Santee River drainage system. Coarse, poorly sorted sand disconformably overlies Pleistocene estuarine clays and is capped by a dense clay plug. Beach ridges prograded seaward over the first inlet sequence. A second cycle of inlet migration truncated the northernmost part of the beach ridges and scoured into the inactive-fill clay plug of the earlier inlet deposit. The resultant stratigraphic framework consists of a stacked series of upward fining, active inlet-fill sands overlain by thicker inactive inlet-fill clay plugs.

Migrating tidal inlets greatly alter barrier island stratigraphy. Reworked beach ridge sediments are incorporated into tidal inlet channels preserved on the updrift end of the barrier island. Fine-grained clay plugs form permeability barriers between adjacent barrier island sand bodies. Shoreline transgression will remove the uppermost barrier island deposits sealing the lower inlet-fill sequences between Pleistocene estuarine clays and continental shelf silts and clays.

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Sedimentary Facies Within Coastal Belt Franciscan Complex, Garberville Quadrangle, Northern California

Mildly deformed shale and sandstone, exposed along the South Fork of the Eel River in the Garberville Quadrangle (northern California Coast Ranges), are thought to represent a distinct lithofacies of the coastal belt Franciscan complex. These rocks have been correlated with the so-called Yager Formation, exposed farther to the north. Near Garberville, the folded sandy turbidites and shales are probably Eocene or younger in age, and are in contact with three other tectonostratigraphic units: (1) melange of the Franciscan central belt; (2) deformed sedimentary rocks of the coastal belt and King Range, exposed to the west; and (3) younger (Miocene-Pliocene) shelf deposits, which resemble the Wildcat Group of the Eel River basin.

Regional mapping of turbidite facies (using the Ricci-Lucchi scheme) shows that a high percentage of the section consists of hemipelagic mudstone and shale; these facies G deposits are commonly interbedded with thin facies E silty turbidites. Locally, the fine-grained strata pass abruptly into sequences of thick-bedded to massive facies B sandstone and associated facies C turbidites. At one locality, thinner facies D turbidites are abundant within a thickening-upward and coarsening-upward sequence that is over 100 m thick. Small-scale thinning-upward cycles within this mega-sequence suggest localized channel migration and abandonment. The measured orientations of flute casts indicate that paleocurrents radiated toward the west and southwest, apparently at a high angle to the continental margin.

Together, these data suggest that sediments exposed in the Garberville area were probably deposited within continental slope and restricted basin settings. If the general model associating the Franciscan complex with a Mesozoic-Cenozoic trench wedge is followed, then these strata can be interpreted as sediments deposited on the trench slope and within small trench slope basins above the deformed "accretionary prism" represented by much of the rest of the Franciscan.

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Effect of Sea Level Change on Shelf-Slope Boundary

Eustatic sea level changes cause alternating periods of subaerial exposure, flooding, or progradation at the shelf-slope boundary. Eustatic falls of sea level that are more rapid than subsidence cause subaerial exposure and canyon cutting. Rises of eustatic sea level coupled with subsidence commonly cause flooding of the shelf margin, marine transgression, and sediment starvation of the middle and outer shelf. Stillstands or slow falls of eustatic sea level that are less than the rate of subsidence commonly cause marine regressions where, in many places, the shoreline progrades out to the shelf-slope boundary.

The effect of eustatic sea level changes on the shelf-slope boundary is readily observable on seismic data despite changes in the rate of subsidence and rate and type of deposition. Seismic and well data from offshore northwest Africa are used to demonstrate these relations. In this area, high subsidence rates followed the opening of the Atlantic in the Early Jurassic and gradually changed to very slow subsidence rates in the Tertiary. Depositional rates increased throughout the Jurassic, reaching a maximum in the Early Cretaceous. Rates of deposition were very low in the Late Cretaceous and Early Tertiarty and increased again in the late Tertiary. Sediment type changed from primarily carbonate in the Jurassic to sands, silts, and shales in the Cretaceous and Tertiary.

This and other examples demonstrate that sea level change is the major factor affecting the shelf-slope boundary in different tectonic settings. The only known cause for the high rates of sea level change determined in these studies is glaciation. Such studies indicate major phases of glaciation occurred periodically throughout the Phanerozoic. Timing of possible glacial periods is shown for the Jurassic and Tertiary.

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Cause of Northern North Sea Jurassic Unconformities

Thirteen unconformities and their correlative conformities (sequence boundaries) divide the strata of the Jurassic of the northern North Sea into twelve cycles of coastal onlap. Comparison of charts showing regional relative change of coastal onlap, unconformity age, stratal patterns, and facies relations from the northern North Sea with global charts of relative changes of coastal onlap and eustatic sea level indicates that the unconformities are global and are caused by eustatic changes of sea level. Nine of the global unconformities are believed to be caused by rapid eustatic falls of sea level, three by slow falls followed by rapid rises, and one by an increased rate of sea level fall. In addition, four marine hiatuses were identified that are interpreted to be related to rapid rises of sea level.

Fault block rotation or differential block subsidence occurred almost continuously throughout the Jurassic, causing tilting of beds. Unconformity recognition is enhanced by periodic truncation of tilted strata by lowstand erosion and/or onlap during the subsequent rises, but the tectonics do not cause the unconformities.

Northern North Sea unconformities and coastal onlap are demonstrated on two seismic sections tied to well control. One section is from the United Kingdom part of the north Viking graben; the second is from the inner Moray Firth. Sequence boundaries and charts showing chronostratigraphy, relative change of coastal onlap, and ages of unconformities are shown for each seismic section.

