From microwatts to megawatts – high heat production granites as geothermal heat sources

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The partial melting and uprising of granite magma from the deeper parts of the Earth's crust constitute one of the main processes of differentiation of the crust and the concentration of volatile elements. Granite formation is the main process of concentrating the radiogenic elements potassium (K), thorium (Th), and uranium (U) in the upper crust. The heat production (A) of a rock, in microwatts per m^3 is given by the formula (Rybach 1976, but changing units from calories/cm^3second):

$$A = 10^{-5}\sigma(3.48K\% + 2.56Th\ ppm + 9.52U\ ppm)$$

where σ is the density in kg per m^3. Typically, most rocks have heat productivities of around 1 or 2 microwatts per cubic metre ($\mu W/m^3$), granites commonly have productivities of up to 5 $\mu W/m^3$, but granites known as high-heat-production granites (HHP granites) have $A > 5\ \mu W/m^3$. A typical analysis of a HHP granite is one with about 4% K, 50 ppm Th and 10 ppm U. Thorium contributes about 50% to the heat productivity of such a granite, U about 40% and K about 10%.

Many granites exposed at the surface in eastern and central Australia are HHP, but the distribution of heat producing elements within the granite will define the heat flow attributable to the granite body. Three kinds of HHP granite are distinguishable:

- **(i)** those where only the apical portions of the emplaced granite body are HHP and the heat flow is low;
- **(ii)** those where volatile elements are concentrated into large batholiths at depth, possibly from horizontal redistribution before intrusion. Heat flow above these bodies is high;
- **(iii)** those apparently derived from crustal sources already enriched in radiogenic elements where there is a general background high heat flow. The central Australian heat flow province provides the best example.

The distribution and origin of these HHP granites are discussed in the context of their geothermal energy potential.

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