tion—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.

ARMENTROUT, JOHN M., Mobil Exploration and Producing Services, Inc., Dallas, TX

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.

ARMENTROUT, JOHN, Mobil Exploration and Producing Services, Inc., Dallas, TX, and HANS SCHRADER, Oregon State Univ., Corvallis, OR

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* ($\sim$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* ($\sim$1 mm) lamination of slope sediments where the oxygen minimum zone impinges the sea floor ($\sim$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.

ARTHUR, MICHAEL A., U.S. Geol. Survey, Denver, CO

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 sea level through time to trends in sedimentation in the oceans. For example, sea level lowstands are expected to result in increased supply of both detrital and chemical (biogenic) sediment to the deep sea. Thus, shelf unconformities, resulting from exposure and erosion of shelf sediments, should correlate with relatively high rates of sedimentation and low incidence of hiatuses in the deep sea. Global sea level highstands would have the opposite effect. The co-occurrence of widespread shelf and deep-sea unconformities, as found in the Oligocene and lower Paleocene contradicts such simple models. These and other examples show that terrigenous and biogenic sediment flux to deep-sea basins is not totally dependent on relative sea level, and that there are commonly significant time lags in the response of deep-sea sedimentation to changes in sea level and shelf sedimentation. Rates of rise and fall of sea level, however, are a major determining factor. Additionally, global and regional climate and overall patterns of oceanic circulation, fertility, and chemistry are equally important in controlling sediment supply to the deep sea and in the development of sedimentary lacunae in deep marine basins.

ASQUITH, GEORGE B., Search Drilling Co., Amarillo, TX, and ROBERT D. SAWVELL, West Texas State Univ., Canyon, TX.

Evolution of Lower Permian Oolite Shoal in Northwest Anadarko Basin

The Lower Permian (Wolfcamp) Council Grove B-zone in the northwest part of the Anadarko basin in Ochiltree County, Texas, is represented by two carbonate rock types: (1) bioturbated oolitic bioclastic wackestones; and (2) cross-stratified oolite grainstones. These oolite and oolitic facies are underlain and overlain by bioturbated argillaceous bioclastic wackestones.

A Council Grove B-zone isopach map indicates that the oolite shoal has an east-west depositional strike. The presence of north-south-trending tidal bars and channels superimposed on the oolite shoal suggest that the tidal currents responsible for the formation of the oolite flowed north and south. A transverse cross section reveals that the base of the oolite facies is stratigraphically higher in a southward direction, indicating that the direction of maximum tidal flow and/or storm surge and direction of oolite progradation was to the south. Paleogeographic time slice maps from a lower datum reveal that the oolite shoal initially formed as two isolated shoals which were superimposed on prominent structural highs. These shoals later merged and prograded southward.

After deposition, the shoal was exposed to early, freshwater phreatic diagenesis, as indicated by oomoldic porosity and equant calcite cementation. Later diagenesis resulted in bladed anhydrite and coarse baroque dolomite partly filling oomoldic porosity.

Oomoldic porosity results in conventional log-derived water saturations (S_W) that are often overly optimistic. Therefore, to adequately evaluate oomoldic reservoirs using logs, the Production Ratio Index ($PRI = S_{W\,sonic} \times \phi_{neu\text{-}den}$) should be used to predict the ratio of hydrocarbon to water production.

AUBERT, JANE, ELF-Aquitaine Oil Co., Pau, France, and W. A. BERGGREN* and K. G. MILLER, Woods Hole Oceanog. Inst., Woods Hole, MA, et al

Flysch-Type Agglutinated Benthic Foraminifera and Maestrichtian to Paleogene History of Labrador and North Seas

Virtually identical agglutinated (arenaceous) benthonic foraminiferal assemblages (ca 30 genera, 45-50 taxa), characteristic of the Alpine-Carpathian flysch basins, occur in the Upper Cretaceous–Paleogene fine-grained clastic (?turbidite) sequences of the East Newfoundland basin, Labrador and North Seas. The assemblages terminate in both areas in the late Eocene or Oligocene although, in the central (deepest) part of the North Sea, elements of this flysch-type fauna have been observed extending into lower or middle Miocene levels.

Independent geologic evidence indicates that these assemblages have an extensive (paleo)bathymetric distribution (< 200 m to > 4 km). Depth alone is not considered a significant factor in their occurrence. In marginal basins, we favor a model which involves relatively rapid deposition of organic rich, fine-grained clastics under somewhat restricted bottom-water circulation conditions, leading to lower pH and low positive or negative eH at the sea floor. The disappearance of the agglutinated assemblage in all but the deepest part of the North Sea may have been due to the shallowing of the basin by sediment infilling resulting in shallower, more oxygenated conditions.

On the Canadian margin, decreases in clay and organic carbon content are associated with the exit of the agglutinated assemblages. In contrast, in the deep Labrador Sea (Site 112), lithology and percent organic carbon are relatively constant across this faunal change. This suggests that, at least in the deep sea, these properties may not be critical to the development of predominantly agglutinated assemblages. We suggest that the exit of agglutinated assemblages in the deep Labrador Sea was due to a change in hydrographic properties associated with the evolution of the psychrosphere. Sedimentologic evidence indicates initiation of northern sources of vigorous bottom water in the late Eocene-early Oligocene which may explain the exit of agglutinated foraminifera. This circulation change resulted in the influx of higher oxygen bottom waters and a lowering of the CCD which may have favored the replacement of predominantly agglutinated assemblages by calcareous assemblages.

BAARS, D. L., Consulting Geologist, Evergreen, CO, and G. M. STEVENSON, Fort Lewis College, Durango, CO

Subtle Stratigraphic Traps in Paleozoic Rocks of Paradox Basin

Significant quantities of petroleum occur in stratigraphic traps of Devonian, Mississippian, and Pennsylvanian age in the Paradox basin. Devonian reservoirs are isolated marine sandstone bodies; the Mississippian and Pennsylvanian traps are biohermal carbonates. Exploration in the past has proven the reservoirs to be elusive and relatively unpredictable, but the realization that the subtle traps are localized on paleostructures simplifies exploration and has led to several recent discoveries.

The tectonic framework of the Paradox basin, which includes a northwesterly series of major basement rifts and a subordinate series of northeast-trending fractures, was already set by late Precambrian. The basin was repeatedly rejuvenated throughout the Paleozoic. Vertical movements along the basement fractures were sufficient to alter sedimentary facies during Cambrian, Late Devonian, and Mississippian throughout the basin. These Paleozoic elements served to localize reservoir facies by creating shoaling conditions that produced Devonian offshore sandbars, Mississippian crinoid banks, and Middle Pennsylvanian algal bioherms.

Algal bioherms grew over subtle paleostructures along the southern and western margins of the Paradox basin in Middle