Geologists and geophysicists have made little effort to purposefully search for the subtle traps—stratigraphic, unconformity, or paleogeomorhic—because of (1) motivation to continue looking for structures which can be found with present-day tools and ideas, and (2) the pressure exerted on explorationists by their knowledge that anticlines, domes, and fault structures are more acceptable to management. As a result, our domestic exploratory successes during the past decades have been declining not only in number of fields found annually, but also in the quality or economic worth of the fields.

Hidden trends may occur below unconformities, at undrilled depths in productive trends, and in relatively unexplored regions. Hidden features may be ancestral anticlines and domes, faults, stratigraphic traps, and buried geomorphic features. The difference between these hidden features and the obvious type is that the former are not obvious to present-day exploratory methods and thinking. Many of these probably can now be found, but only if we point our methods and thinking toward them, not around them.

Domestic explorationists must make a turn in the direction of purposefully looking for the obscure trap. The large domestic reserves required for the future are contained in hidden trends and features. If we are to succeed in finding them, geologists and geophysicists, and, equally, management, will have to place greater emphasis on the deliberate search for the subtle trap. In this search, emphasis must be placed on detailed study and research in stratigraphy, paleogeomorphology, paleogeography, paleostructure, paleontology, and palynology.

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Burial Cement in Sunniland Reservoirs, Lower Cretaceous of Southern Florida

Loss of porosity in the Sunniland Limestone is the result of processes associated with burial of the formation to its present depth of about 3,400 m. Early diagenetic alteration was a relatively minor factor in porosity loss. Significant processes which reduced porosity are mechanical compaction (dewatering, grain fracture, and deformation), chemical compaction (stylolitization, both on a macro and micro scale, and interpenetration of grains along contacts), and burial cementation. Burial cements, the product of chemical compaction and calcite solution transfer, are most evident in grainstones, including Sunniland reservoir rocks.

Three petrographically distinct burial cements are recognized as: (1) scalenohedral or dogtooth calcite, of grain size generally less than 100 μm, filling primary porosity and fractured by burial pressure; (2) equant or blocky calcite, of grain size generally larger than 100 μm, filling primary, secondary, and fracture porosity, and commonly poikilotopic; and (3) equant or baroque dolomite, of grain size generally larger than 100 μm, filling primary, secondary, and fracture porosity, occasionally poikilotopic, with larger grains exhibiting undulatory extinction and curved crystal faces.

These cements account for as much as 30 to 40% porosity loss in some grainstones and are present to a lesser extent in most reservoir rocks.

Isotopic analyses of cements ($\delta^{18}O$, $\delta^{13}C$) and water ($\delta^{18}O$) are consistent with an interpretation that these cements formed in the subsurface over a range of temperatures (about 40 to 100°C) in pore water that was continually modified by dissolving Suniland calcite. Quantification of these processes requires accurate predictions of the rate of calcite solution transfer. Estimates of this parameter suggest that very little cement is precipitating now and that most cementation was complete before the Oligocene (burial depth about 3,000 m).

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Facies Anatomy of Modern Continental Sabkha, Bristol Dry Lake, California

Bristol Dry Lake is a 155-sq km fluvial-lacustrine dominated, continental sabkha, or playa, in the Mojave Desert of southeastern California, and is filled with at least 300 m of interbedded terrigenous clastics, gypsum, anhydrite, and halite. The evaporite facies roughly form a bull's-eye pattern with abundnat gypsum and anhydrite surrounding a basin center accumulation of halite. Transects through Bristol Dry Lake, from the alluvial fan and sand flat to the center of the playa, reveal (1) crudely bedded, coarse-grained clastics prograding over and interfingering with either (2) wadi (alluvial/eolian) sand and silt, or (3) mud-flat facies of nodular to enterolithic gypsum or anhydrite and blades of gypsum in red-brown silt and clay, followed by (4) saline mud-flat facies of red-brown silt and clay crowded with giant (15 cm diameter), displacive, hopper-shaped crystals of halite, and (5) salt-pan beds of chaotic mud-halite up to 4 m thick in the center of the playa.

Deposition of terrigenous clastics was by fluvial-sheetflood processes around the toes of alluvial fans, fluvial flow through very shallow rills and suspension settling in the mud-flat environments. Much of the sediment is reworked by eolian processes. Evaporites are precipitated at or just below the sabkha surface from discharging brines.

Lithofacies of this modern continental sabkha are nearly identical to those comprising the Middle-Upper Permian evaporites of the Texas and Oklahoma panhandles, and they are excellent process analogs for ancient facies analysis.

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Control of Early Carbonate Diagenesis by Carbon Dioxide Production and Loss

The early diagenesis of recent marine carbonate sediments is pervasive and rapid in coastal ground-water systems characterized by the dynamic influx and mixing of meteoric and marine waters. In coastal areas subjected to high and continuous seaward fluxes of meteoric water, such as the eastern coast of Yucatan, extensive dissolution and removal of carbonate result simply from the physical mixing of meteoric and marine waters. However, comparative studies of coastal phreatic systems on St. Croix, Bermuda, and Jamaica demonstrate that where there is a marked seasonal variation in the influx of meteoric waters, carbonate dissolution and precipitation become progressively controlled by the in-situ production and loss of CO_2. In seasonally variable systems, rates of CO_2 production are controlled primarily by the availability of oxygen and the abundance and type of organic water episodically introduced into the pore waters and sediment. Rates of CO_2 loss are controlled by the dissolution of carbonate and by vertical mass transport resulting from the spatially and temporally variable processes of diffusion, dispersion, and hydraulic pumping.

