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Estimation of Sediment Compaction Profiles Using Combination of Real-Time Drilling Response Modeling and Direct Porosity Measurements

The detection of overpressured formations at the wellsite has been limited in the past to empirical rate-of-penetration normalization equations (e.g., "d" exponent). These equations are limited to specific bit types and require much interpretation by well site geologists, particularly in wildcat areas.

A new, theoretically based method of evaluating overpressures handles several bit types independently (milltooth, insert, Stratapax, and diamond), and the output (drilling porosity) is calibrated to true formation porosity through the use of pulsed nuclear magnetic resonance techniques on drill cuttings.

Extended output from the method produces the following: online formation porosity curves, formation permeability, formation pressures (pore, overburden, fracture), bulk rock properties (e.g., Poisson's ratio, using a compressibility model that observes the change in porosity with incremental overburden pressure), and formation and bottom-hole temperatures. The method frees the geologist to interpret the output as the well is drilled. Several examples describe the interpretive significance of the output. For example, a pseudosonic log generated by the model shows excellent correlation with wire-line sonic measurements in consolidated formations; on certain wells the maximum value attained by the formation pore pressure is controlled by the overlying fracture gradient (hence, an on-line fracture gradient allows prediction of the maximum pore pressures likely to be encountered).

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Carbon Isotope Composition of an Upper Triassic Evaporite Section in Israel: Evidence for Meteoric Water Influx

Upper Triassic (Upper Carnian) extensive evaporites occur in shallow-water basins that are surrounded by supratidal dolomites. The evaporites consist of laminated and nodular anhydrites (gypsum in outcrop) interlayered with dolomitic mudstones and, rarely, with algal or oolitic grainstones. The evaporitic section reaches a thickness of about 180 m (590 ft), whereas the surrounding dolomitic facies amount to 80–100 m (260–330 ft).

Systematic $\delta^{13}C$ profiles of the carbonates of the entire Triassic section in an outcrop and two boreholes revealed an extreme ^{13}C depletion in the evaporitic section (the Mohilla Formation) in both the basins and highs, relative to the lower parts of the Triassic section in all three investigated sections. The $\delta^{13}C$ values range from -2 ‰ to -14 ‰ in the Mohilla sections, whereas in the lower parts of the section the $\delta^{13}C$ values range from $+1$ ‰ to -5 ‰.

The systematic repetition of $\delta^{13}C$-depleted rocks in different basinal sections as well as from dolomitic highs, rules out the possibility of post-depositional diagenetic changes in the $\delta^{13}C$ composition.

Alternatively, one may assume changes in the $\delta^{13}C$ composition of the Upper Carnian Tethys ocean. However, such low values are not plausible to reflect the oceanic $\delta^{13}C$ composition. It is therefore proposed to relate the $\delta^{13}C$ values to an influx of fresh continental water floating upon the dense evaporated brine. Such a periodic influx of continental water is also compatible with the repetitive alternation of evaporites and carbonates within the Mohilla Formation.

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Upper Jurassic Norphlet Formation—New Frontier for Hydrocarbon Prospecting in the Central and Eastern Gulf of Mexico Regions

Since the discovery of oil in 1967 from the Smackover Formation at Toxey field, Choctaw County, Alabama, and of condensate in 1968 from the Norphlet Formation at Flomaton field, Escambia County, Alabama, the Upper Jurassic has become the primary exploration target in southwestern Alabama. Following those initial discoveries, 39 Upper Jurassic fields have been established in Alabama, but only in 4 of these has the Norphlet produced hydrocarbons. The discovery of productive Norphlet gas sandstones in 1979 at the Lower Mobile Bay-Mary Ann field, offshore Alabama, has demonstrated the potential of the Norphlet in the central and eastern Gulf of Mexico regions. All 4 wells drilled to test the Norphlet in Mobile Bay have been successful gas wells, and have tested between 10.5 and 19.4 mmcf per day. Although drilling is to depths exceeding 20,000 ft (6,100 m) subsea, the projected gas reserves justify continued exploration.

Norphlet petroleum traps in the region are principally combination traps involving favorable stratigraphy and salt anticlines (Copeland field), extensional fault traps associated with salt movement (Flomaton field), and faulted salt anticlines (Hatter's Pond and Lower Mobile Bay-Mary Ann fields). Reservoir rocks include marine, dune, and fluvial sandstone lithofacies. Sandstone porosity involves both primary intergranular and secondary dissolution and fracture. Smackover algal carbonate mudstone is probably the source for much of the Norphlet hydrocarbon, but downdip Norphlet marine shales may also be source rocks.

The central and eastern Gulf of Mexico regions should continue to be excellent areas to explore for hydrocarbons in the years ahead. Successful Norphlet petroleum prospecting in the area has involved the identification of favorable sandstone lithofacies and structural hydrocarbon traps by using geologic and geophysical methods. Future Norphlet discoveries will require the delineation of stratigraphic and structural/stratigraphic combination hydrocarbon traps using seismic-stratigraphic techniques.

