Analyses of variations in the entire assemblage with time were conducted on samples from several onshore localities. These were conducted by counting more than 40 important family and generic groups. The results reflect the fluctuating role of oceanic processes in the Neogene shelf environments. Abundance and diversity increase (particularly in the rarer nassellarians and in apparently deeper dwelling forms) in the intervals interpreted to have been strongly influenced by oceanic processes (i.e., upwelling of subsurface waters). Abundance and diversity decrease, and dominance by certain spumellarians increases in the intervals believed to represent shallower, lower salinity and/or more terrestrially influenced environments, as interpreted from independent paleontological and sedimentological evidence.

These results are consistent with the idea that both coastal upwelling and deltaic progradation were significant processes in the Neogene development of the U.S. mid-Atlantic continental margin. Their relative importance at any given time or locality appears to have been determined by paleobathymetry and amount of terrigenous influx, resulting from effects of changes in sea level and local tectonic conditions.

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Concepts and Creativity (AAPG Presidential Address)

No abstract.

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Reference-Rotated Eigenshape Analysis of Sands and Sandstones

Sedimentary particles with minor differences in overall shape are selectively sorted according to shape during transport. Krumbein in 1942 demonstrated a difference in fall velocity for "disks" and "rollers," and Nagle in 1967 showed that right and left pelecypod valves transported by the same longshore current ended up at different locations along a beach. Selective shape sorting of sand-size particles occurs at various rates and in distinct patterns during different modes of transport, but the subtle shape differences are hard to recognize by conventional techniques. Visual comparison methods for "roundness" and "sphericity" have such low accuracy and reproducibility as to be virtually meaningless. Also, two particles can have equal sphericity and roundness and yet be of different overall shape. The Corey shape factor (widely used by civil engineers) with its various modifications is inadequate for subtle shape variations. In two-dimensional maximum projection, simple symmetrical shapes (i.e., ellipse) are fully defined by two measurements: length of major and minor axes. Less symmetrical shapes (i.e., oval or kidney bean) need more than two measurements. Griffiths in 1967 stated that n measurements are needed for an irregular shape (where n is not known in advance).

Eigenshape analysis is a method of reducing a large number of measurements (i.e., 36 radial lengths at equal angular increments) to the minimum number of linear combinations needed to portray a significant proportion (80 to 90%) of observed shape variation. Reference-rotation is needed for sand grains in order to compare the wide variety of shapes that occur; when comparing only similar objects, reference-rotation may not be necessary. Unlike Fourier shape analysis, which as currently used involves only small-scale irregularities, Eigenshape analysis is a new approach to quantifying larger scale shape characteristics.

Laboratory experiments designed to simulate shape-sorting effects of sediment transport (slow versus fast fall velocity in a sedimentation tube; inner versus outer ring in a gold prospecting pan) separated quartz sand samples composed of grains of the same sieve size into two subsamples. These showed recognizably different assemblages of shape types by Reference-Rotated Eigenshape Analysis. Similar Eigenshape distinctions were observed when the same size fraction of two sands with different Eigenshape "signatures" were mixed in 2:1 ratio and then separated by selective shape sorting as above.

Eigenshape analysis achieved similar results with thin-section input data. Artificial rocks were made with the above sands by "lithifying" with epoxy resin. Thin sections were made perpendicular and parallel to "bedding" and at other orientations. Eigenshape analysis was performed on the grains as seen in section (not "maximum projection"). Results from bedding-parallel sections most closely resemble results from loose-grain mounts.

Inferences about provenance, transport mode, transport distance, mixing from different sources and/or different transport histories, and depositional environments are made from Eigenshape analysis results. The intrinsic R-mode factor analysis approach helps untangle these intermixed effects.

