Caprock seal capacity is a function of pore size, rock integrity, regional continuity, and thickness. Calculations of the oil or gas the pore system of a rock can seal can be made by Smith's 1966 formula:

$$H = \frac{PdB - PdR}{(pw\text{-}ph) \times 0.433}$$

Data necessary to make these calculations are: pore size, oil and water density, oil-water interfacial tension, and wettability.

Rock integrity, or lack of open fractures, controls whether or not the pore system of the rock will be dominant in controlling seal capacity or of minor importance. Rock integrity is a function of mechanical properties, structural stress and fluid pressures in the subsurface. Mechanical properties can be measured in the laboratory and qualitatively used to estimate rock integrity when incorporated with subsurface stress conditions.

Samples from seals for 27 reservoirs were collected and analyzed for detailed lithology, pore size, and rock mechanical properties. On the basis of this sampling, all major rock types can act as local caprock seals for hydrocarbons. Evaporites and ductile clay shales are the most likely rock types to act as regional caprock seals because of their small pore size and ductile mechanical properties. Limestones, dolomites, siltstones, and sandstones can act as local caprock seals based on this sampling.

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Prediction of Lateral Seal Capacity from Core Data

Mystery Reef field produces oil from a porous stromatoporoid, limestone reef buildup. Only a small part of the total reef porosity is filled with oil. The maximum oil column in the field is 120 ft (37 m). The upper half of the column is sealed by marine shales that filled in depositional topography. The lower half of the oil column is sealed by the reservoir-equivalent fore-reef facies.

Lateral seal capacity, in terms of vertical oil column, were calculated from capillary pressure curves for five wells updip from the field. The seal capacity for the lowest displacement pressure rock in each well ranged from 10 to 150 ft (3 to 46 m). This spread of values for the updip reservoir equivalent facies at Mystery Reef field suggests that the prediction of lateral seals from core samples can provide only a very rough approximation of seal capacity in heterogenous carbonate rocks.

Two of the five wells studied updip from the field were oil stained in the reservoir equivalent horizon. Calculations of the minimum oil column necessary to explain the oil shows in these rocks range from 10 to 84 ft (3 to 26 m). Seal capacity of the higher displacement pressure oil stained rocks ranges from 60 to 84 ft (18 to 26 m). These values are similar to the oil column known to be trapped by the sampled fore-reef facies. Estimates of lateral seal capacity from core data should put the greatest emphasis on the oil stained samples with the highest seal capacity.

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Core and Log Analysis for Subtle Trap: Cotton Valley Tight Gas Sand

Several Cotton Valley zones that appear wet from standard log calculations have proven to be gas productive in recent months. In an attempt to understand this phenomenon, a case study was performed in conjunction with Champlin Petroleum Co. on cores from the Carthage field, east Texas. The zone studied was of low resistivity (less than 2Ωm) which, when combined with porosity (16%), calculates very high water saturation (>60%) using the standard Archie equation and $m = n = 2$.

Geologic studies indicate the low resistivity zone was deposited as a middle to upper bar sequence exhibiting massive and laminated bedding while a normal resistivity zone (~8Ωm) immediately below exhibits both a dense characterless section and a lower bioturbated facies with marine trace fossils.

Examination of the pore system using an SEM shows authigenic illite (identified by XRD) lining the pores and pore throats in both zones. Authigenic clay precipitation was subsequent to the development of quartz overgrowths and prevented complete occlusion of the pore system by the quartz. Secondary intergranular porosity is developed where feldspar grains have undergone dissolution.

The total porosity of the low resistivity interval (16%) is twice that of the normal resistivity zone (8%). Permeability is low throughout the interval (< 20 md), but somewhat higher in the low resistivity zone. Cation exchange and surface area measurements indicate that the authigenic clay is of equal volume in each zone. However, electrical measurements suggest greater rock conductivity and lower m and n Archie parameters in the low resistivity zone. The petrophysical and geologic data collected on the Cotton Valley provided more realistic petrophysical parameters for water saturation calculations, and led to a better understanding of the pore network and origin of the low resistivity interval.

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Evaporitive Limestone: Its Generation and Diagenesis

The Calcare-di-base is the only significant carbonate facies of the upper Miocene evaporites of Sicily. It was deposited within an exceedingly saline but marine water body adjacent to older, exposed carbonate terranes which surround the depositional basin. This somewhat dolomitic limestone is commonly cavernous or brecciated at outcrop and contains numerous zones of evident halite dissolution. It also interfingers with thin gypsum stringers in many areas and overlies diatomites of variable thickness. Based on petrographic and isotopic studies, it appears that this limestone was produced by diagenetic processes from an origininal aragonitic mud containing displacive halite hoppers and massive halite zones. Regional variation in carbon-13 (δC^{13} from 0 to 49 ppt PDB) and oxygen-18 (δO^{18} from +6 to −5 ppt PDB) can be tied to variations in the mineral content of the original sediment and to later diagenetic waters and their organic content. The very negative carbon-13 values and the presence of native sulfur are indicative of the calcitization of gypsum, the by-product of the life processes of sulfate-reducing bacteria. These bacteria utilize part of the available and commonly copious organic matter associated with both the carbonate and with the diatomite. Inversion of the original aragonite to calcite has resulted in expulsion of strontium from the carbonate crystal lattice and the formation of celestite ($SrSO_4$) which now fills the voids left by the dissolution of halite, and the associated pore spaces.

