geometrically consistent with all observed data. The methods described are especially useful for resolving sparse or erratic data and predicting subtle traps and deep structures from shallow control.

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Sea-Floor Characteristics and Dynamics Affecting Geotechnical Properties at Shelf-Slope Breaks

Shelf-break geotechnical and sea-floor stability investigations are rare but such studies offer challenging scientific and engineering opportunities in a unique sea-floor environment. The uniqueness stems from the highly variable sea-floor properties, morphology, and dynamic processes. Some characteristics and processes at the break are nonexistent in nearshore environments where most of our understanding and experience exists. The geotechnical properties and stability of submarine deposits are strongly influenced by the nature of the geologic environment, dynamic processes, sediment type, and sea-floor slope. Sediment properties and sea-floor morphology at the break can be highly variable over relatively short horizontal and vertical distances.

The outer shelves and slopes off Cape May, New Jersey, and the Mississippi delta are among the few geotechnically investigated continental margins. Off Cape May, mobile shelf sands contribute to sandy silts overlying the upper slope muds which occasionally exhibit structures and geochemical properties suggesting slope-creep processes. In contrast, the Mississippi delta's shelf-slope break is characterized by clays and silty clays that mobilize as mudflows which encroach upon the upper slope. Geotechnical properties such as shear strength and water content display striking differences between the two areas as a function of regionally differing dynamic processes, sedimentation rate, type, and texture.

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Hatter's Pond Field: Complex Combination Trap in Smackover and Norphlet Formations (Upper Jurassic), Southwest Alabama

The Hatter's Pond field in northern Mobile County, Alabama, has produced 7 million bbl of condensate and 26 Bcf of gas since its discovery in 1974. Production is from the Upper Jurassic Norphlet and Smackover Formations which form a transgressive-regressive package overlying the Jurassic Louann Salt. The Norphlet Formation is a subarkose which was deposited in a coastal dune complex. Subenvironments identified include dune, interdune, wadi, and an upper, massive marine sand lithology which is gradational into the overlying Smackover Formation. The Smackover Formation in the Hatter's Pond field is composed of mudstones, peloidal packstones, oolitic grainstones, and nodular anhydrite deposited in a coastal sabkha complex. The Smackover grades upward into the Buckner Anhydrite Member of the Haynesville Formation. Reservoir development in both the Norphlet and Smackover is facies selective and a product of diagenesis.

Porosity in the Norphlet is most abundant in the massive marine and dune lithlogies and is mesogenetic, secondary porosity formed by the solution of eogenetic carbonate cement and/or solution of grains. Smackover porosity is moldic in the higher energy lithofacies and intercrystalline to vuggy in the finer grained lithologies, with dolomitization and leaching as major factors in porosity evolution. Algal-rich mudstones within the Smackover provide an internal source for the hydrocarbons.

The trapping mechanism in the field is a highly complex, combination structural and stratigraphic trap. The structural component involves salt movement in association with normal faulting. Porosity distribution, and hence reservoir development, is facies selective and is significantly modified by diagenetic alteration. A thorough understanding of facies distribution, diagenetic alteration, and structural relations is necessary for delineation of combination petroleum traps in the Hatter's Pond area.

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Spontaneous Subsurface Combustion of Rocks of Monterey Formation, California

Rocks of the Monterey Formation rich in organic matter have undergone spontaneous subsurface combustion (combustion metamorphism) at many localities, particularly during the Pleistocene. At the best studied locality, the Grimes Canyon area, the burnt-out rock body is 20 km long, 1 to 3 km wide, and at least 400 m thick. The original rocks were mainly mudstones with lesser amounts of diatomites, phosphorites, shales, some cherts, and carbonate rocks. The trace element composition of the parent rocks is that of oil shales; Ba, Cr, Ni, Sb, and Se contents are higher. Rock melting started below 1,000°C. The initial melt (5% of rock volume) is highly differentiated and has a major, minor, and trace element composition indistinguishable from high-calcium granites. These melts intruded to form sills and dikes, and cooled to obsidian-like glasses. As the temperature rose, the melt changed composition and approached the composition of the parent rocks. These melts formed intrusive stocks and cooled to crystalline rocks resembling, in the field, scoriaceous basalt. At the highest temperatures, in excess of 1,650°C, phosphorites were molten; the resulting melt had the composition of apatite and was immiscible with the coexisting silicate melt, with which it formed an emulsion.

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Seismic Detection and Evaluation of Delta and Turbidite Sequences: Their Application to the Exploration for the Subtle Trap

Energy conditions at the seaward edge of deltas allow their division into fluvial-dominated, wave-dominated, and tide-dominated deltas. Each kind of delta has a distinct framework orientation and depositional pattern which results in a characteristic seismic reflection pattern. Fluvial-dominated deltas are characterized by clinoform seismic reflection patterns which include: oblique (tangential), complex oblique (tangential), sigmoid, and complex sigmoid-oblique. Seismic facies analysis can be used to define those facies which contain sand. Wave-dominated deltas are characterized by shingled seismic reflection patterns. Seismic facies analysis of this delta is not effective in identifying those facies which should be sand prone. Shingled reflections may be used in determining the possible location and depositional attitude of strandline sands. Tide-dominated deltas have not yet been identified using seismic stratigraphic methods and therefore are not covered in this paper.