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Upwelling Deposits: Nature of Association of Organic-Rich Rock, Chert, Chalk, Phosphorite, and Glauconite

An association of organic-rich sediment with phosphorite and glauconite is commonly found in modern coastal upwelling zones. The three lithologies do not always occur together, but where they do, they lie in a characteristic facies pattern, with organic-rich sediment in the center, surrounded by a phosphorite facies which is, in turn, rimmed by a glauconite facies. A fourth lithologic element of upwelling deposits is biosiliceous ooze. Biosiliceous ooze is most commonly composed of diatoms, which evolved in the Cretaceous Period. Radiolarian oozes tend to occur in the deep sea, under divergence zones in the open ocean. Despite the predominance in modern upwelling zones of diatoms, the association of chert, organic-rich rock, phosphorite, and glauconite is common in older rocks as well; the chert in these rocks is radiolarite or spiculite. A possible fifth element of upwelling deposits is calcareous ooze; phosphatized and/or glauconitized and cherty chalks are common in the fossil record, as are organic-rich chalks. The relationship of chalk to upwelling is obscure because in modern upwelling zones, siliceous organisms are far more abundant; calcareous and siliceous phytoplankton appear to occur almost mutually exclusive of one another. By analogy with the sediments under modern upwelling zones, the presence or absence in rocks of each of the five lithologies—organic-rich rock, phosphorite, glauconite, chert, and chalk—provides clues to the nature of individual upwelling deposits. The presence or absence of each lithology, particularly chert versus chalk or the presence or absence of phosphorite, can also provide clues to such parameters as temperature and water mass characteristics.

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Sandstone Diagenesis and its Variation with Deltaic Depositional Environments, Upper Cretaceous, Southern Rio Escondido Basin, Coahuila, Mexico

Prodelta, delta-front, and delta-plain sandstones and shales were deposited in a wave-dominated lobate delta in the Rio Escondido basin during Campanian and Maestrichtian time. The

composite diagenetic sequence based on petrographic analyses of over 300 thin sections from sandstone samples from these environments consists of: (1) bioturbation of sediment and compaction of ductile grains before cementation; (2) infiltration of minor amounts of pedogenic illite and precipitation of chlorite and minor amounts of smectite; (3) cementation by euhedral, syntaxial quartz overgrowths; (4) extensive poikilotopic calcite cementation; (5) widespread dissolution of calcite; (6) precipitation of kaolinite as patches in some of the dissolution pores; (7) replacement of calcite and framework grains by iron-rich carbonates (ankerite-ferroan dolomite, ferroan calcite, siderite). The relative intensities of these diagenetic events, and thus porosity and permeability, are controlled by and vary with the environment of deposition of the sandstones. The two main factors controlling the differences in diagenetic features within the environments are (1) original composition of the sands, and (2) geometry of the sandstone bodies.

Prodelta siltstone and very fine-grained sandstone, deposited as thin frontal-splays, are enclosed in thicker sequences of marine shale. These rocks (dominantly feldspathic litharenite and lithic arkose) typically have the lowest porosity ($\bar{x} = 4\%$) and permeability ($\bar{x} = 1$ md) of the three environments. Primary porosity was destroyed early by extensive bioturbation and by widespread calcite cementation ($\bar{x} = 23\%$). The thicker, impermeable shale above and below the thin, lenticular sandstone bodies served as barriers to subsequent fluid migration, thus inhibiting any creation of secondary porosity by dissolution and any later diagenetic changes.

Channel-mouth-bar and sheet-sand deposits of the delta-front facies are generally more quartz-rich and thus, due to a greater stability of the quartz grains, underwent the least amount of compaction. Consequently, calcite cementation was widespread; later dissolution of calcite produced secondary porosity up to 28% and permeability up to 557 md. These fine to medium-grained sandstones (dominantly feldspathic litharenite, lithic arkose, and subarkose) have the highest porosity ($\bar{x} = 18\%$) and permeability ($\bar{x} = 81$ md) of rocks from the three facies.

Delta-plain fine to medium-grained sandstone has intermediate porosity ($\bar{x} = 8\%$), but low permeability ($\bar{x} = 1$ md). These sandstones (primarily feldspathic litharenite) have the highest concentration of sedimentary and volcanic rock fragments, which were squashed during compaction and altered during burial. Thus, only a relatively small amount of pore space remained for calcite cementation. Kaolinite cement filled in most of the secondary porosity created by dissolution of early formed calcite.