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Geology and Diagenesis of Belridge Diatomite and Brown Shale, San Joaquin Valley, California

The late Miocene to Pliocene argillaceous and siliceous shales of the upper Monterey Formation (the Brown Shale and overlying Belridge Diatomite) represent laterally continuous deposits of nearshore, diatom-rich muds and open marine, argillaceous, diatom-bearing muds on a developing shelf and growing anticline which flanked the San Joaquin basin. These units are laterally equivalent to submarine fan and turbidite sedimentary rocks deposited into the basin from the west, south, and east.

The lithology of the Brown Shale and Belridge Diatomite is controlled by original composition and subsequent burial diagenesis. The muds underwent diagenetic alteration with the development of silica phases in the sequence: (1) unaltered diatom frustules (biogenic amorphous silica or opal-A); (2) diagenetic amorphous silica (opal-A); and (3) diagenetic crystalline silica (opal-CT). In the oil field, the Belridge Diatomite grades downward from a massive or faintly laminated siliceous mudstone with diatom frustules and opal-A', to a laminated and massive siliceous mudstone with opal-A' and some well-preserved diatoms. The Brown Shale grades from a massive or laminated siliceous mudstone with opal-A' and some diatoms to a well-laminated argillaceous, diatom-bearing mudstone with opal-A' and some opal-CT. There is no distinct break in lithology between the Belridge Diatomite and Brown Shale reservoirs, but recrystallization and detrital clay increase downward across the boundary.

Porosity in the best diatomite is about 62%, and permeability is about 1 md.

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Lower Pleistocene Quiet-Water Lacustrine Ooliths from Koobi Fora Tuff, East Lake Turkana, North Kenya

Complex, asymmetric ooliths occur within a thin (5 to 50 cm) carbonate deposit exposed along the northeastern margin of Lake Turkana, an alkaline lake located south of the Kenya-Ethiopia border. The limestone is part of a lower Pleistocene sequence of tuffaceous lake margin sediments (the Koobi Fora tuff) and outcrops over an area of 45 sq km. It is the only laterally extensive, oolitic unit within the 300-m section of Pliocene-Holocene lacustrine and fluvial sediments in the basin. Structurally, the limestone consists of multiple, well-cemented layers, the tops of which in some places exhibit desiccation cracks. Texturally, it ranges from oosparite to biosparite. The unit is composed predominantly of complex ooliths (2 to 80%), biogenic grains (0 to 10%), micritic, low-Mg calcite cement (0 to 15%), and blocky/sparry low-Mg calcite cements (15 to 90%). The ooliths average 0.8 mm in diameter and consist of nuclei that are unevenly coated by as many as 15 incomplete, overlapping, fan-shaped rims of radial-fibrous, low-Mg calcite. Both texture and mineralogy appear to be primary. Within a single oolith, every "fan" shows an orientation of fibrous crystals which is unique with respect to adjacent "fans." Each fan-like lamina thus represents a different episode of calcite accretion.

The ooliths formed on a coastal plain inundated by proto-Lake Turkana during a relatively high stand of lake level. Calcite precipitated only on the up-sides of stationary nuclei, however grains remained at the sediment surface long enough to be moved repeatedly by high energy waves and acquire composite cortices. The occurrence of asymmetric ooids indicates that agitation may play a minor role in oolitic deposition. In quiet water settings, nuclei availability, presence and concentration of organic matter and/or microorganism activity may be the major factors controlling ooid growth and morphology.

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Biostratigraphy of Discocyclinid-Bearing Beds, Eocene Llajas Formation, Southwestern Santa Susana Mountains, California

Tests of the discocyclinid foraminifer *Pseudophragmina clarki* occur in several 50-cm thick beds that are widely dispersed within alternating laminated and bioturbated sandstone of the Llajas Formation. At the 575-m thick type section, this sandstone makes up the interval from 100 to 370 m above the base of the formation.

Most of the beds consist of laminated to bioturbated, calcareous, very fine to fine quartzarenite; many are channel deposits, within which tests are concentrated in small pods. *Turritella andersoni lawsoni* may or may not occur with the discocyclinids, but if present it is the only megafossil. Associated foraminifers, listed in decreasing abundance, include *Robulus, Nodosaria, Cibicides, Operculina, Asterigerina,* and *Quinqueloculina.* Most of the genera are extant and are found today in tropical to subtropical shallow marine waters.

The fragile tests of *Pseudophragmina clarki* are mostly complete, unabraded, and 1.5 to 7 mm in diameter. Associated fossils also show no obvious signs of abrasion but they must have been transported because they occur in what are interpreted to be channels. Absence of significant abrasion and fragmentation is suggestive of minimal transport. *P. clarki* and associated fossils, therefore, constitute transported assemblages which are in the same environment in which they lived. The paleontologic evidence of a shallow marine environment is in keeping with the presence of the fossil beds within alternating laminated and bioturbated sequences. Modern examples of such sequences are found predominantly in inner shelf environments.

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Mesozoic and Cenozoic Base Maps

Sixteen maps are presented illustrating the relative positions of the continents from the Early Triassic to the Recent. The spreading history of the Atlantic and Indian Oceans is based on the plate tectonic models of Sclater et al; Norton and Sclater; and Phillips and Tapscott. The age of the oceanfloor has been plotted using Sclater's data-base of worldwide linear magnetic anomalies.

Mesozoic and Cenozoic paleomagnetic data were compiled and selected for reliability. Pole positions obtained from samples that were insufficiently demagnetized, that were from unstable tectonic areas, or that did not exhibit a primary remanence, were rejected. A global apparent polar wander path (African coordinates) was constructed using these selected paleomagnetic determinations. The position of the magnetic pole for each plate tectonic reassembly was estimated by interpolating along this polar wander path.

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