Thermal Properties

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Outline

- Geothermal Gradient
- Heat Capacity
- Thermal Conductivity

Geothermal Gradient

- The temperature within the earth's crust increases with depth approximately in accordance with the equation:

$$T = T_s + \omega D$$

- Where T_s is the average yearly temperature and D is the depth.
- The geothermal gradient ω varies from place to place but is approximately $3℃$ per $100\ \mathrm{m}$.

Heat Capacity

- Heat capacity is a measure of the ability of a body to store heat.
- Heat capacities of sandstone and limestone can be accurately predicted from heat capacities of constituent mineral oxides.
- Heat capacity of a sandstone can be approximated by the following equation:

$$C_{\mathrm{p,sandstone}} = 0.1812 + 1.452 \times 10^{-4} T - \frac{1.495 \times 10^{3}}{T^{2}}$$

- For the limestone:

$$C_{\mathrm{p,limestone}} = 0.1968 + 1.189 \times 10^{-4} T - \frac{3.076 \times 10^{3}}{T^{2}}$$

- Temperature is expressed in Kelvin, and the unit of heat capacity is in $\mathrm{kcal/kg\text{-}^{\circ}C}$.
- These heat capacities apply to the rock skeleton material. For fluid-filled rocks, the fluid heat capacity must contribute and it can be taken into account as follows:

$$\rho_{\mathrm{f}} C_{\mathrm{pf}} = (1 - \phi) \rho_{\mathrm{rock}} C_{\mathrm{p,rock}} + \phi \rho_{\mathrm{fluid}} C_{\mathrm{p,fluid}}$$

Thermal Conductivity

TABLE 2.3 Measured Thermal Conductivities at 32°C [23]. (Thermal Conductivity, K_t, kcal/m²-sec-°C)

Sample	Porosity	Air filled ($\times 10^4$)	Oil filled[b] ($\times 10^4$)	Water filled[c] ($\times 10^4$)	Oil and water filled[d] ($\times 10^4$)
1. Sandstone	0.196	2.1	3.25	6.58	5.89
2. Sandstone	0.4	1.18	2.39	4.34	—
3. Silty sand[a]	0.4	1.18	—	—	—
4. Silty sand[a]	0.43	1.08	2.58	4.59	—
5. Siltstone	0.36	1.40	2.29	4.29	—
6. Siltstone	0.196	1.64	—	—	—
7. Shale	0.071	2.49	—	4.03	—
8. Limestone	0.186	4.06	5.15	8.74	6.99

[a] Disaggregated sample.

[b] The thermal conductivity of the oil was 0.318×10^{-4}kcal/m-sec-°C.

[c] The thermal conductivity of water is 1.46×10^{-4}kcal/m-sec-°C.

[d] The water saturation was about 35%.