and are better sorted and rounded due to abrasion on a shallow shelf.

Depositional environments did not control sandstone composition. Distinctive Naknek petrofacies are due to (1) erosion of Lower Jurassic volcanics followed by unroofing of Lower to Middle Jurassic diorite and granodiorite plutons; and (2) variations of provenance in separate drainage basins through time.

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Reservoir Quality of Sandstones Influenced by Mineralogy and Texture: Example of Brazilian Offshore Basins

Lower Cretaceous sandstones in four basins off Brazil illustrate that reservoir quality is controlled by diagenetic events that were pre-programmed by (1) detrital mineralogy, (2) grain size, and (3) sorting.

The northeasternmost basin (Cassipore) received volcanic-rock detritus. At depths less than 3,000 m all pores in these lacustrine turbidite sands were cemented by pervasive corrensite and local laumontite. Secondary porosity is trivial.

Five hundred km to the southeast, the Ilha de Santana basin received granitic and reworked red-bed detritus. Samples from fluvial and lacustrine turbidite sandstones between 1,500 and 2,800 m show that sands lost porosity by cementation by patchy calcite, minor quartz, and pervasive mixed-layer clays. Modest secondary porosity developed by dissolution of calcite and clay cements, and detrital plagioclase.

Five hundred km farther to the southeast, the Ceara and Potiguar basins received granitic detritus and minor metamorphic-rock debris. Lacustrine deltaic deposits of the Ceara were sampled between 1,500 and 2,700 m and fluvial deposits of the Potiguar between 1,600 and 2,500 m. Except for the presence of kaolinite beneath an unconformity in the Ceara basin, the basins had a similar history. Porosity was lost successively by precipitation of clay coatings, quartz and calcite cement, and by compaction. Good secondary porosity developed by dissolution of calcite and plagioclase, but much porosity was lost subsequently by precipitation of mixed-layer clays derived from reaction of pore fluids with feldspars.

The best secondary porosity developed in the coarser and better sorted sandstones. Coarser sandstones (1) had more calcite cement that yielded clean secondary-pores and (2) have larger pore throats that were affected less by clay cement. Fine sandstones (1) have more ductile micas and rock fragments that compacted and plugged pores and (2) have smaller pore throats that were strongly affected by clay cement.

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Vibroseis System: a High-Frequency Tool

Exploration methods are extended to their limits as the search for energy resources continues. Successful application of high-frequency seismic methods requires evaluating each element in the seismic data acquisition system and assuring that each part of the system contributes to the success of the method. This extends from seismic signal generation through data processing where good equipment performance and correct parameter selection are required.

The Vibroseis system depends upon the ability of vibrators to generate synchronous, repeatable sweeps over the frequency range of interest. Many considerations are used in building a vibrator. Typical baseplate responses show excellent drive levels at the design goal of 200 Hz. With an excellent source available, correct application is essential to assure retention of high-frequency data. Recording offsets, array lengths, and array sampling must be selected for the sweep frequencies used. Also, approximate matching of the data acquisition system response to the spectral response of the earth reduces the dynamic range requirements for recording systems and subsequent data processing. Data are included to show the successful application of high-frequency techniques to stratigraphic exploration problems.

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Geometry and Facies of Latest Cretaceous Deltaic and Submarine Fan Systems, Southern Sacramento and Northern San Joaquin Basins, California

Regional cross sections and net-sand isopach maps depict the geometry and genetic relations of Maestrichtian deltaic and submarine fan depositional systems in the southern Sacramento and northern San Joaquin basins. The six Starkey sands are multilobed cuspate to lobate deltas with east-west or northeast-southwest axes and apices near Sacramento and Stockton. The overlying sand ("Bunker," "3rd Massive," etc) in the Sacramento Valley is an elongate delta with north-south axes and multiple apices. Submarine fans (lower and upper Winters, Tracy, Blewett, and Azevedo sands) are elongate northwest-southeast, parallel to the basin axis. Most fan shapes are distorted owing to onlap on basin slopes or the cross-valley sill termed the Stockton Arch, but less confined fans show the expected fan shape.

Initially the slope was fault controlled, but the deltas prograded the slope, constricting the basin. Five deltas overtook the prograding slope and fed sand over the shelf edge or through shallow slope channels to the fans. Deltas were abandoned during cyclic sea level rises; during the succeeding progradations, mud was swept out of the deltas and draped over the slope and previous fan. Thus, five cycles of delta progradation, fan growth, delta retreat, and fan abandonment are preserved. As the basin filled and water depth decreased, deltas became larger and fans grew smaller.

Local cross sections show facies relations and lithologies. Cuspate deltas consist mainly of coarsening-upward prodelta mud-delta front/shoreface sand. Elongate deltas are largely delta-plain marsh and channel facies. Fans are mainly thick-bedded (amalgamated) massive to fining-upward sand; bed thickness and grain size decrease in a narrow periphery where fans onlap basin slopes or grade to basin-plain shale. Gas is produced from both suprafans and fan margins.

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Clay Fabric—New Aspect of Clay Petrology

Geologists have long been interested in the fabric of clastic sediments and their use in the reconstruction of current direction. However, study of the fabric of argillaceous sediments has not been extensive due to their extremely fine texture and complex composition.