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Paleocene Lignite Deposits of Southwest Alabama

In southwest Alabama, lignite having economic potential occurs in the Oak Hill Member of the Naheola Formation. This middle Paleocene lignite generally consists of a single bed of 1-14 ft (0.5–4 m) in thickness and is the most extensive lignite in the southwest Alabama region. The Oak Hill lignite deposit accumulated in lower delta plain coastal marshes in interchannel areas behind a barrier system. The source area for the deltaic sediments was probably to the west and/or northwest of Choctaw County, Alabama. The lignite occurs in a clay-dominated sequence. Oak Hill interdistributary bay ripple-laminated clays are interbedded with ripple-laminated, crevasse splay sands generally less than 15 ft (5 m) thick. The glauconitic sands of the overlying Coal Bluff Marl Member of the Naheola Formation represent times of marine encroachment into the interchannel basin area.

Lignite having subeconomic value at present occurs in the upper part of the Tuscahoma Sand. This upper Paleocene lignite is irregular in its outcrop pattern and apparently is not represented over extensive areas. It is locally persistent with one or more beds less than 3 ft (1 m) thick. The Tuscahoma may contain up to 6 lignite seams that may exceed a total thickness of 5 ft (1.5 m). These lignite beds were deposited in lower delta-plain coastal marshes adjacent to high constructive deltaic bar finger sands. Tuscahoma marsh clays are interbedded with ripple-laminated and cross-bedded bar finger sands. The Tuscahoma Sand is overlain by the Bashi Marl Member of the Hatchetigbee Formation. The Bashi contains a diverse lower Eocene marine fossil assemblage.

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Rotating Parallel Faults—"Book Shelf" Mechanism

In various tectonic environments, simple shearing or extension of crustal parts has been accommodated by the rotation of parallel faults in an array. Because of its kinematic resemblance to the tilting of a row of books on a shelf, the tectonic process may be referred to as a "book shelf" mechanism. Its most important manifestations are cross-faulting between normal faults or parallel wrench faults, the extension of deltaic slope deposits, and all forms of tilted block tectonics.

The process is addressed from a geomechanical point of view to determine geological operating conditions and controlling parameters. Kinematically, one has to distinguish between two basic modes of the book shelf mechanism: the dilational mode, where rotating faults tend to open up and may become migration paths, and the domino style, where the rotating faults remain closed. In both cases, formation and rotation of the faults may occur in one tectonic event. Fault displacements may therefore remain small and difficult to detect on seismic records. From the mechanical point of view, one has to differentiate between book shelf operations controlled by an externally imposed simple shearing and those responding to an imposed extension.

The mechanical analysis of book shelf operations induced by simple shearing shows that, under certain conditions, this operation requires less driving shear stress than an accommodation of the imposed shear by shear-parallel faulting. The operation of cross faults between neighboring Riedel faults in a wrench zone is a typical example.

Large-scale rotation of parallel normal faults in domino style (tilted block tectonics) is primarily associated with the extension of ductile substrata. It may be inferred from mechanical arguments and sandbox experiments how the process, and in particular the dip direction of the faults, is controlled by the way the substratal extension progresses, by the direction of a substratal squeeze flow, by the presence of a surface slope, and by the configuration of the rock boundaries that confine the set of faults in the direction of extension.

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Late Mississippian Lime Mud Mounds, Pitkin Formation, Northern Arkansas

Carbonates deposited under shallow, open shelf conditions during the Late Mississippian in northern Arkansas exhibit numerous discrete to coalescing lime mud mounds up to 20 m (65 ft) high and tens of meters in diameter. The mounds are composed of a carbonate mud core, typically with fenestrate texture, entrapped by a loosely organized framework dominated by cystoporate bryozoans and rugose corals in the lower part, and by blue-green algae and cryptostomous bryozoans in the upper part. Disarticulated crinozoan detritus is common throughout the core, suggesting that these organisms also contributed to entrapment of lime mud. During deposition, the mud core was indurated enough to support and preserve vertical burrows. Also, rubble of core mudstone is found on the flanks of some mounds, suggesting some erosion.

Intermound lithology is a shoaling-upward sequence dominated by oolitic and bioclastic grainstones and packstones. Shale is also present in minor amounts. The Pitkin mounds, interbedded with these intermound sequences, developed contemporaneously with them. Depositional relief was probably less than 3 m (10 ft). The mounds expanded laterally during periods of quieter water; their growth was impeded during times of higher energy. Contacts of the mound and intermound lithologic characteristics are sharp, truncating surfaces. Mound deposition ended with the onset of high energy conditions throughout the region.

