

turbidites. An outward-radiating paleocurrent pattern suggests north-eastward transport of sand through a single major inner-fan-channel complex, succeeded by radial downfan dispersal to smaller middle-fan channels, outer-fan lobes, and fan-fringe deposits. Sandstone-to-shale ratios are 99:1 in inner-fan-channel deposits, 10:1 in middle-fan-channel deposits, 2.5:1 in middle-fan-levée deposits, 1.3:1 in middle-fan-interchannel deposits, 11:1 in outer-fan-lobe deposits, 2.6:1 in fan-fringe deposits, and 0.25:1 in basin-plain deposits. Orderly and progressive downfan changes in most sedimentary parameters, such as maximum clast size, thicknesses of fining- or coarsening-upward cycles, facies, and facies associations permit the growth history of the fan to be determined. The Gottero Sandstone provides a useful model for petroleum exploration in small deep-sea fans characterized by a mixture of grain sizes and deposited adjacent to tectonically active, convergent continental margins.

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Comparison of Tectonic Framework and Depositional Patterns of Hornelen Strike-Slip Basin in Norway and Ridge and Little Sulphur Creek Strike-Slip Basins of California

Deposition in basins that develop adjacent to strike-slip faults can yield thick nonmarine sequences with similar facies and geometry. In this paper, we compare 3 basins of different age and size whose tectonic and depositional characteristics suggest a similar origin and history.

The Hornelen basin developed during the Middle Devonian in western Norway. The basin is bounded on the north and south by east-west trending faults; the northern fault is considered to have been a zone of major right-slip movement. The basin is 60-70 km (38-43 mi) long, 15-25 km (9-16 mi) wide, and about 1,250 km² (480 mi²) in areal extent; its 25,000 m (82,000 ft) of fill accumulated at an estimated rate of 2.5 m/1,000 yr (8 ft/1,000 yr). The Ridge basin developed during the Miocene and Pliocene between the right-lateral San Gabriel and San Andreas faults in southern California. The basin is 30-40 km (20-25 mi) long, 6-15 km (4-10 mi) wide, and about 200 km² (80 mi²) in areal extent; its 7,000-11,000 m (23,000-36,000 ft) of fill accumulated at an estimated rate of about 3 m/1,000 yr (10 ft/1,000 yr). The 3 Little Sulphur Creek basins probably developed 4-2 m.y.B.P. along the east side of the right-lateral Maacama fault zone in northern California. These basins cumulatively are about 12 km (7 mi) long, 1.5-2 km (0.9-1.2 mi) wide, and about 15 km² (6 mi²) in areal extent; their 5,000 m (16,000 ft) of fill accumulated at an estimated rate of about 2.5 m/1,000 yr (8 ft/1,000 yr).

Coarse angular sedimentary breccia, which constitute a relatively small volume of the basin fill, was deposited in each of these basins along the active right-slip-fault margins as talus, landslide, and small but steep debris-flow-dominated alluvial fans. Along other margins of the basin, a much larger volume of the fill accumulated as larger streamflow-dominated alluvial fans, braided-stream, meandering-stream, fan-delta, and deltaic deposits. Lacustrine deposits that include turbidites and local chemical precipitates accumulated in the centers of the basins. The basin floors are generally tilted toward the active right-slip-fault margins so that the basin axes and the depocenters are subparallel to and shifted toward this margin. Sediment was transported toward the basin axis from surrounding highlands and then longitudinally down the basin axis. The basin fills were syndepositionally folded and faulted, and postdepositionally folded into large plunging synclines. The basins lengthened over time and contain thicknesses of sediment that are comparable to or greater than their widths.

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Retardation of Vitrinite Reflectance in Green River Oil Shales, Piceance Creek Basin, Northwestern Colorado

Vitrinite reflectance (R_o) of coaly inclusions in the otherwise alginitic rocks of the Green River Formation, northwestern Colorado, is greater in sandstones, marlstones, and organic-lean oil shales than in adjacent organic-rich oil shales. The R_o of the coaly inclusions in these organic-lean rocks increases from about 0.30% for samples with a maximum burial depth of less than 1,000 m (3,300 ft) to 0.55% for samples with a maximum burial depth of more than 1,500 m (5,000 ft). The higher R_o in

the organic-lean rocks (oil yield < 10 gal/ton with the modified Fischer assay method) thus appears to record the thermal history of the area more precisely. In contrast, coaly inclusions from oil shales (yields > 10-15 gal/ton) all have lower R_o values—typically in the range 0.20-0.27—regardless of depth of burial. This retardation effect appears to be very localized and has not altered the vitrinite in coaly material as close stratigraphically as 30 cm (12 in.) to rich oil-shale beds.