Turbidite fans are sequences of sands and shales deposited in conjunction with, and basinward of, deltas or submarine canyons. Turbidite sands can be generally classified into channel and suprafan sands. Certain seismic events and reflection patterns suggest the presence of turbidites. The interpreted events and reflection patterns include troughs, submarine canyons, mounds, a prograded fluvial-dominated delta reflection pattern and variations in its thickness, and onlap-offlap patterns on a depositional slope. Regional studies provide the best means of identifying and mapping depositional sequences. Examples from the North Sea, Gulf Coast, and Sacramento Valley illustrate the geologic and geophysical expression of delta and turbidite sequences, and their interrelation.

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Calculation of Seal Capacity from Porosity and Permeability Data

Porosity and permeability measurements can be used to calculate oil columns trapped by grain-size changes. Calculations can be useful when capillary pressure measurements are not available. Calculations are based on two major assumptions: (1) the rocks are water wet; and (2) mean effective grain size and pore size may be determined from average porosity and permeability. The first assumption is widely applicable; the second assumption has been tested and found to be reliable over a wide range of porosities and permeabilities for sandstones. Important in the calculations is that interfacial tension does not decrease to low values under subsurface conditions of higher temperatures and pressures but remains at a relatively large value of 30 dynes/cm for both gas and oil.

Calculations of oil column based on porosity and permeability data are particularly useful in evaluation of hydrodynamic flow as a trapping mechanism. Once hydrostatic or capillary-pressure oil column has been estimated, the effects of hydrodynamic flow can be evaluated as in independent variable. In many simple stratigraphic traps, the amount of oil trapped by hydrodynamic flow greatly exceeds that which can be trapped by capillary-pressure differences alone.

Studies of Recluse Muddy and Kitty Muddy fields in the Powder River basin of Wyoming indicate that hydrodynamic flow makes up a major part of the trapping element for the hydrocarbon column. Such examples show that downdip hydrodynamic flow can be an effective trapping mechanism in basins where reservoir systems are subject to recharge by meteoric waters.

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Origin of Thin, Siliceous Beds in Monterey Shale, Elk Hills Field, California

The Miocene Monterey Shale consists of thinly interbedded black shale and siliceous beds in a section 1,800 ft (550 m) thick on the western anticline, Elk Hills field. Selected full-diameter cores were examined through the upper section west of, and partly equivalent to, the Stevens Oil Zone sandstones. The siliceous beds are commonly 1 to 5 cm, and rarely 8 to 10 cm, thick. The beds are generally structureless or contain a few indistinct laminae. Bases are in sharp contact with underlying shale, and some tops are gradational to overlying shale. In a few beds, the uppermost parts show curved laminae that represent low-amplitude ripples. Therefore, the beds seem to be distal turbidites composed of common, massive A divisions and rare, rippled C divisions.

Many beds have a fine granular, graded texture with a thin basal zone of coarser detritus. The beds are composed of finely-crystalline, siliceous material, in some places partly replaced by dolomite(?). Petrographic study shows a significant content of fine sand to silt-size detritus. In a typical graded sequence, grains of quartz, plagioclase, and rock fragments form a thin lag at the base where they comprise more than 50% of the rock and have an average size of 0.13 mm. Detrital grains decrease upward to less than 3% at the top, and average size decreases to 0.05 mm.

The thin, regularly bedded nature of the section, significant detrital content, and graded texture suggest that the siliceous beds are turbidity-current deposits. The siliceous component was probably pelagic, diatomaceous sediment from the basin floor that was incorporated in turbidity flows, transported a short distance, and redeposited with terrigenous detritus in massive A divisions of the turbidite sequence. Alternatively, subsequent recrystallization destroyed original lamination and produced the structureless beds.

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Use of Sediment Gas Anomalies in Surface Prospecting

Measurements of methane and other hydrocarbon gases in near-surface marine sediments have been made with increasing frequency over the last 10 years as part of various geochemical prospecting efforts. Presumably, the presence of light hydrocarbon anomalies in sediments is indicative of seepage of hydrocarbons from nearby reservoirs. However, gas concentrations and compositions can be altered by filtering effects during gas migration through sediments as well as by microbially induced interferences and alterations. Methane is apparently consumed and oxidized by aerobic and anaerobic bacteria in near-surface sediments. The bacteria can alter isotopic compositions of microbially produced methane to yield thermal-like compositions which can be misinterpreted as oil-related gas. Ethane and higher ($C_2$+) hydrocarbon anomalies are considered more positive indicators of commercially prospective oil and gas accumulations but these gases can be selectively filtered by sediment chromatographic effects yielding bacteria-like compositions which might be passed over as non-anomalous.

These concerns, coupled with methodologic problems such as (1) the difficulty of measuring isotope ratios on small amounts of sediment gas, (2) the fact that the hydrocarbons which initially outgas from a sediment sample are different in composition than subsequent outgassing, and (3) disputes over the optimum depth for sediment gas measurement and anomaly detection, demand that surface gas anomalies used for prospect evaluation should be interpreted with care.

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Seismic Stratigraphy of Veracruz Tongue, Southwestern Gulf of Mexico

The Veracruz tongue is an area of continental slope and rise sediments bounded topographically by the Mexican Ridges foldbelt and the Campeche-Sigsbee salt province. Study of two multichannel lines and single fold sparker data enables five