Heat flow, geothermal gradient, and the thermal conductivity of sedimentary rocks

Understanding the time and place of maturation of source rocks for petroleum requires an understanding of past geothermal gradients. We of course can't go back in time to measure those geothermal gradients, so we have to estimate them. Attempts to estimate past geothermal gradients commonly involve modeling of the flow of heat through layers of sedimentary rock.

Between the terms heat flow (*Q*), thermal conductivity (*c*), and geothermal gradient (*dT/dz*),
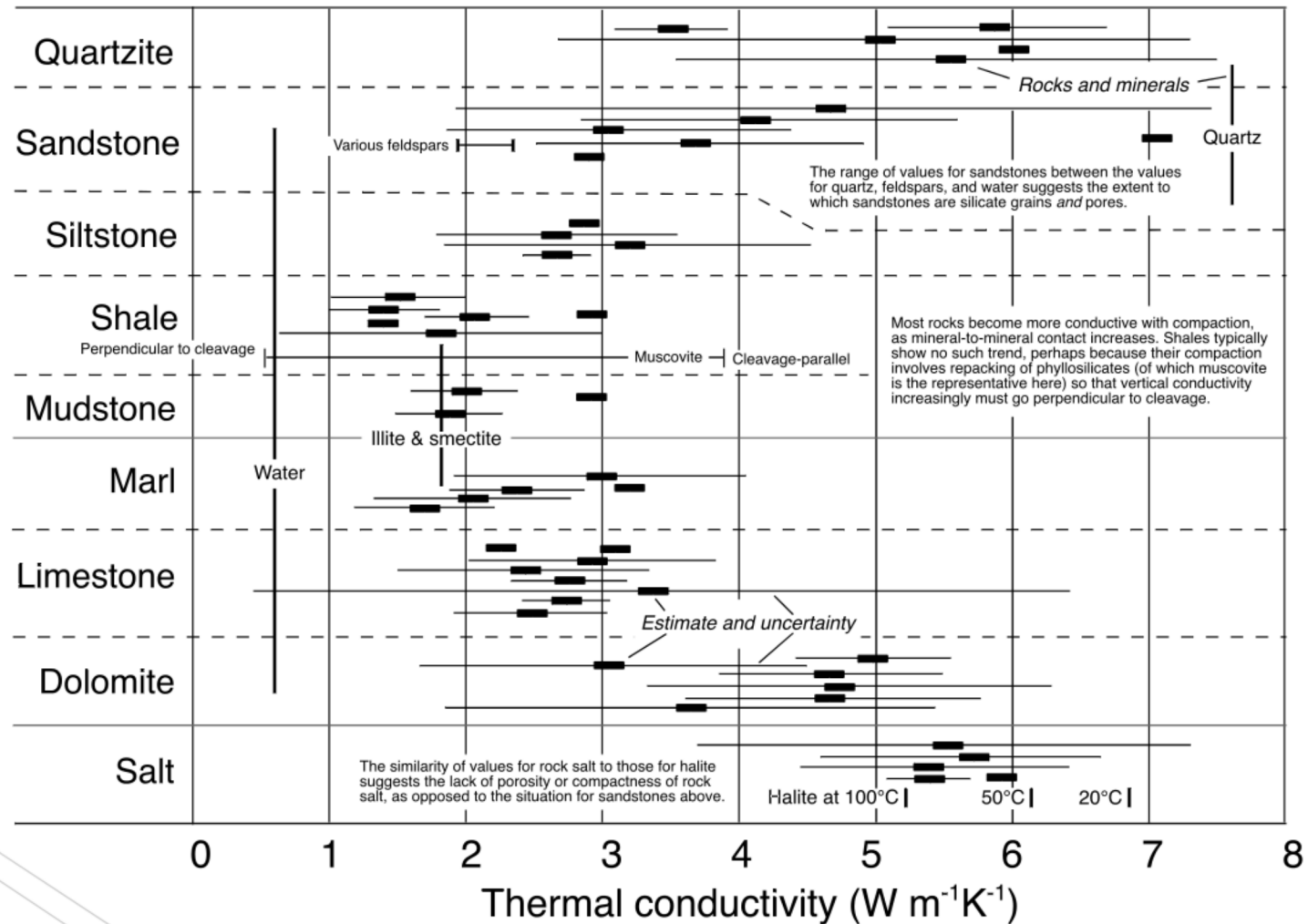
$$Q = c \times dT/dz$$

or alternately

$$dT/dZ = Q \div c$$

If one can make a reasonable assumption about the past heat flow in a sedimentary basin, one can use the thermal conductivity of the strata in the basin to calculate the geothermal gradient at any given time and thus estimate the past distribution of temperatures. The data at right show that shales have small values of thermal conductivity, whereas more quartzose siliciclastics and purer carbonates have greater values. Values are greatest for halite.

If the relationship at right between thermal conductivity and geothermal gradient isn't intuitively obvious, consider this example: when you take a hot item from the oven, you want a steep thermal gradient between that item and your hand (you want that item hot and your hand cool). To do that, you put a hotpad (an insulator and thus an object with a small thermal conductivity) between the hot item and your hand to enforce the desired large thermal gradient.

Quartzite

Sandstone — Various feldspars

Rocks and minerals

Quartz

The range of values for sandstones between the values for quartz, feldspars, and water suggests the extent to which sandstones are silicate grains *and* pores.

Siltstone

Shale — Perpendicular to cleavage — Muscovite — Cleavage-parallel

Most rocks become more conductive with compaction, as mineral-to-mineral contact increases. Shales typically show no such trend, perhaps because their compaction involves repacking of phyllosilicates (of which muscovite is the representative here) so that vertical conductivity increasingly must go perpendicular to cleavage.

Mudstone — Illite & smectite

Marl — Water

Limestone

Estimate and uncertainty

Dolomite

Salt — The similarity of values for rock salt to those for halite suggests the lack of porosity or compactness of rock salt, as opposed to the situation for sandstones above.

Halite at 100°C | 50°C | 20°C |

0   1   2   3   4   5   6   7   8

Thermal conductivity (W m^{-1}K^{-1})

Greater heat flow (for a given geothermal gradient) ⟶

⟵ Greater geothermal gradient (for a given heat flow)