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Regressive and Transgressive Sand Bodies Associated with Lafourche Delta in South Louisiana

The beach ridge plains and coastal barrier systems along the seaward margin of the wave-dominated Lafourche delta represent regressive and transgressive events associated with multiple delta lobe progradations and abandonments over the last 1,500 years. Two major delta lobes, the Early Lafourche and the Late Lafourche, can be recognized by the subaerial expression of the abandoned deltaic plain. Associated with each delta lobe is a regressive beach ridge plain deposited during distributary progradation and coastal barrier system deposited during distributary transgression.

The Cheniere Caminada beach ridge plain is associated with the Late Lafourche delta lobe. It consists of more than 70 subparallel beach ridges in an arcuate fan-shaped configuration which flare seaward along the eastern levees of Bayous Lafourche and Moreau. Radiocarbon dates indicate beach ridge building began approximately 600 years ago when Bayou Lafourche built seaward of the older Bayou Blue shoreline and started intercepting westward longshore sediment transport, resulting in the formation of Cheniere Caminada. Near the fan apex, beach ridges are 7 to 8 m (23 to 26 ft) thick and thin westward to 2 to 3 m (6.5 to 10 ft) thick. A typical beach ridge stratigraphic sequence coarsens upward with shoreface silty sands overlain by a cap of washover and aeolian sands. Beach ridge growth ceased approximately 300 years ago when Bayou Lafourche was abandoned.

Distributary abandonment initiated the transgression at Bayou Lafourche and the development of an erosional deltaic headland, the Caminada-Moreau coast, with a set of symmetrical, flanking barriers, the Timbalier Islands to the west and the Caminada Pass spit and Grand Isle to the east. Reworking of distributary and beach ridge sand bodies by shoreface retreat supplies the sand source required for coastal barrier generation. Shore-parallel transport distributes sand from the headland source into downdrift marginal spits, tidal deltas, and flanking barrier islands. Cores show that the flanking barriers (Timbalier Island and Grand Isle) increase in thickness from 2 to 3 m (6.5 to 10 ft) near the headland to 5 to 6 m (16 to 20 ft) at their downdrift ends. A typical flanking barrier stratigraphic sequence shows a coarse-grained tidal inlet fill overlying a finer grained interdistributary bay fill and underlying a thin cap of washover and aeolian sands.

In the Early Lafourche delta, only remnants of an older regressive beach ridge plain, Chenier Caillou, can be recognized owing to its advanced stage of transgression. A series of relict, partially submerged beach ridges associated with the Caillou headland can be seen spreading seaward on their western margin in the central Isles Dernieres indicating the dominant longshore transport direction was westward. Cores show a regressive sequence 7 to 8 m (23 to 26 ft) thick, similar to Cheniere Caminada, where shoreface silty sands underlie washover and aeolian deposits.

The Isles Dernieres represent the transgressive barrier system of the Early Lafourche delta lobe. Abandonment of the Caillou distributaries occurred approximately 600 to 800 years ago. Due to long-term subsidence, the Caillou headland is now submerged below sea level and the Early Lafourche barrier system has evolved into a transgressive barrier island arc separated from the mainland by an intradeltaic lagoon. Sediment dispersal consists of seaward transport into an inner-shelf sand sheet, landward transport into washover deposits, and shore-parallel transport into tidal deltas and marginal recurved spits. Cores show the central Isles Dernieres consist of a thin washover sand sheet 1 to 2 m (3 to 6.5 ft) thick transgressing over delta plain and beach ridge deposits. The downdrift ends of the Isles Dernieres islands are thicker, up to 4 to 5 m (13 to 16 ft), and overlie fine-grained interdistributary bay fills.

In the subsurface of Grand Isle and Cheniere Caminada, lies the transgressive barrier system of the Bayou Blue distributary abandoned 1,200 years ago. The sand source for barrier generation is two Bayou Blue distributaries which lie −10 m (−33 ft) below sea level adjacent to Barataria Pass. The transgressive sand body strikes northwest and is overlain by a sequence of regressive interdistributary clays and silts, regressive beach ridge sands (Cheniere Caminada), and a transgressive flanking barrier sand (Grand Isle). Radiocarbon dates indicate Bayou Blue Barrier was actively transgressing landward 920 years ago.

The identification of regressive beach ridge plains along the Lafourche delta suggests that these wave-dominated delta plain components may be stratigraphically more significant in the Mississippi delta than recognized before. Sequential delta lobe abandonments have led to the development of imbricating regressive