of the whole North Sea basin shows that the mean gradients rarely exceed 40°C/km and are rarely lower than 20°C/km. In broad outline, the gradient pattern seems to reflect the major structural elements. The positive geothermal anomalies are explained in terms of convective heat transport within an actively subsiding basin. Major fault systems serve as conduits for fluid flow. Salt pillows and salt diapirs are centers of hot areas caused by heat conduction. Isothermal maps of key structural horizons and geoisothermal maps are presented to support these interpretations.

The importance of constructing thermograms is emphasized. In the North Sea basin, variations in interval geothermal gradients are explained by a combination of differences in lithology-related conductivity and subsurface fluid flow. Locally, interval gradients twice as high as the mean gradients are observed.

This investigation does not support the idea that geothermal anomalies are uniquely associated with oil or gas accumulations and hence could be used as an exploration tool. Rather, it seems that detailed mapping of geotemperatures can help explain the pattern of subsurface fluid flow of which water (and not hydrocarbons) constitutes the major part.

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Clay Mineral Evidence for Movement of High Temperature Subsurface Fluids

The study of geopressured formations has provided considerable information on the probable pathways for subsurface fluid movement. The fluids have been traced and associated with structure, pressure distribution, salinity of formation waters, various organic and inorganic diagenetic effects, as well as local changes in the geothermal gradient and the temperature of formations. The temperature changes may be measured directly or inferred from the presence of temperature-controlled reaction products such as the modification of illite/smectites.

Clay mineral changes are detected initially at temperatures as low as 50°C and may extend to temperatures in excess of 300°C. The smectite-illite conversion is most pronounced in the range from 50°C to about 160°C. Significant changes in kaolinite and chlorite occur between 75°C and 250°C.

In shales from the Gulf Coast, the smectite-illite conversion is readily recognized, while kaolinite-chlorite reactions are most apparent in associated sands. In several places the development of kaolinite in sandstones is directly linked to the movement of high temperature fluids and the subsequent blocking of secondary porosity. Kaolinite is most abundant in those zones which experienced maximum flushing.

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Temperature Anomalies and Gulf Coast Structures

Temperature anomalies associated with various structures in the Gulf Coast are interpreted to be the result of fluid migrations from depth. Pressure and salinity data are also part of an exploration model where hot, fresh, hydrocarbon-laden waters are believed to be migrating up faults. Traps in the vicinity of these migrations are of special interest to the explorationist because they are more likely to be charged with hydrocarbons.

The part of southeastern Louisiana studied has twelve areas of possible subsurface fluid migrations. Eight hydrocarbon fields are in the vicinity of these migrations. The areas of migration are most likely to occur at areas of structural expansion, i.e., grabens, crests of diapirs, and most importantly, intersections of faults.

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Relations Between Hydraulics, Temperatures, and Crude Oil and Natural Gas Composition in Some Upper Devonian Reefs of Alberta, Canada

The Upper Devonian Woodbend Group and Beaverhill Lake Formation of Alberta contain numerous crude oil and natural gas occurrences pooled in several carbonate reef chains, which are hydraulically distinct with small but subtle differences in present reservoir temperature. Regionally, these hydrocarbon occurrences exhibit typical trends from immature gases in the shallower pools, sometimes associated with biodegraded crude oils, to deeper mature crude oils. Examination of the composition of the natural gases and the broad general characteristics of the crude oils suggests that there is imposed on these typical maturation trends differences in the fluid compositions and reservoir temperatures which are related to the different hydraulic systems and the position of each system within the low fluid-potential drain which essentially channels flow within the thick sequence of highly permeable Upper Devonian and Carboniferous carbonate rocks in the medium-depth part of the Alberta basin.

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Rocks, particularly those formed from clayey sediments, are capable of retaining pore fluids at pressures greater than hydrostatic. Such pressures are frequently encountered while drilling for oil and gas, and consequently the phenomenon of excess fluid pressure has been studied extensively. Anomalous temperature changes with depth have been observed associated with overpressured zones and these anomalies have themselves been the object of considerable thought. However, few studies have attempted to model simultaneously the generation of overpressuring and the associated temperature patterns. Such a model has been constructed, with an equation describing one-dimensional flow through a porous medium at its heart. Through a computer program, this equation describes the vertical movement of fluids and heat through accumulating sediments and the resultant densities, pressures, and temperatures. This program was applied to an accumulating thickness of "mud" and sand approximating a generalized Gulf Coast section. The resultant plots of pore pressure, porosity, and temperature versus depth are similar to those typifying the drilled areas of the Gulf Coast. These characteristic profiles can be viewed as a consequence of the Gulf Coast overpressured environment.

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Estimation of Heat Flow in Oil Wells Based on Relation Between Heat Conductivity and Sound Velocity

Based on published data, it is assumed that the ratio of sound velocity to thermal conductivity exhibits a linear relation with formation temperature for most sedimentary rocks.