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Lineament Analysis for Oil and Gas Exploration and Production in Wyoming

Lineament analysis from satellite and aerial photos is being used successfully in exploration for anticlinal oil and gas traps and to select drilling locations for maximum porosity in tight formations. Meticulous mapping of lineaments on a series of overlays by a specially trained team of interpreters commonly reveals complex, conjugate nets of lineaments. Many of the lineaments are interpreted as strike-slip faults and shears on which relative movement can usually be ascertained by the direction in which cross faults are dragged. A lineament pattern resulting from drag is the Nu pattern which resembles the lower case Greek letter ν. Overlapping Nu patterns are characteristic of anticlines. As a refinement to models relating anticlines to intersections of synthetic and antithetic wrench faults, a model containing the Nu pattern indicates the trend and location of the anticline better than existing models. Correlation of Nu patterns with faults in known oil fields indicates that cross-lineaments at tips of Nu patterns tend to be normal faults. Lineament analysis was used to delineate the Overland Dome oil and gas field, Carbon County, Wyoming, and to select each well site. To date, each of the 10 wells drilled into the Niobrara Formation (drilled 1 to 2 mi or 1.6 to 3.2 km apart to outline the 7 mi or 11.3 km long field) has tested at 150 to over 600 bbl of oil per day in contrast to numerous dry holes within the field which were not located by lineament analysis.

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Petroleum Occurrences in Nonmarine Rocks

For many years petroleum was assumed to be largely of marine origin. However, it is now clear that significant amounts of petroleum of nonmarine origin are present in the Rocky Mountains, Europe, Africa, China, and elsewhere.

Petroleum in the Green River Formation (Eocene) is indigenous to continental beds, whose lacustrine facies were largely responsible for their formation. Green River source rocks were deposited in fresh to brackish water environments in stratified lakes. Large amounts of organic material accumulated over widespread areas in stable, reducing, low-energy settings. Migration distances from source beds to reservoir beds were small. Similar types of nonmarine marginal basins occur in west Africa.

In the southern San Juan basin, oil is trapped in eolian beds of the Entrada Sandstone (Jurassic). Overlying lacustrine limestone and anhydrite of the Jurassic Todilto Formation provide a seal. Oil was formed within the Todilto and migrated into the Entrada.

Eolian sandstone beds commonly are good reservoir beds in other situations. In the Overthrust belt of the Rockies, eolian parts of the Nugget Sandstone (Jurassic) contain large amounts of petroleum that migrated into the sandstone from marine Cretaceous sources. The best reservoirs in the Permian Rotliegendes of the southern North Sea consist of eolian dune sandstone. Exceptional porosities of 30% are found in some intervals that produce gas.

Gas has formed in several early Tertiary fluvial beds of the Rocky Mountain area and migrated short distances into fluvial sandstone reservoirs. Fluvial sandstone sequences also contain oil generated in nonmarine source beds.

The examples of petroleum occurrences in nonmarine rocks given in this program may serve to reawaken the interest of petroleum geologists. Certainly, the petroleum potential of nonmarine beds is large.

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Seismic Modeling of Pennsylvanian Carbonate Mounds in Paradox Basin, Utah

The Aneth oil field in southeastern Utah produces from a Pennsylvanian carbonate mound which forms one of the largest stratigraphic oil traps in the United States. Efforts in the past 20 years to locate this and other carbonate mounds using reflection seismology have been spectacularly unsuccessful in this area.

From very detailed isopach and structural maps made from well control, it was found that these carbonate mounds are characterized by an extremely abrupt thickening of the producing zone and a thinning of the overlying shale. Also, contrary to normal stratigraphic traps, the productive zone is actually less porous than off-mound non-productive carbonate rocks. To determine if these thickness changes would be detectable seismically, one- or two-dimensional seismic models were generated using wavelets of varying frequency content and phase. It was determined from these models that thickness changes which characterize carbonate mounds would be detectable by a decrease in amplitude of reflections from overlying shale owing to the tuning effect. However, this decrease in reflection amplitude was only found for zero-phase wavelets having a bandwidth of 10 to 70 Hz or more.

The significance of these results is that by using seismic amplitudes, we are able to determine the thickness of the shale bed even if the bed is less than 10 ft thick and surrounded immediately above and below by other thin shale beds. Since many, if not most, stratigraphic traps involve changes in bed thickness, these results suggest that with seismic modeling, zero-phase processing, and high resolution techniques many stratigraphic traps could be located with a higher degree of accuracy.

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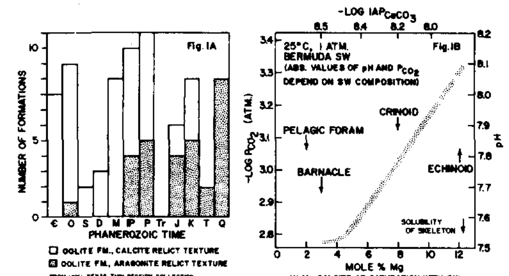
Phanerozoic Carbonate Diagenesis—A New Model

Observations from petrography, paleontology, and geochemistry indicate the varied carbonate mineralogy of Holocene sediments may not be representative of pre-Carboniferous rocks.

