Chemical weathering and transport of heat in active mountain belts by groundwater: evidence from coupled models of mechanical and chemical weathering, inverted weathering profiles, and low heat flow

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It is generally believed that in mountainous regions, physical and chemical weathering are coupled. While this hypothesis makes intuitive sense and agrees with the observed log-linear relationship between suspended and dissolved load in large river systems, such a hypothesis ignores the decrease in chemical weathering flux which may accompany an increase in landslides. To explore this problem, we developed a model that incorporates explicit equations to predict bedrock to soil conversion, landsliding, and chemical weathering. Using both constant and exponentially decreasing rates of soils formation as maximum and minimum bounds of chemical weathering, we compared chemical and physical weathering for a reasonable parameter space. Our model predicts that increases in physical weathering do not correspond with increases in chemical weathering. Given that goundwater provides a dissolved load to rivers without a concurrent suspended load, it may be the best candidate to reconcile this discrepancy. In order to test our hypothesis, we examined a road-cut exposed paleo-sol on Mt Kilimanjaro, Tanzania, an active volcano. The degree of weathering was found to increase with depth in the soil profile. At depths greater than 200 cm, the major elements Si, Na, K, Ca, and Mg are depleted by nearly 100 % while at depths shallower than 200 cm, depletion was significantly less. Furthermore, sequential leach experiments on soils from Mt. Meru, Tanzania suggest lateral transport of Sr, Ba, and Ca below 150 cm depth. These data are consistent (but do not prove) that subsurface lateral flow, at least locally, may have been important in chemical weathering. Finally, we show that in active or recently active mountainous regions, such as the Andes, the Sierra Nevada, and the Cascades, apparent surface heat flows are paradoxically as low as those measured in the stable Archean cores of continents. One explanation is that these regions are underlain by rocks with low radioactivity. However, the more likely possibility is that there is an advective component of the heat flow that has not been accounted for and we speculate that this may be attributed to groundwater flow. These three lines of reasoning suggest that it may be worth considering the possibility that groundwater may play a non-trivial role in the transport of material and energy in tectonically active regions. If so, solute transport to the oceans may be greater than accounted for in rivers alone.