charges may be combined in the CDP technique.

The Vibroseis system does more; it allows us to precompensate the seismic signal for any expected attentuation. In principle, we can raise any frequency above the noise merely by transmitting it for a longer time. However, desirable increases of bandwidth can increase the cost of the field work by several times. There is no limit to the bandwidth we can achieve, but bandwidth is expensive. Delineation wells (and certainly dry holes) are even more expensive. We must find a new balance of cost-effectiveness.

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Glacial Lithofacies of Neogene Yakataga Formation, Gulf of Alaska

Lithofacies, biofacies, and chronostratigraphic analyses indicate three relatively warm and three relatively cool paleoclimatic intervals within the 5,000-m thick strata of the lower Miocene through Holocene Yakataga Formation of the Robinson Mountains, eastern Gulf of Alaska. Glacial periods, recognized by the predominance of glacial lithofacies associated with populations of *Neoglobigerina pachyderma* s.l., are interpreted for the cool intervals. In the sections studied, the interglacial intervals have little or no glacial deposits.

Yakataga Formation strata of glacial origin can be classified as having formed in either ice-contact or glacial-aqueous depositional environments. Ice-contact deposits consist of stratified or chaotic sedimentary materials, but erratics are rare in the Yakataga Formation. Glacial-aqueous deposits are of three principal types: glaciolacustrine, glaciofluvial, and glaciomarine. Glaciolacustrine deposits have not been identified in the Yakataga Formation. Glaciofluvial deposits, characterized by interbedded poorly sorted lenticular sand and gravel, occur in geographically limited and stratigraphically restricted intervals of the Yakataga Formation. Glaciomarine silts and clays, containing floating pebbles and cobbles and insitu marine fossils, are the dominant glacial aqueous deposits in the Yakataga Formation. Detailed lithofacies associations and geometries define open-shelf and fjord glaciomarine subenvironments. Lithofacies sequences within these subenvironments suggest deposition by advancing and retreating ice masses.

Mapping of the relative percentages of lithofacies types within the late Pliocene-Pleistocene glacial sequence defines the late Neogene paleogeography of the Yakataga district. This mapping suggests that the late Pliocene and Pleistocene distribution of alpine glaciers, coastal-outwash and alluvial flood plains, and fjords, and the associated rates of sedimentation, are analogous to the depositional pattern during the Holocene.

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Models for Formation of Organic-Rich Diatomaceous Laminae in Miocene Monterey Formation: Documentation from Analogous Recent Sediments in Gulf of California

Depositional modeling of the Monterey Formation has traditionally focused on basin scale models. Analysis of homogeneous and laminated, organic- and diatom-rich sediments from the central Gulf of California permits modeling of small-scale depositional environments that may be useful in mapping within the Monterey Formation.

Sedimentologic, micropaleontologic, and geochemical characteristics of recent Gulf of California sediments permit definition of three depositional environments.

(1) *Thick* (~ 1 cm) lamination of the silled anoxic San Pedro Martir Basin. The laminae are indistinct in color and contain a uniformly mixed opal phytoplankton population of both oceanic and upwelling floras. Only the darker laminae contain the silt- and clay-sized material washed into the area during the rainy season.

(2) *Thin* (~ 1 mm) lamination of slope sediments where the oxygen minimum zone impinges the sea floor (~ 400 to 1,300 m water depth) on both the Baja and mainland sides of the Guaymas Basin Slope. Laminae are generally distinct in color and consist of alternating oceanic and upwelling opal phytoplankton assemblages. Dark laminae contain clay- and silt-sized terrigenous material. Dark laminae on the Baja side also contain an upwelling microfloral assemblage. Dark laminae on the mainland side contain an oceanic microfloral assemblage.

(3) Homogeneous sediments overlie laminated sediments off Santa Rosalia. The homogeneous sediments are characterized by uniformly distributed microfloral and macrofloral elements and terrigeneous material due to bioturbation by a mollusk infauna.

The differences between the various laminated and the nonlaminated (= homogeneous-bioturbated) facies are due to differing levels of primary productivity in surface waters which in turn controls oxygen consumption. Oxygenated bottom water underlies low primary productivity areas while anoxic bottom water underlies high primary productivity areas.

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Supply of Sediment to Oceans: Climate and Eustatic Sea Level Changes and Interregional Unconformities

The completeness of the deep-sea stratigraphic record depends upon the balance between sediment supply from biogenic surface production and delivery of detrital sediment across continental margins, and sediment removal by mechanical erosion and/or chemical dissolution. These parameters, in turn, are controlled by a combination of interrelated changes in global sea level, climate, and oceanography. Studies of the rates and patterns of accumulation of both biogenic and detrital sediment in the deep sea, based largely on data from DSDP drill holes, demonstrate that no single factor determines trends in deep-sea sedimentation.

It is tempting to link the global patterns of rise and fall of