With advanced technology and instrumentation, particularly transmission electron microscopy (TEM) and scanning electron microscopy (SEM), a new era of clay petrology has arrived. The superior resolution, wide range of magnification, very great depth of field, stereo, and x-ray analysis capability affored by TEM and SEM, enable us to examine the individual clay particles by the use of ultra-thin sections (TEM), to observe the particle surface and its three dimensional structure (SEM), and to determine the clays' chemical composition.

Clay fabric from various environments, such as shallow-marine deltas, deep ocean trenches, and laboratory consolidated samples have been investigated. Clay fabric study of these sediment reveals a good correlation with their physical properties as well as depositional history. Thus, combined information of clay fabric analyses, geotechnical properties, and mineralogic data will not only be useful in reflecting different conditions of sedimentation, but will also be beneficial in depicting postdepositional history. It is the time to develop the new science of clay fabric analysis, and hope that our understanding of argillaceous sediments can be further improved by these new analytical approaches.

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Icebergs and Glacial-Marine Sediment of Central Arctic Ocean

Mechanism of one variety of glacial-marine sediment transportation and deposition is inferred from observation of the activity of ice island T-3. This iceberg carries a significant sediment load. As T-3 moves with the Arctic pack ice, several meters of ice melt annually, releasing sediment to the ocean floor. The sediment accumulates at rates measured in a few mm per 1,000 years but in remarkably homogeneous layers. This uniform sedimentation in a seemingly heterogeneous environment is unexpected. The uniformity results from clockwise rotation of the pack ice that transports T-3–sized icebergs at rates up to several km/day in constant patterns. T-3 currently is in at least its third traverse of the Amerasian Basin during the past 30 years. The consistent Arctic surface currents have brought T-3 over the same areas during the different cycles.

There has been little change in central Arctic sedimentation since at least the late Miocene. Late Cenozoic layers of glacial-marine sediment on the Alpha Cordillera have been organized into thirteen lithostratigraphic units. Even thin units can be correlated over several hundred thousand square kilometers. A textural classification of Arctic glacial-marine sediment recognized four classes, all forming since the late Miocene in the Alpha Cordillera region.

Quantities of glacial ice, bearing sediment derived from similar source areas and transported in similar patterns by constant ocean basin currents, account for the uniform glacial-marine sediment in the Arctic Ocean.

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Depositional Environments and Diagenesis of Salem Limestone (Middle Mississippian) Reservoirs in Southern Illinois

The 1972 discovery of oil in the Salem Limestone (Valmeyeran Series) in Wayne County, Illinois, stimulated a resurgence of Salem and deeper exploration that continues to dominate Illinois basin activity.

Lower parts of the porous pay intervals in the Salem reservoirs are cross-bedded, oolitic grainstones and packstones, grading upward into highly bioturbated, mixed oolitic-skeletal grainstones. Hardground surfaces and fenestral vugs filled by anhydrite and sparry calcite are common in the uppermost parts of the pay zones. The reservoirs are capped by fine-grained, dolomitic, and argillaceous peloidal packstones and wackestones. Although most Salem reservoirs discovered occur at or near the crests of plunging anticlines, there commonly is no apparent structural closure over the pool, and the updip entrapment is entirely stratigraphic owing to thinning of the porous oolitic facies and thickening of the overlying packstone-wackestone facies. These variations in thickness probably reflect relict topography across oolite shoals.

Porosity and permeability in the Salem are closely related to depositional facies. Most Salem porosity is primary—depositional interparticle and intraparticle spaces, subsequently reduced in volume by pressure solution and cementation. Cementation of Salem grainstones was strongly influenced by the availability of suitable particle surfaces for nucleation of cement crystals. Sparry calcite cement is common on clean crystalline substrates (fossil fragments, especially monocrystalline echinoderms) and is rare on microcrystalline substrates (micritized fossils, peloids, oolites). Highest porosity and permeability occur in rocks with high percentages of oolitic coatings and micritized grains—most notably the oolitic grainstone facies.

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Superposed Laramide and Basin-and-Range Deformation in Santiago and Northern Del Carmen Mountains, Trans-Pecos Texas

Persimmon Gap, the northeast entrance to Big Bend National Park, lies astride a reverse-faulted monocline of a northwest-trending segment of the Santiago Mountains. Preserved Cretaceous rocks, about 762 m of Comanchean, and an incomplete section of Gulfian, consist of limestone, marl, and sandstone. Slip reversal, between Laramide and basin-and-range deformation using part of the Santiago thrust, is well-displayed in this range.

Laramide deformation produced the southwest-facing, N58°W-trending, reverse-faulted monocline of the Santiago Mountains. Structural relief across this faulted monocline is about 914 m. On the upthrown side, northeast of the Santiagos, are en echelon folds that suggest a left-lateral component of movement along the fault. The northwest end of this segment turns north where it becomes an unfaulted monocline with about 762 m of structural relief. To the southeast, structures in the Santiagos turn south and the monocline is unfaulted, with structural relief being about 762 m. The transition southward from the narrow northwest-trending Santiagos to the relatively broad, asymmetric anticlines with faulted limbs of the northern Sierra del Carmen involves both Laramide and basin-and-range episodes of deformation.

Basin-and-range deformation has reactivated the steeply-dipping Laramide fault planes and displacement is reversed. Throw along these faults ranges from 30 to 945 m. This area lies along the southeastern extension of the Texas lineament and suggests a left-lateral component of movement during Laramide time and a right-lateral component during basin-and-range time.

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Rapid Evaluation of Mature Hydrocarbon Producing Provinces in Sedimentary Basins