Combination of this assumption with Fourier's heat-flow law yields

$$q^* = \ln \frac{T_L + c}{T_u + c} \cdot \frac{1}{A(t_L - t_u)}$$

where T_L and T_u are the subsurface temperatures at the top and the bottom of an interval, respectively, t_L and t_u the sound travel times, and q^* is the heat flow. This relation has been tested in the case of 10 wells, for which accurate data were available. The relation generated satisfactory fits with the measured data for siliciclastic and carbonate rocks. The parameters a and c take respective values of 1.039 and 80.031; heat flow (q^*) is expressed relative to the heat flow in the standard well Bolderij-1 in the Groningen gas field Bolderij Unit (BU).

A method for estimating the relative heat flow from bottom-hole tempeatures as observed during logging operations, and sound-travel times from well-shoot in combination with sonic-log data, has been developed and tested in the Viking and Central grabens of the UK sector of the North Sea. In this region the mean relative heat flow using data from 120 wells is 0.601 BU, with a standard deviation of 0.055 BU.

Comparisons of calculated relative heat-flow values in BU, with heat-flow values in Si-Units conventionally obtained suggests that the Bolderij Unit is equivalent to about 77 mWm^{-2}.

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Geothermal and Hydrocarbon Regimes in Northern Gulf of Mexico Basin

Geotemperature transients and the phenomena of heat flow define the fluid hydrocarbon regime in petroliferous sedimentary basins. The redistribution of heat and the thermo-physical properties of the rocks are mainly determined by the hydrogeology. As the temperature thresholds of smectite dehydration and kerogen diagenesis are passed, endothermic chemical changes convert solid rock mineral matter to fluids, reducing the net volume of mineral solids in each unit volume of rock and thereby increasing its porosity. As this occurs the pore-fluid pressure rises markedly in response to the loss of load-bearing strength in the altered rock. Simultaneously, the aqueous solubility of fluid hydrocarbons is enhanced and the hydraulic permeability of the altered rock is greatly increased. Pore water carrying dissolved hydrocarbons moves through the altered rock and into adjacent aquifers, driven by steep hydraulic gradients. Subsequently, mass movement of water from the geopressure zone to the hydropressure zone migrates the dissolved hydrocarbons to traps, near which a sharp pressure drop causes exsolution.

The threshold temperature of smectite dehydration generally occurs a short distance below the top of the geopressure zone. The 100°C isothermal surface closely approximates the top of the geopressure zone, except where water loss from the geopressure zone is in progress. At depths where temperature exceeds 150°C, petroleum occurrences are rare indeed. The abundance of natural gas, however, in both vapor phase and in aqueous solution, increases with pressure and temperature—and thus with depth—probably as a result of progressive natural cracking of petroleum residues in the rocks with deepening burial.

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Effect of Temperature and Pore Pressure on Velocity and Attenuation of Seismic Waves in Rocks: Applications to Crustal Exploration

Compressional seismic wave velocities have been used with much success in defining structural features likely to serve as hydrocarbon reservoirs. Recent advances in data collection and processing and, as we will describe, a greater understanding of the factors governing wave propagation in rocks indicate much additional information regarding the in-situ temperature, degree of saturation, and pore pressure may be obtained if data are available on seismic attenuation and shear velocity in addition to compressional velocity.

Both velocity and attenuation are strongly temperature dependent. In dry sandstones, velocity increases rapidly with temperature to 100°C then levels off. V_p/V_s increases with tempeature. Shear and extensional attenuations increase rapidly with temperature from a Q of about 90 at room temperature to over 500 at 225°C. Shear attenuation is less than extensional attenuation below 200°C; the opposite is true above 200°C. In rock with a small amount of free water, thermal fracturing of rocks becomes dominant above 170°C decreasing velocities because of the increased porosity and increasing attentuation due to additional surface area in contact with water. In partly saturated rocks at elevated temperatures (200°C) attenuation is high in bulk compression and about half as great in shear. In fully saturated rocks, shear attenuation is high and bulk attenuation is low. Compressional velocity is greater in a fully saturated rock than in a dry or partly saturated rock. Shear velocity is less in a saturated rock than in a dry rock. Velocity and attenuation roughly follow an effective stress law.

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Subsurface Temperatures Calculated by Chemical Geothermometers Applied to Formation Waters from Northern Gulf of Mexico and California Basins

Twelve chemical geothermometers based on the concentrations of silica and proportions of sodium, potassium, calcium, and magnesium in water from hot springs and geothermal wells are used successfully to estimate the subsurface temperatures of the reservoir rocks. These twelve geothermometers together with a new geothermometer based on the concentrations of lithium and sodium were used to estimate the subsurface temperatures of more than 200 formation-water samples from about 40 oil and gas fields in coastal Texas and Louisiana and the Central Valley, California. The samples were obtained from reservoir rocks ranging in depth from less than 1,000 m to about 5,600 m.

Quartz, Na-K-Ca-Mg, and Na-Li geothermometers give concordant subsurface temperatures that are within 10°C of the measured values for reservoir temperatures higher than about 75°C. Na-Li, chalcedony, and a modified Na-K geothermometers give the best results for reservoir temperatures between 40°C to 75°C. Subsurface temperatures higher than about 75°C calculated by chemical geothermometers are at least as reliable as those obtained by conventional methods. Chemical and conventional methods should be used where reliable temperature data are required.

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Geothermal Trends in Petroliferous Regions of Louisiana