The Scott Simpson Lecture

The economic geology of granite - an integrated view

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Long associated with metallic ore minerals and industrial minerals such as china clay, granitic rocks are, in some parts of the world, also sources of petroleum and potentially geothermal energy. They may also have value as fertilizers, given that two of their constituent minerals (K-feldspar and mica) have been identified as sources of K for plant nutrition. This paper reviews briefly different aspects of the economic geology of granites, culminating in a conceptual generic model intended to provoke discussion and lateral thought.

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Introduction

Granite, in the broadest sense, includes a suite of rocks with a mineralogical composition that characteristically includes quartz, alkali feldspars and biotite. Granitic rocks commonly occur in continental crust, as part of the crystalline basement beneath younger sedimentary cover. They vary in age, ranging from Precambrian to as little as 0.8 Ma, in the case of very young granites exposed in the Hida Mountain Range, central Japan (Ito *et al.*, 2013). Following decades of controversy (Tuttle and Bowen, 1958), the origin of granite is now widely accepted to be magmatic, although many features of granites can best be explained by invoking the role of volatiles, which accumulate during crystallization. In addition to water, incompatible fluxes such as fluorine (Manning, 1979, 1981) and boron (Pichavant, 1981) become concentrated in late stage rocks, reducing melt viscosity (especially B) and allowing residual melts to persist to low temperatures (especially F). Once magmatic crystallisation is complete, residual aqueous fluids escape, carrying specific ore-forming elements in solution and leading to the eventual formation of mineral deposits.

The economic value of granite (and related or similar rocks) has long been recognized, with a history of mining of granite-associated metal ores dating back to prehistoric times (Dines, 1956). At the present time, granite is immediately associated with the production of tin and tungsten, and is associated with a wide range of other ores and industrial minerals such as fluorite and china clay. The potential of granites as sources of geothermal energy has a relatively long history, which continues. What is less well known is the occurrence in some parts of the world of economic deposits of petroleum within granitic rocks. Additionally, their constituent minerals possibly have use as alternatives to chemical fertilizers, enabling granites to respond to the need to feed the rising world population.

In this paper, a brief overview is given of the economic geology of granite, in its broadest sense, with the intention of stimulating novel thinking behind the development of the conceptual models that synthesise the value of granite to humanity.

Granites and metal ore deposits

The association between granites and metal ore deposits was investigated rigorously in South-West England long ago. The zoned distribution of minerals around granite cusps was described by Hosking (1951; Figure 1), and remains a valuable field-based observation. Further work by Jackson *et al.* (1989) describes the spatial distribution of minerals in more detail.

Although Figure 1 emphasises the importance of mineral veins, the accumulation of volatiles as crystallization of the melt proceeds gives rise to low viscosity magmas that precipitate pegmatites (London, 2008). Pegmatites vary greatly in their mineralogical composition, but can be associated with enrichment in incompatible elements that are increasingly important as raw materials for modern technology. An example of a deposit with a history of producing tantalum is Tanco in Manitoba (Stilling *et al.*, 2006), where a wide range of minerals

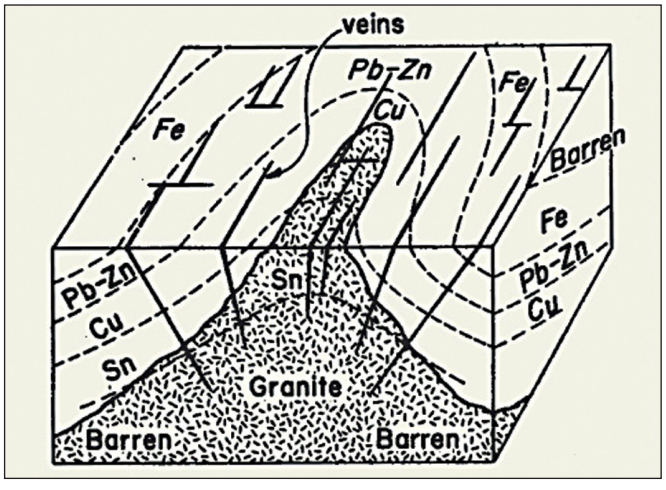

Figure 1. *Mineral zoning around granitic cusps in Cornwall and Devon (from Hosking, 1951). Reproduced with permission from the Royal Geological Society of Cornwall.*