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In-Place Barrier Drowning on Louisiana Continental Shelf

An extensive data set consisting of vibracores, seismic reflection profiles, surface sediment sampling, bathymetry, and historical maps and bathymetric charts strongly suggests that the two major shoals on the western Louisiana shelf, Ship Shoal and Trinity Shoal, originated through the in-place drowning of earlier barrier-island systems. The last barrier remnants were still visible in the early 1800s.

The island systems originated as delta-flank barriers during the abandonment of Holocene lobes of the Mississippi delta. The islands probably developed through rapid shoreface retreat and transgression of deltaic distributary-mouth bar sands along the central part of the abandoned "headland." Flanking these headlands, regressive barrier spits and islands developed in response to a high rate of sediment supply from the eroding headland. These barriers prograded into the progressively deeper water of old interdistributary bays. Rapid, local, relative sea level rise, due to delta lobe subsidence, prevented the destruction of these flanking barriers by the erosional effects of the retreating shoreface. Consequently, the barriers drowned in place and the shoreline was "instantaneously" displaced approximately 15-20 km (10-12 mi) landward.

Ship Shoal and Trinity Shoal provide the only convincing case of recent barrier island in-place drowning along the United States coastline. An additional, possible example may exist in the western extension of the Maguire Island chain off Prudhoe Bay, Alaska.

Barriers subject to in-place drowning have the potential of preserving thick reservoir sands in the geologic record. These Louisiana shelf shoals, in particular, may be rapidly buried by the prodelta muds of a new phase of delta progradation. In contrast, barrier islands along coastlines with a slower relative rate of sea level rise, such as the United States east coast, are generally completely removed by the eroding shoreface. Their sand is transported seaward into an inner-shelf sand sheet. This sand sheet may subsequently be molded into linear sand ridges by contemporary storm-generated shelf currents. Such ridge sands are stratigraphically and sedimentologically distinct from the drowned barriers.

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Carbonate Pore Systems: Porosity/Permeability Relationships and Geologic Analysis

The porosity/permeability relationships of the common carbonate rock types have been studied, with emphasis on the variety of pore types in upward-shoaling grainstone sequences including: Smackover, Lansing, Salem, and San Andres Formations. A result of these studies is an improved conceptual understanding of permeability gained from the cross-plotting of porosity and permeability data from plugs and whole cores accompanied by textural and fabric analyses of rock samples, thin-sections, serial sections, and pore casts. Importantly, many depositional rock types cross-plot as distinctly different populations, commonly yielding linear trends on semi-log paper. These trends indicate a degree of order in the seemingly chaotic pore systems of carbonate rocks which have undergone cementation and/or compaction. For grainstone samples, there appears to be a change in the slope of this trend between the compaction and cementation phases of diagenesis.

Once the depositional texture and fabric of the rock are defined in terms of porosity and permeability, the evaluation of fractures and secondary porosity can be addressed. The secondary porosity is observed to be as high as 14% of the rock volume in the Smackover example and 21% of an oolitic sample from the Lansing Formation. Pore casts and serial sections reveal that the grain-moldic porosity is poorly connected to the intragranular pore system and contributes little to the permeability of the rock. This insight allows quantitative estimates of this type of secondary

porosity using standard porosity and permeability data. The geologic and quantitative analysis of the various pore types and porosity/permeability relationships also aided in the interpretation of the log data from the reservoirs studied.

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Economics of Natural Gas Resources and Supply

The relative availability and cost of finding and producing natural gas fields of varying size, located in regions of the United States at various depth intervals, are examined under different economic assumptions. First, historical trends related to the discovery and availability of natural gas are identified and discussed. These include trends in drilling activity, reserves production, and field-size distributions. Exploration, drilling, and production costs are presented and analyzed. This information is integrated, along with other data, as part of an economic evaluation of the natural gas discovery and production process in the United States. Finally, possible future discoveries of natural gas are projected based on varying assumptions related to the underlying distribution of natural gas resources.

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Interpretation of Underpressuring Using Pressure-Depth Profiles, Palo Duro Basin, Texas

Investigations of underpressured basins can be improved by identifying factors which impede accurate interpretation of pressure-depth (P-D) plots. The majority of P-D data from drill-stem tests are poor quality and are biased in distribution toward exploration and production; thus, true P-D trends, are obscured. Plotted P-D data may not only reflect flow conditions and underpressuring, but they can also be distorted by the hydrogeologic setting, i.e., surface topography, basin structure, and potentiometric surface. For example, surface topography can cause plotted data to appear more underpressured than it really is. Varying surface topography in conjunction with basin structure can cause P-D gradients to erroneously indicate potential cross-formation flow. If the effects of the hydrogeologic setting are not identified, P-D trends may be misinterpreted.