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Cenozoic Basin Development in Hispaniola

Four distinct generations of Cenozoic basins have developed in Hispaniola (Haiti and Dominican Republic) as a result of collisional or strike-slip interactions between the North America and Caribbean plates. First generation basins formed when the north-facing Hispaniola arc collided with the Bahama platform in the middle Eocene; because of large post-Eocene vertical movements, these basins are preserved locally in widely separated areas but contain several kilometers of arc and ophiolite-derived clastic marine sediments, probably deposited in thrust-loaded, flexure-type basins. Second generation basins, of which only one is exposed at the surface, formed during west-northwesterly strike-slip displacement of southern Cuba and northern Hispaniola relative to central Hispaniola during the middle to late Oligocene; deposition occurred along a 5-km (3-mi) wide fault-angle depression and consisted of about 2 km (1 mi) of submarine fan deposits. Third generation basins developed during post-Oligocene convergent strike-slip displacement across a restraining bend formed in central Hispaniola; the southern 2 basins are fairly symmetrical, thrust-bounded ramp valleys, and the third is an asymmetrical fault-angle basin. Fourth generation basins are pull-aparts formed during post-Miocene divergent strike-slip motion along a fault zone across southern Hispaniola. As in other Caribbean areas, good source rocks are present in all generations of basins, but suitable reservoir rocks are scarce. Proven reservoirs are late Neogene shallow marine and fluvial sandstones in third generation basins.

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Comparison of Basin Types in Active and Ancient Strike-Slip Zones

Hydrocarbon exploration in strike-slip zones requires awareness of several distinct basin types, traditionally defined on the basis of bounding fault geometry: pull-aparts (P), fault-wedge basins (W), fault-angle basins (A), fault-flank basins (F), and ramp valleys (R). We compare the characteristics and frequency of these basin types in an active (40 post-Eocene basins of the northern and southern Caribbean) and ancient (19 Late Devonian-Carboniferous basins of the northern Appalachians) strike-slip setting. Pull-apart basins, which lengthen and deepen at fault discontinuities with increased strike-slip offset, constitute the best studied and most numerous basin type. Other recognizable basin types are less numerous and often shorter lived than pull-aparts, and this may reflect: (1) their role as precursory structures prior to concentration of strike-slip displacement on a single fault; (2) their role as interference structures at random fault junctures; and (3) the unlikelihood of preservation because of thinner sedimentary fill. Several disrupted basins of complex or unknown origin (D) appear to have initiated as pull-aparts and subsequently to have been been offset into halves or modified into compressional ramp valleys. Using observations from active basins, several geologic criteria for distinguishing compressional vs. extensional origin of reactivated ancient basins are discussed.

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Dead Sea Rift: Impact of Tectonics and Climate on Patterns of Sedimentation

The Dead Sea Rift, a classic strike-slip basin, occurs along a transform that connects the Red Sea, where sea-floor spreading is occurring, to the Taurus Mountains, where plate convergence is occurring. The rift formed primarily from left-lateral displacement of about 105 km (65 mi) since the Miocene, producing uplift and normal faulting along its shoulders. Sedimentation within the transform occurs primarily in elongate, asymmetric pull-apart basins such as the Dead Sea, as transform segments pass each other along the zone of strike slip.

Pleistocene and Recent patterns of sedimentation were mapped on a scale of 1:50,000 along the west bank of the Dead Sea for a distance of 50 km (30 mi). Three sedimentologic units are recognized: an older sequence of debris flows and shallow-water fans; a medial unit of fan deltas interfingering with shallow-to-moderately deep-water lacustrine deposits; and an upper unit comprised of beach gravels, deltaic sands, and playa deposits. Their combined thickness is about 3,500 m (11,500 ft) along the western border fault, where they exhibit repetitive small-scale cyclical patterns of deposition within a general fan delta complex that prograded into the Dead Sea; there, geophysical studies show that the prograding subsea fans have been intruded by salt diapirs.

Such patterns of deposition clearly are related to recurrent movement along the border faults, producing rhomb-shaped basins, high-relief topography, and a unique rift climate. As the moist air rises over the shoulders of the rift, it cools adiabatically yielding as much as 800-1,000 mm (31-39 in.) of rain per year to high discharge ephemeral streams that transport huge quantities of coarse clastics into the basin. Conversely, as the air descends into the basin, it warms adiabatically, evaporating more than 2,000 mm (80 in.) of water per year, thus causing a concomitant drop in the Dead Sea level, precipitation of evaporites, change in the base level, and progradation of fans into deeper water.

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Computer Modeling of Minnelusa (Pennsylvanian-Permian) Paleotopography in Eastern Powder River Basin, Wyoming, with a Case History

Most Minnelusa Formation (Pennsylvanian-Permian) oil production in the Powder River basin is from paleotopographic traps. These traps