Petrographic examination of Phanerozoic oolites reveals that ooids with calcitic relict textures are characteristic of pre-Carboniferous carbonate rocks, whereas ooids with aragonitic relict textures are dominant in younger rocks. Marine invertebrates that secreted magnesian calcite or aragonite hard parts characterize post-Permian fossil assemblages, whereas calcitic forms decline or become extinct. These observations imply a post-Carboniferous change in the chemistry of the earth's surface environment.

To determine the relative importance of factors controlling magnesian calcite solubilities in seawater, saturometry experiments were performed. It is important to recognize from these experiments that the composition of a magnesian calcite precipitating at saturation from seawater can be treated as a function of atmospheric CO_2 pressure, at an essentially constant seawater Mg/Ca ratio. Thus, observed trends in the textures of ooids and their interpreted mineralogy through the Phanerozoic may be due to changes in atmospheric CO_2 levels, not necessarily to a major change in the Mg/Ca ratio of seawater. It is possible that pre-Carboniferous CO_2 levels were high favoring precipitation of calcitic ooids and skeletal parts; after the Carboniferous, CO_2 levels fell and aragonite and high magnesian calcites increased in abundance as precipitates.

Diagenetic implications of the time variance in CO_2 pressure are many. Diagenetic patterns based on Holocene models may not be valid for the Paleozoic; solution-reprecipitation and inversion would be less common than recrystallization prior to the Carboniferous. Reservoir targets of intraparticle porosity in relict aragonite oolitic sands would be less important in pre-Carboniferous rocks. Higher atmospheric CO_2 pressure favors dolomite formation. Finally, the CO_2 content of an environment rather than the Mg/Ca ratio may be the important parameter to consider in many carbonate diagenesis studies.



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Differential Diffusion During Carbonate Diagenesis

Most of the movement of ions during carbonate diagenesis occurs in aqueous pore systems in which the average diameter is too small to permit mass transfer by fluid flow. In such situations, ionic motion proceeds instead by aqueous diffusion. In pore systems of sufficient diameter, ion transport occurs by fluid flow. Water occupies both habitats in typical carbonate sediments. Sediment-water interactions occur predominantly in the diffusion-controlled system, and flushing of the sediments is achieved in the flow-controlled (aquifer) system.

Three parameters control the diffusion of cations from diagenetic sites to the aquifer (or vice versa): (1) the concentration difference between diagenetic site and aquifer; (2) the diffusion coefficient for the particular cation under ambient conditions; and (3) the length and geometry of the pore path to be traversed. Under the conditions typical of carbonate diagenesis, concentration difference is the dominant variable and pore path plays a secondary role. Concentration differences between diagenetic site and aquifer may be positive or negative; the sign determines the direction of diffusion and the absolute magnitude determines the efficiency of diffusion. At a given moment, cations of different species may travel in different directions and at different rates; hence the concept of differential diffusion. Unlike fluid flow, cation transfer by diffusion is not limited to a single direction and a single velocity. A diagenetic site may thus be relatively open to one cation yet, at the same moment, relatively closed to another. The trace element composition of a limestone is not a simple function of either the aquifer solution or the diagenetic solution, rather it reflects the complex diffusion interaction between the two.

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Diagenetic Mobilization of Uranium and Iron from Red Beds of Catskill Formation in Eastern Pennsylvania

The content of uranium, thorium, lanthanum, and major elements in 272 samples of clastic sedimentary rock from red beds of the Devonian Catskill Formation in eastern Pennsylvania varies with grain size and color (oxidation state). The samples were derived largely from fining-upward cycles in which sandstones, commonly gray to green, were deposited as channel fillings, while overlying shales, commonly red, were deposited as overbank muds. The contents of iron, aluminum, uranium, thorium, titanium, and lanthanum correlate negatively with grain size. Gray to green (reduced) shales and fine-grained sandstones have distinctly lower iron and higher uranium and uranium/thorium content than red (oxidized) sandstones and shales of the same grain size and the same aluminum content. The differences are greatest in shales. Thorium content does not vary with oxidation state.

The levels of uranium, thorium, and iron in green shales are inferred to be approximately the amounts present in the original detritus. Gray sandstones have apparently lost iron and may have locally gained uranium probably by flow of reducing pore waters through the buried channels during early diagenesis. Red muds apparently lost uranium just after deposition because of strong oxidation and at least limited permeation by surface waters. The uranium lost from the red muds furnishes a probable source for uranium in roll-type uranium deposits found in sandstones in the area near Jim Thorpe, Pennsylvania. Recrystallization of amorphous iron oxides to hematite may have promoted the release of adsorbed uranium from the muds.