be oriented so as to facilitate induced crack propagation.

Combined with an analysis of hydrocarbon potential and the location of detachment zones related to basement deformation, these relationships offer a useful rationale for targeting areas for future unconventional gas recovery programs. In addition they provide a framework for understanding the behavior of the rock mass in response to hydrofracture stimulation in less promising areas of the basin.

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Enhanced Gas Recovery From Watered-Out Reservoirs

Major additions to future gas reserves will depend partly on development of resources that are presently unconventional. Recently, coproduction of gas and water has been proposed as a method to increase ultimate gas recovery from reservoirs that have begun to water out or were abandoned because of high water production. The enhanced recovery method involves producing large volumes of water and reducing reservoir pressure to the point where dispersed gas, trapped in the water-invaded zone, is mobilized and flows to the well bore. Research involving the coproduction method was funded by the Gas Research Institute.

Integration of geological and engineering studies indicates that the Port Arthur field in Jefferson County, Texas, is a prime area for research to test the coproduction techniques. Prior to abandonment, the field produced from lower Hackberry (Oligocene) sandstones at depths less than 12,000 ft (3,600 m). The field contains 11 reservoirs with a maximum net sandstone thickness of over 450 ft (135 m). Individual sandstones are 10 to 120 ft (3 to 36 m) thick, but gas columns are usually less than 20 ft (6 m) thick. The reservoirs are relatively narrow and elongate and are oriented nearly perpendicular to the local structure, a simple rollover anticline. These reservoirs, interpreted as submarine channel and fan deposits, are internally heterogeneous owing to the vertical imbrication and dip-alignment of the sand lenses. Optimum reservoir facies occur as thick, massive sandstones with uniformly high porosities and permeabilities that average 28% and 60 md, respectively. Reservoir quality is more variable and diminishes somewhat away from the channel axes in the more thinly bedded sandstones with intercalated shales. Upward decreases in porosity and permeability characterize the zones of gas accumulation.

The "C" sandstone was selected for detailed investigation because of high abandonment pressure, excellent reservoir quality, high productivity, and good lateral continuity. Reservoir simulation studies suggest that 5.5 bcf of gas and some condensate could be recovered from the "C" sandstone under natural flow conditions by producing slightly more than 9 million bbl of water over a 5-year period. Brine disposal would be accomplished by injection into thick Miocene sandstones that occur at shallow depths. If successful, the recovery efficiency of the "C" sandstone would be increased from 42% (primary) to 53% of the original gas in place.

An economic analysis of the enhanced recovery project indicates a favorable payout under prevailing gas prices. Project economics are even more attractive if gas prices increase or if gas production from other abandoned reservoirs is commingled with production from the "C" sandstone.

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Quantitative Paleobathymetry of Early Proterozoic (1.9 B.Y.) Continental Slope, Rocknest Formation, Wopmay Orogen, N.W.T., Canada

The Rocknest Formation is an early Proterozoic (1.9 b.y.) westward-facing, rimmed carbonate shelf that evolved from a ramp developed on quartzites of the underlying Odjick Formation. Shelf interior facies are cyclic peritidal dolomites; shelf edge facies are reefal stromatolitic boundstones and intraclast/ooid grainstones, and slope facies are turbidites, slope breccias, and shelf edge breccias. The carbonates are overlain by black shales and graywackes of the Recluse Group.

Facies that represent the shelf edge-to-slope transition of the Rocknest Formation are well exposed for almost 200 km (125 mi) along the strike length of the major north-south trending syncline. At the southern end of the syncline, the Rocknest Formation comprises 230 m (755 ft) of slope deposits on the west limb and 660 m (2,165 ft) of shelf edge deposits on the east limb. The difference in the decompacted thickness of the Recluse Group on both sides of the syncline, as measured from the top of the Rocknest Formation to a marker bed in the Recluse, is 590 m (1,935 ft), which represents the total paleobathymetric relief. However, the difference in thickness of the Rocknest Formation, 430 m (1,410 ft), is less than the total paleobathymetric relief, which indicates that most, but not all of the total paleobathymetric relief was produced by constructional aggradation of the shelf edge. The remaining relief, 160 m (525 ft), was inherited from a preexisting slope at the top of the Odjick Formation and therefore represents the initial relief of the Rocknest slope.

Average inclinations of the Rocknest slope can be calculated given the distance between sections (approximately 4,500 m, 15,000 ft). The initial average inclination of the slope is 2°, and the final average inclination of the slope is 7°.

The sedimentologic and stratigraphic evidence strongly suggests a depositional model involving a ramp that evolves into a steep, marginal escarpment passing seaward into a shallow-dipping slope. As such, the geomorphic development of the Rocknest slope is considered to be analogous to the slopes of many Phanerozoic rimmed shelves, implying that similar evolutionary processes were operative during the early Proterozoic.