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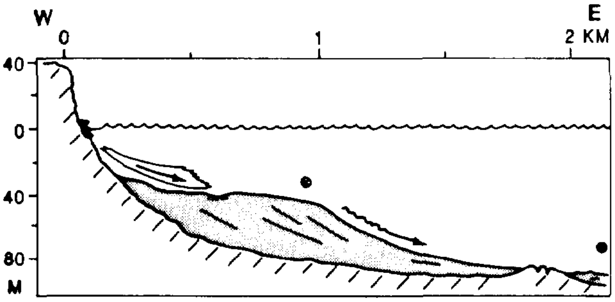
Downslope Transport on a High-Energy Shoreface: Evidence From Eastern Australia

Large shore-parallel sand bodies on the lower shoreface of the embayed and cliffed coast of central New South Wales, Australia, provide indirect evidence of downslope transport of sand. These sand bodies are 10 to 30 m (33 to 100 ft) thick, extend discontinuously for 40 km (25 mi) along the coast, and add a pronounced convexity to the shoreface profile.

Evidence from surface samples, deep borings, and side-scan sonar and high-resolution seismic reflection profiling from the sand bodies indicates that deposition occurred by downslope transport of sand from the upper shoreface and surf zone. The sand bodies consist entirely of locally derived quartz sand intermixed with marine mollusk fragments and microfauna. The internal acoustic structure of the sand bodies indicates growth by seaward progradation; the seaward face, or foreslope, locally attains a slope greater than 5°. Surface morphology indicates coalescing of individual sediment lobes and damming of bedload sediment against bed-rock ridges at the toe of the sand body in water depths of 70 to 80 m (230 to 262 ft). Channels and individual sediment lobes oriented normal to the shoreline also indicate seaward transport.

On this coast, the sea level reached its present position 6,000 years ago, and these sand bodies were produced by high-energy conditions on a steep shoreface during the stillstand period. Average waves here are 1 to 2 m (3 to 6.5 ft) and storm waves are much higher. Radiocarbon dates from analogous sand bodies elsewhere in New South Wales suggest continuous seaward progradation and upbuilding since the cessation of sea level rise. No direct observations or measurements of downslope transport are available, but we infer that sand derived from along the coast or the cliff face is gradually reworked seaward on the steep upper shoreface during fair-weather conditions. During storm periods, sand is flushed seaward by returning bottom flows onto and across the surface of the sand body.



In addition to downslope transport of sand to deeper water, there is strong evidence of concurrent modification of the sand bodies by processes acting parallel to the shoreline. This evidence consists of textural trends, shore normal sand waves, and the overall alongshore continuity of the sand bodies.

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Sediment Failure on Continental Shelf: Response to 1980 Earthquake off Northern California

On November 8, 1980, a large magnitude earthquake (M ~ 7) occurred 60 km (37 mi) off the coast of northern California. Damage was minimal onshore, but extensive changes to the sea floor were reported from the area of the Klamath River delta. Data from three successive surveys conducted in the area at intervals of 1, 6, and 11 months after the shock demonstrate the extent and type of sea floor failure. Side-scan sonar and high-resolution seismic reflection profiles, together with sea floor photographs and video images, define a thin (< 15 m, 49 ft) failure zone that measures 1 × 20 km (0.6 × 12.5 mi) and trends parallel to the shoreline on the shallow (~ 60 m, 200 ft) and nearly flat (~ 0.25°) surface of the Klamath River delta. The failure zone is characterized by a very flat (~ 0.02°) terrace that is mantled by silty sand and is bounded to seaward by an irregular 1 to 2 m (3 to 6.5 ft) high scarp.

Sonographs and bottom photographs provide evidence that failure occurred by liquefaction, lateral spreading, and sediment flow, producing various sediment patterns and relief features on the sea floor. The modes of failure with their corresponding features are: (1) liquefaction—identified from side-scan sonographs showing sand boils 5 to 25 m (16 to 82 ft) in diameter; (2) lateral spreading—identified from photographs and sonographs showing a prominent, nearly continuous, blocky, chaotic scarp at the seaward terminus of the failure zone and belts of small (10 m long, 0.5 m high; 33 ft long, 20 in. high) pressure ridges seaward of the scarp; and (3) sediment flow—identified from sonographs showing both (a) overlapping rhythmic flow deposits that become more irregular in a seaward direction as flow became progressively less mobile, and (b) flow "windows," or voids, left by highly viscous, dewatered flows.