A quantitative mass transport model has been developed to evaluate the diagenetic response of a vertical, magnesian calcite-aragonite sand sequence to temporal variations in rates of CO_2 production and loss. The model can be used to help predict the spatial distribution of zones of dissolution and cementation is various coastal marine carbonate sediments.

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Lateral Seals of Small Stratigraphic Traps in Cretaceous Rocks, Western Nebraska

The lateral seals of straigraphic traps located on monoclines offer some interesting perspectives on problems of hydrocarbon entrapment. On the eastern flank of the Denver basin, oil reservoirs in Cretaceous valley-fill sandstone bodies afford a particularly instructive example. There the updip seal is provided by sandy, silty, and clayey marine facies into which were cut the slightly younger valleys. A subsequent marine transgression covered the entire sequence with clay shale, providing a top seal.

The lateral seal can be visualized as a maze of pipes and capillaries through which the oil phase finds its way, until blocked at each potential escape route by entry pressures that exceed that generated by the buoyancy of the oil column. Cores of the sealing facies show that burrowed silty sandstone is a small-scale maze, where silty laminae shortly block oil invasion. Wave-rippled shallow-shelf sandstone beds offer more continuous conduits, but are lenticular on a scale of a few hundred meters and are separated by shale beds that ultimately baffle oil escape. Cross-stratified shoreline sandstone is also a sealing facies by diagenetic kaolin; stained sets of cross-laminae are enclosed in unstained rock, a testimony to slightly different capillary pressure characteristics.

Careful examination of cores of rock facies can give vital information on the geometric nature of a seal; on how to convert laboratory measurements of capillary pressure using mercury and air to natural oil-brine systems; on critical oil saturation levels that distinguish seal and non-seal rocks; and on the height of hydrocarbon column than may be trapped by a seal.

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Upper Jurassic Evaporites and Carbonates of Gulf Coast

Shallow-water carbonate rocks of the Upper Jurassic Smackover Formation contain some of the most promising exploration targets of the Gulf Coast. Evaporites of the Louann, the Buckner, and within the Smackover have been important factors in forming the reservoirs.

The Louann, a thick salt lying stratigraphically below the Smackover, localized production and influenced facies patterns and diagenesis. The updip limit of the Louann coincides with peripheral basin faults, so fault traps in the Smackover arr to some degree related to salt movement. Salt flowage created highs on the sea floor that localized high-energy oolite bars and, in some places, reef development. Some Smackover porosity was created secondarily during early freshwater diagenesis in association with the highs. Late-stage burial diagenesis in the Smackover, which is also important in forming reservoir porosity, may have been caused by interstitial fluids that were expelled from the Louann during salt compaction.

Anhydrite occurs in the Buckner and Smackover in several forms: (1) nodules, (2) microcrystalline replacement, (3) laminations of blocky crystals, (4) poikilitic cement, (5) poikilitic replacement, (6) fracture fill of blocky or lath-shaped crystals, (7) lath-shaped replacement crystals, and (8) plugging of oomoldic porosity. The Buckner anhydrites and shales are important seals for Smackover reservoirs. Commonly the Buckner interfingers with the reservoir at the updip limit of a field and as a result of basinward progradation forms an impermeable cap. The Buckner may have influenced early diagenesis of the uppermost Smackover by introducing brines into the lime sands. Thickness maps of the Buckner serve as a valuable exploration tool for the Smackover, because porous facies are associated with Smackover highs underlying the Buckner thins. Anhydrite within Smackover grainstones can locally reduce porosity to form internal seals. The presence of minor amounts of anhydrite in Smackover carbonate rocks can confuse log interpretations on neutron and density log crossplots by causing overestimates of the dolomite percentage and underestimating of porosity.

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Subaerial Exposure Surfaces: Variations on a Theme

Carbonate sediments are commonly subjected to subaerial exposure and surficial alteration relatively early in their history through real or relative changes in sea level. The resultant diagenetic overprint may be superficial or pervasive, subtle or profound, depending upon the interplay between a number of controlling variables. It is particularly important to realize that, to a first approximation, the nature and extent of near-surface subaerial diagenesis is not exclusively a time-dependent function, but rather commonly reflects the prevailing subaerial (climatic) regime. Because of this, the course of such diagenetic modification is highly variable.

Studies on Pleistocene deposits from localities such as Barbados and Florida demonstrate a tremendous range in exposure-surface fabric. These fabrics encompass lithified but otherwise little-altered horizons, thin but texturally variable calcrete crusts, thick complex caliche profiles, in-situ psuedo-breccias, and solution karst with pits and channels of high relief. It is common to find sharply contrasting fabrics developed in close proximity on the same exposure surface.

To recognize such breaks in outcrop or core, it is necessary to maintain a critical appreciation that variability is the rule rather than the exception. There is no question about the importance of such breaks, for they serve as major time-stratigraphic datums, provide insight into basin history, and may either locally enhance porosity or act as substantial vertical permeability barriers, commonly within stratigraphic sequences that otherwise appear to be lithologically uniform.

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Geologic Studies of Steam Drives Pay Off in Kern River Field, California

The Kern River field in California currently produces over 100,000 bbl of heavy crude oil per day from several steam-drive projects. Conservatively, recoverable reserves of 600 million bbl remain as the prize of enhanced oil recovery techniques. Operating costs for steam-drive projects are high because for every three barrels of crude produced, one barrel is burned to generate the steam. To effectively operate such projects, geologic conditions of the reservoir must be thoroughly understood. Close coordination between the geologist and the engineer is needed to evaluate and follow steam-drive performance on a pattern-by-pattern basis. Detailed cross sections and isopach maps of the reservoir sands and their overlying