there is strong evidence of concurrent modification of the sand bodies by processes acting parallel to the shoreline. This evidence includes 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 further inland was transported downslope during fair-weather conditions. During storm periods, sand is flushed seaward by returning bottom flows onto and around the shelf edge.

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.

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 (~ 0.15 m, 49 ft) failure zone that measures 1 x 20 km (0.6 x 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 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 dehaic 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 wave-
dominated 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 30 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 reflector’s 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 subma-