In addition to these large- and small-scale changes to the morphology of the sea floor on the Klamath River delta, the sediment failure resulted in several distinctive phenomena. These phenomena include a net seaward translation of sand, a reported temporary decrease in the abundance of Dungeness crabs, and plumes of gas venting into the water column that were still evident 11 months after the earthquake.

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Comparison of Depositional Systems and Reservoir Characteristics of Selected Blanket-Geometry Tight Gas Sandstones

Future development of gas in tight sandstones is highly dependent upon price and the state of technology, including detailed understanding of internal and external reservoir geometry. Part of the tight gas resource lies in blanket-geometry, siliciclastic sandstones; over 30 such sandstones in 16 sedimentary basins and at depths mostly less than 10,000 ft (3,000 m) were reviewed for the Gas Research Institute. Emphasis was placed on depositional systems and resulting lithogenetic facies as an important control on sand body geometry.

In contrast to lenticular sandstones, blanket-geometry tight gas sandstones were deposited as deltaic, barrier strand plain, and shelf systems. Overlap occurs between systems, as in the case of a strand plain developed marginal to a deltaic depocenter. Not all parts of all sandstones are tight (< 0.1 md permeability); tight areas vary from extensive ("J" Sandstone, Denver basin) to very limited (Hartselle Sandstone, Black Warrior basin). Five stratigraphic units were selected from which developments in reservoir characterization, fracture treatment, and other technologies can likely be extrapolated to a wider group of tight gas reservoirs.

The Travis Peak Formation (East Texas basin/North Louisiana salt basin) is a fan delta system. It ranges in depth from 3,000 to 11,000 ft (900 to 3,350 m), with net pay of 30 to 86 ft (9 to 26 m) and post-stimulation gas flows of 500 to 1,500 MCFGD. The Frontier Formation (Greater Green River basin) is a wavedominated deltaic system with associated barrier strand plain facies; shallower prospective areas range in depth from 7,000 to 12,000 ft (2,100 to 3,650 m). The Frontier has net pay of 10 to 90 ft (3 to 27 m) and post-stimulation gas flows up to 2,500 MCFGD. Characteristics of the Travis Peak have extrapolation potential to Tuscarora-Medina-"Clinton" sandstones of the Appalachian basin; deltaic facies of the Frontier may correspond to parts of the Davis Sandstone (Fort Worth basin), Olmos Formation (Maverick basin), and the Fox Hills Sandstone (eastern Greater Green River basin). Cozzette and Corcoran Sandstones (Piceance Creek basin) are predominantly barrier strand plain deposits; they range in depth from 2,500 to 8,000 ft (760 to 2,400 m), with net pay of 10 to 70 ft (3 to 21 m) each and post-stimulation gas flows average 1,250 MCFGD. The upper Almond Formation (eastern Greater Green River basin) may contain more shallow marine and offshore bar than barrier strand plain facies. It occurs at depths of 6,000 to 15,000 ft (1,800 to 4,600 m), with net pay of 14 to 18 ft (4 to 5.5 m); and post-stimulation gas flows up to 1,700 MCFGD. The characteristics of the Cozzette, Corcoran, and upper Almond may be extrapolated to other marginal marine units in the Mesaverde Group and parts of the Dakota Sandstone in several Rocky Mountain basins. Shelf deposits include the Mancos "B" interval of the Mancos Shale (Piceance Creek and Uinta basins) at depths of 3,500 to 5,000 ft (1,000 to 1,500 m) in areas of recent drilling. Mancos "B" net pay ranges from 38 to 120 ft (11.5 to 36.5 m), and post-stimulation gas flows range up to 350 to 1,200 MCFGD. Extrapolation potential exists in the Anadarko basin and Northern Great Plains area.

These five stratigraphic units have potential for increased commercialization. By understanding the initial properties derived from the depositional setting of a tight gas sand, the explorationist can better extrapolate successful exploration, stimulation, and production techniques between reservoirs in similar depositional settings.

