instructive in predicting the behavior of fluid movement during burial diagenesis/metamorphism of pelitic sediments.

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Oxygen Isotopic Studies of Diagenetic Clay Minerals: Implications for Geothermometry, Diagenetic Reaction Mechanisms, and Fluid Migration

Oxygen isotope ratios of diagenetically formed minerals in shales and sandstones can provide information about temperatures of diagenesis, mechanisms of clay mineral reactions, degree of openness of the rocks to the movement of water during diagenesis, and sources of water involved in reactions.

The isotopic approach has proven especially effective in studying the shales of the United States Gulf Coast in which the predominant diagenetic reaction involving clays is the conversion of smectite layers to illite layers in mixed-layer illite/smectite. Clay minerals affected by this reaction appear to undergo oxygen isotope equilibration with the ambient water. A byproduct of the smectite-illite transition is quartz. When the diagenetically formed quartz can be isolated for isotopic analysis, oxygen isotope fractionations between coexisting quartz and clay are indicative of diagenetic temperatures when temperatures are higher than 70 or 80°C. There is some evidence that at temperatures above 180°C clay-size detrital quartz may exchange isotopically with pore fluids and other rock constituents, perhaps permitting the determination of maximum burial temperatures of shales even in the absence of the smectite-illite conversion reaction.

During diagenesis the shales studied approximate closed systems, the isotopic composition of the diagenetic waters being determined largely by isotopic exchange with the rocks. Water lost form the shale sequences during diagenesis apparently moves outward or upward along cracks, passing out of the system without isotopically affecting overlying shales.

Diagenetic minerals in sandstones, like those of shales, reflect temperatures and isotopic compositions of pore waters. While few isotopic studies of minerals from sandstones have been done to date, those by Land and his coworkers indicate that this is a very promising approach for unraveling and understanding complex histories of diagenetically altered sandstones.

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Numerical Model of Shale Compaction, Aquathermal Pressuring, and Hydraulic Fracturing

Clastic sediments, which are fine-grained or clayey, are capable of retaining fluids at pressures considerably greater than hydrostatic. The excess pressures can be induced by any of several mechanisms. A numerical model is developed which considers simultaneously the effects of compaction disequilibrium and aquathermal pressuring. Energy transport by conduction only is used to provide temperature profiles. The pressure and temperature dependency of isobaric thermal expansivity and isothermal compressibility are integrated in the solution. Simulations were conducted for a variety of heat flux, permeability, stratigraphic, and sedimentation conditions.

It is shown that, while compaction disequilibrium itself explains the general pressures in Gulf Coast sections, aquathermal pressuring can lead to fluid pressures greater than lithostatic. Fluid release by hydraulic fracturing must then occur. This combination of processes provides an explanation for the observed variations in shale bulk density, excess pressure, and thermal gradient. A Mohr failure diagram, using a two-part failure envelope combined with horizontal versus vertical stress data provides a means of determining when fracturing is initiated and the orientation of the fractures. A variety of stress conditions that result in both horizontal and vertical fractures are considered. The depth of fracture initiation is highly dependent on the sedimentation rate, the sand versus shale ratio of the sediments, and on the tensile strength and hydraulic conductivity of the shale.

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Importance of Physical Properties of Clays in Oil Formation and Migration

Many source rocks have argillaceous matrixes. Until recently, only chemical interactions between clay minerals and organic matter (catalytic effect) have been given serious consideration. It appears now that the physical or physico-chemical properties of clays also play a key role in the processes of primary migration of oil. Among these properties are (1) microstructure of clays which influences the porosity and permeability in both the water and oil phase, (2) mechanical behavior of clays which may contribute to the microfracturing processes thus allowing the expulsion of oil from source rocks, and (3) physico-chemical properties of adsorption and wettability of clays which act strongly because of the high specific area of clay minerals. This property may influence the permeability of clay shales. In addition, adsorption is selective toward various components generated by organic matter, thus explaining major differences observed between the composition of source rock extracts and reservoir oils.

On a larger scale, such as anticlinal structures, clays are commonly the origin of fluid pressure anomalies. High pressures modify the flow system, since fluids are drained preferably by the tops of structures. The flow of water due to natural convection eventually may cause the alteration of clay minerals and enhance the permeability of the overpressured sections beneath the pressure seal. This process contributes to the modification of geothermal conditions in undercompleted rocks where poor thermal conductivity conditions exist.

These combined effects influence both the nature and spatial distribution of hydrocarbons trapped in reservoirs. Therefore, a better knowledge of the physical properties of clays should lead to a better understanding of the role of clays in the formation and migration of oil and gas and thus lead to better exploration practices.

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Effect of Bulk Composition on Clay Mineralogy: Examples from Jurassic Sandstones of North Sea

It is now common to estimate diagenetic grades of claystones and shales using the composition of interstratified dioctahedral minerals. It is also well known that sandstones commonly have mineralogies which are different from those in associated shales. It has, therefore, been proposed that solution composition of formation waters can play an important role in determining the clay mineralogy of sandstones.

Chemiographic analysis of clay minerals present under conditions of deep burial can be used to determine the key assemblages which will be useful to establish maximum expandability of the mixed layered clays. This then allows one to establish the maximum pressure-temperature conditions of burial experienced by the sediments. This analysis allows one to estimate the effects of composition as well as pressure and temperature.

Several sandstone samples from the North Sea were analyzed using the electron microprobe. This study allows one to establish the compositional range of diagenetic minerals present for a given paragenesis and to estimate the relative influence of local bulk composition upon the new minerals. It appears that small variations in mineral composition can be attributed to local chemistry, but major differences in mineralogy (i.e., mixed layering) are due to differences in pressure-temperature during the recrystallization of the minerals. The extent to which the minerals have recrystallized and the apparent mobility of the constituent elements in both fine- and coarse-grained material indicate that there has been a great approach to mineral chemical equilibrium in the samples studied. This leads one to believe that the phase equilibrium approach to clay mineralogy could be useful in rocks which have experienced burial diagenesis.

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Mechanical Properties of Clays in Fault Zones Under High Pressure Conditions

No abstract.

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