In the Palo Duro basin, the problems of the hydrogeologic setting are reduced by delineating regions with little variation in surface topography and structure. The P-D plots for these different regions vary considerably. To evaluate the effects of the hydrogeologic setting on these P-D plots, theoretical models of hydrostatic conditions were computed for the hydrogeologic setting of each region. Comparison of regression lines through real P-D data to those through modeled data distinguishes true hydrologic conditions from the misleading effects of the hydrogeologic setting.

P-D plots indicate regional underpressuring in Palo Duro basin. Variations in potential vertical flow within the underpressured basin are indicated by variations in P-D gradients across the basin. Potential upward flow is indicated along the western flanks of the Amarillo uplift, while potential downward flow is indicated in the southwestern and eastern parts of the basin.

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A Microcomputer Log Analysis System

A comprehensive friendly log analysis system for use on a microcomputer requires only average log analysis skills. Most systems require both log analysis and computer professionals for operation.

This one has many capabilities: (1) data entry is handled by office personnel after minimal training; (2) entered data is filed and cataloged for future retrieval and analysis; (3) the system can handle more than 9,000,000 ft (2,700 km) of log data in over 60,000 files; (4) all data can be edited; (5) searches and listings can be made using factors such as formation names; (6) facsimile reproductions can be made of any log on file; (7) a screening program turns the system into a sophisticated hand calculator

to quickly determine zones of interest; and (8) up to 1,100 ft (335 m) of contiguous data from a well can be analyzed in one run.

Innovative features include: (1) a discriminating factor to separate reservoirs for individual attention concerning rock type, fluid content and potential reserves; and (2) a written report of each reservoir using artificial intelligence. The report discusses, among other things, the rock type and its consistency, comparing the system finding with the geologist's opinion. Differences between the two will elicit alternative analyses.

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Surface and Subsurface Structural Analysis of a Part of Washita Valley Fault Zone, Southern Oklahoma

The Washita Valley fault zone is one of the major northwest-trending structures in southern Oklahoma. This fault system is believed to have originated as a series of normal faults during the formation of the southern Oklahoma aulacogen by late Precambrian or early Cambrian time and to have been reactivated during the Arbuckle orogeny in the Pennsylvanian. Descriptions of movement along the Washita Valley fault zone during Pennsylvanian deformation include numerous interpretations, the most common being left-lateral strike slip with 30-40 mi (50-65 km) of displacement. Structures in the area, however, suggest an alternate model.

A detailed field study of small folds, faults, fracture arrays, slicken-sides, and drainage patterns was conducted along the southeastern half of the Washita Valley fault zone. An attempt has been made to relate these small-scale features to the major structures in the area to determine the orientation of the major compressive stress during deformation and the relative amounts of strike-slip vs. reverse dip-slip movement along the fault zone.

Exploration for oil and gas along the Washita Valley fault zone has identified several overturned folds and repeated sections. Field observations in the study area include small drag folds and thrust faults parallel to the trend of the Washita Valley fault zone. The two major anticlines in the area, the Arbuckle and the Tishomingo, are both nearly parallel to the trend of the fault zone. These data suggest a model of deformation involving a large component of reverse dip-slip faulting with major duplication of strata.

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Depositional Control of Diagenesis in Tight Gas Sands, Corcoran and Cozzette Sandstone Members of Price River Formation (Upper Cretaceous), Book Cliffs of Western Colorado

Diagenetic history and petrophysical properties of the Corcoran and Cozzette sandstones are closely related to depositional environment. Coarsening-upward shoreface-beach sequences and fining-upward tidal-inlet sequences display the same diagenetic phases: (1) compaction and deformation, (2) overgrowth of quartz, (3) cementation by carbonate, (4) dissolution of feldspar and carbonate, and (5) precipitation of kaolinite. Development of the phases differs according to vertical position within the sequences. Finer grained (3 ϕ -4 ϕ) shoreface and upper tidal-inlet deposits contain abundant pseudomatrix. Poorly developed quartz overgrowths and little secondary porosity indicate that pseudomatrix and carbonate restricted fluid movement during phases 2 and 4. Abundant overgrowths and pervasive secondary porosity in coarser (2 ϕ -3 ϕ) beach and lower tidal-inlet deposits suggest freer movement of diagenetic fluids apparently in the absence of much pseudomatrix. Kaolinite is best developed in coarser sandstones and occurs as local replacement and ubiquitous pore-filling phases, but its abundance varies with abundance of feldspar and prekaolinite porespace. Lower tidal-inlet sandstones containing 8-13% feldspar display both replacement and ubiquitous pore-filling kaolinite. Beach sandstones with less feldspar (3%) contain only local replacement kaolinite. Lower tidal-inlet deposits present a paradox: well-developed secondary porosity but abundant diagenetic kaolinite has reduced permeability. Permeability is greatest in high-energy beach deposits where the least pseudomatrix and diagenetic kaolinite occur; these are the best targets for exploration.