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North Channel Slope Fault, Santa Barbara Basin, California: A Reevaluation

Recently a "major fault zone," the "North Channel Slope fault" was mapped along the northern margin of the Santa Barbara basin by U.S. Geological Survey personnel. The fault consists of a steep topographic escarpment (the north channel slope) and two well-documented faults to the east and west. By connecting the Pitas Point fault, the escarpment, and the F-1 (or Point Conception) fault to the west, a major zone over 100 km (62 mi) in length was postulated. Unfortunately, the connection and the continuous zone are nonexistent.

We have reviewed over 100 deep penetration to high resolution seismic reflection profiles along the escarpment between the Point Conception fault and Coal Oil Point—a distance of 50 km (31 mi). No through-going fault zone is present. Several small, discontinuous faults are mapped, such as the faulting south of the Molino anticlinal fold. But continuous, unbroken, late Neogene and Quaternary reflectors separate such minor high-angle reverse faults. Our interpretation of the deep structure along the margin is in agreement with that of the industry; there is no through-going fault zone.

Rather than connecting with the "steep escarpment," the Pitas Point fault appears to die out south of the Hondo anticlinal structure and cannot be traced beneath the Conception submarine fan to the west. In this area, the fault is expressed as a series of steeply south-dipping, monoclinal flexures.

The F-1 or Point Conception fault dies out immediately west of Gaviota. From this point westward to Point Conception, it is a north-dipping (65° ±), high-angle reverse system that is composed of three en echelon segments with total length of approximately 20 km (12.5 mi) but less than 25 km (15.5 mi). Holocene activity along the eastern and western fault segments is documented by the disruption of the Holocene shelf surface and the distribution of Holocene sediment veneer. The surface over the fault zone is bowed about 3 m (10 ft), and the estimated maximum rate of uplift is 0.3 mm/yr.

The South Santa Ynez fault extends offshore southwestward from Gaviota. The fault is cut by the Point Conception fault near the shelf break. Beyond the edge of the shelf, the South Santa Ynez fault is located south of the Point Conception fault, and represents a north-dipping, high(?)-angle reverse fault. The latest displacements appear to be mid-late(?) Quaternary. The western part of the fault, which underlies the Conception fan, is poorly defined.

A review of the earthquake activity (1932-1981) of the northwestern Santa Barbara Channel region shows several scattered epicenters with magnitude range of 3.0 to 4.5. The fault plane solution for the October 1, 1959 ($M = 4.5$), event indicates right-lateral strike-slip faulting along a north-south direction with northeast-southwest compressive stress. No major historical earthquakes (1800-1932) have occurred in this region, nor is there a trend of epicenters along the north channel slope.

In summary, the existence of a "North Channel Slope fault zone" is not supported by the available evidence.

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Diagenetic Calcite Varieties from Travertines of Central Italy

Quaternary travertines in Latium and Tuscany, Italy, were deposited by warm springs containing abundant CO_2 and H_2S. The major rock-formers were bacteria that precipitated calcite to form shrubs, pisolites, mats, foamrock, and clastic silt-size sediment. The calcite cement in these rocks shows extraordinary morphology. The elementary building block is a subspherical clump of bacteria 10 to 40 μm in diameter, which becomes surrounded by a single crystal of calcite shaped like a pecan shell. SEM shows that these crystals are riddled with cavities (voids representing bacteria) and contain internal moats. Later the bacteria-rich crystals became coated with clear, chemically-precipitated inorganic calcite cement; but even these crystals are strange, as they have curving edges and consist of a series of scales parallel to the rhomb faces, like superimposed Gothic arches. Other cement crystals bear a forest of sharp spikes parallel to the C axis like a fakir's bed. The final sparry calcite that fills large pore spaces occurs as large bladed crystals with apparent basal parting planes.

Primarily inorganic sediment includes ray-crystals and pisolites. Ray-crystals can be up to 1 m (39 in.) long and in some places show daily, bacteria-rich growth bands indicating deposition rates of as much as 1 m (39 in.) per year. These formed as travertine dams, on sloping surfaces, and at ancient spring orifices. Crystals can be shaped like cedar-tree needles or club-shaped stromatolites, show undulose extinction, and in the SEM consist of helically twisted calcite ribbons. Inorganic pisolites formed in hot-spring mouths, and are made of smoothly concentric rings of tightly bundled radial rods, like fasces.