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Sunbury Shale of Central Appalachian Basin—Depositional Model for Basinal Black Shales

A model for the deposition of basinal black shales and associated base-of-slope turbidites is established in the central Appalachian basin. The model is based on an outcrop and subsurface stratigraphic study of the thin, but extensive Lower Mississippian Sunbury black shale. This model is termed the Sunbury cycle and it provides an explanation for the geometrid relations observed between basinal black shales and laterally adjacent gray/green slope shales and siltstones.

Two genetic types of black shales are recognized—transgressive and regressive. The transgressive black shale is the basal unit that initiates the cycle. Characteristically thin and widespread, it was deposited in the anaerobic zone of a stratified water column. Its sharp basal contact represents the rapid migration of the anaerobic environment over base-of-slope and slope deposits. This is caused by an increase in the subsidence rate of the active basin, decrease of clastic influx, and a minor rise in sea level. The regressive black shale overlies the basal unit. It is thicker, more laterally restricted, and represents the distal facies of base-of-slope turbidites formed by a progressive increase of clastic influx and a decrease in the subsidence rate of the basin floor. The thick regressive black shale and laterally adjacent non-black clastics represent facies of a continuous unit (base-of-slope turbidites) containing varying amounts of preserved organic material. The degree of organic preservation is the result of deposition in zones of varying oxygen content caused by the intersection of the stratified water column with the basin floor.

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Seismic Stratigraphy of Modern Carbonate Slope

Based on analysis of 1,350 km of high resolution, 5 cu in. air-gun and 3.5 kHz seismic reflection profiles, as well as 30 piston cores, the open ocean, windward, deep carbonate bank margin north of Little Bahama Bank has been divided into upper and lower slope facies. The seismic character of the post-Paleocene upper slope unit (200 to 1,000 m water depth) consists of a low-energy slope-front fill facies characterized by parallel to subparallel reflectors that downlap onto a regional unconformity near the Paleocene-Eocene boundary. Sediments of this upper slope facies are interpreted to be primarily fine-grained pelagic carbonates. In contrast, the post-Paleocene unit on the lower slope (1,000 to 1,300 -m water depth) consists of a variable energy chaotic-fill facies characterized by hummocky/discordant to wavy subparallel reflectors. Sediments of this facies are interpreted as coarse, high-energy mass transport deposits such as turbidites and debris flows. Detachment scars on the upper slope and erosional gouge on the lower slope indicate that submarine slides and sediment gravity flows originated on the upper slope. The sediment gravity flows have bypassed the fine-grained upper slope facies via numerous evenly spaced small canyons, which act as a "line source," and were deposited at the base of the slope in a broad "apron" rather than a fan. The seaward transition in the lower slope chaotic fill facies from hummocky/discordant to wavy subparallel reflectors suggests that the sediment gravity flows become thinner and more "distal" seaward. Recurrent faulting and oversteepening of unlithified carbonate slopes are believed to be responsible for the generation of mass movements. Similar facies relations should be recognizable in the rock record. In terms of hydrocarbon exploration, the coarse, lower slope sediment gravity flow facies would appear to have the greatest reservoir potential.

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Geochemical Prospecting for Hydrocarbons in Navarin Basin Province

The Navarin basin province, which lies beneath the northwestern Bering Sea shelf, is a large (45,000 sq km) frontier area for petroleum exploration. Our preliminary geochemical survey of this province measured hydrocarbon gases in near-surface sediments in search of evidence for the possible occurrence of petroleum. Hydrocarbons (methane through butanes) were analyzed from sediment samples taken at a depth of 1 m from cores collected during the summer of 1980 at 32 stations spaced approximately 50 km apart. In addition, samples at the same depth were analyzed from five stations spaced about 5 km apart over a shallow acoustic anomaly. All samples analyzed contained hydrocarbon gases, but none had significant amounts of hydrocarbons of obvious thermogenic (petroleum-related) origin. At only two stations on the shelf and one on the slope were concentrations of methane and ethane significantly above background values, whereas those of propane and the butanes were not. Concentrations of methane and ethane were 5 to 9 and 10 to 20 times, respectively, higher than background values, and ratios of ethane to ethene of 6, 30, and 25 were unusually large relative to background values of about 1. The ratios of methane to ethane + propane of 100, 140, and 180, and the large ratios of ethane to ethene, suggest that some thermogenic hydrocarbons are present. Although petroleum is potentially present at depth in the Navarin basin province, our preliminary survey did not detect surface hydrocarbon-gas anomalies that would unequivocally signal its presence.

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Subduction-Related Structure Along Eastern Aleutian Trench

Along the eastern Aleutian Trench between Kayak and Sanak Islands, the trench, magmatic arc, and active Benioff zone define a modern convergent margin 13,000 km long. The structures developed during the past 10 to 15 m.y. show the deformation associated with subduction. Fore-arc basins have been formed on pre-Neogene rock that was presumably accreted, uplifted, and then locally depressed. Structures in the basins are compressional near the shelf edge and extensional farther toward the arc. The trench lower slope is underlain by rocks that are coeval with those in the fore-arc basin, but are deformed as a result of subduction. Despite a uniform convergence history, the margin has marked structural variations along strike that reflect local non-tectonic influences on structural style. The structure could be influenced by a variety of geologic variables such as sediment volumes on the slope, in the trench, and on the ocean crust, and perhaps by the morphology of the igneous ocean crust. Although we have not yet successfully reconciled all the effects of local variation on structural style, a comparative study of these styles and local features can help define kinematic processes associated with plate convergence.

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