A tale of two peaks: Effects of continental insulation and the partitioning of heat producing elements on the Earth's heat loss

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Continental lithosphere plays two roles in the Earth's heat loss: (1) it locally insulates the mantle beneath it and (2) it sequesters radioactive elements from the convecting mantle. These two roles have potentially opposing contributions to Earth's heat loss, as the former effect increases the average mantle temperature whereas the latter decreases the internal mantle temperature. Understanding this duality becomes important since the internal mantle temperature influences mantle rheology, melt production, convective vigor and other geological processes that impact the dynamics and chemistry of the Earth's interior. To determine the net consequence of the competing influences on the Earth's heat loss, we conducted simulations that couple the convection of a mixed internally- and bottom-heated mantle to the conduction through a radioactively enriched continental crust. While holding the total heat production within the system constant, we varied the enrichment and the surface area of the continental crust. In addition, we also varied the bottom-heated Rayleigh number. We found that increasing continental surface area enhances global heat loss for a range of heat production distributions and Rayleigh numbers explored. The effect of the enriched continents and varied heat production distributions was evident in value of continental surface area that maximizes global heat loss. For mid-range ratios of continental to mantle heat production, the dependence of global heat loss on continental surface area showed two peaks. This double peak effect could reflect trade off between mantle heat production depletion and the increased continental insulation. Finally, the insulating effect of continents was shown to alter the temperature signature associated with bottom- vs. internally-heated convection. In addition, that the presence of continental lithosphere could increase average mantle temperature despite the mantle being depleted suggests that continents can significantly influence mantle potential temperature.

Alpha thermochronlogy of calcite

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High-U minerals such as zircon, apatite and others have proven to be valuable tools in assessing the thermal history of rocks as they pass through the upper crust. However, there are many locations in which high-U minerals are absent; we are investigating the prospect of using the low-U mineral calcite as an alpha thermochronometer.

Step-heating experiments on 17 calcites from 11 different samples and 6 dolomites from 5 samples suggest a closure temperature (T_c) of He in carbonates ~70±10 °C for a cooling rate of 10°C/m.y. The bulk T_c in some samples may tend to be slightly higher due to the presence of diffusion domains larger than the sites in which the majority of He resides. The diffusivity of He in calcite is independent of the genesis of the mineral (igneous, metamorphic or sedimentary) or the source of the He (radiogenic, common, or laboratory induced). Compilation of available diffusion data for He in calcite, dolomite and apatite shows a strong similarity with average values of E = 32.5±3.8 kcal/mole and log D_0/a^2 = 5.3±2.3 log (sec^{-1}) for carbonates and of E = 32.3±3.6 kcal/mole and log D_0/a^2 = 5.4±1.6 log (sec^{-1}) for apatite.

Although calcite is a low-U mineral, this shortcoming can be overcome by analyzing large samples. A sample 3.8 mm in diameter with concentrations of U, Th, and Sm of 0.1, 0.01, and 1 ppm, respectively will produce enough ^{4}He to allow for an analysis that is 1% blank in ~1 m.y. However, this assumes no common He; our experience shows that this is usually not correct and therefore the problem is not having enough He to overcome the blank but having enough radiogenic He to overwhelm the common He. Using the criteria of geologic reasonableness, we find very few samples with [U]<100 ppb to be suitable and most samples with [U]>250 ppb to give good results.

Crinoid columnals have shown to be potentially valuable thermochronometers; preliminary data for the shells of *Inoceramus sp*. suggests a T_c similar to other calcite.

Analysis of secondary calcite from subsurface samples of the Ordovician Ellenberger Group suggest that this unit experienced karstification in the Permian in west Texas but that diagenesis in the Llano uplift area is Tertiary in age.

Early work has concentrated on coarse-grained calcite but it is clear that the diffusion domain size is less than the grain size in all material analyzed so far. We are investigating fine-grained travertine deposits in the Miocene Barstow Fm of southern California, which have [U]>100 ppm in order to determine how fine-grained calcite can be and still give geochronologically reasonable results.