undeniably very old, there is nothing exceptional about their geological- geomorphological setting. There is neither a dearth of erosive energy, nor a particularly great bedrock resistance ... Moreover, not only the upland surfaces are old, so too are the canyons which dissect them.'[17]

As a result, current uniformitarian models for landscape development are seriously challenged:

'One possible solution to the problem posed by such ancient land surfaces is that the conventional models of landscape evolution are in error.'[18]

A better explanation is to take the evidence at face value — the landforms look young because they really are young. The geomorphology of the landforms also calls into question the conventional dating methods that produce old dates.

Similar landforms as found in Australia are also common around the world:

'. . . *the ancient landscape of southeastern Australia may be typical of very substantial parts of the earth's surface.*'[19]

Some are readily apparent in Montana and Wyoming in the United States. Thus, the geomorphological evidence implies that a worldwide erosional event occurred not long ago. Since many of these erosional surfaces are at high elevations, the terrain has been recently uplifted. What better explanation than the worldwide Genesis Flood? The erosion surfaces, especially the horizontal surfaces that bevel tilted sedimentary rocks, likely represent the final scouring of the land by fast currents draining off the rising continents at the end of the Genesis Flood.

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M.J. Oard

'Rapid' Granite Formation?

One of the persistent scientific objections to the Earth being young (6,000-7,000 years old rather than 4.5 billion years), and the Flood being a year-long, mountain-covering, global event, has been the apparent evidence that the large bodies of granitic rocks found today at the Earth's surface took millions of years to cool from magmas. However, contrary evidence pointing to relatively rapid, even catastrophic, formation of granites is now beginning to surface.

Granites are crystalline rocks that occur over large areas, sometimes exposed over hundreds of square kilometres. Deep in the Earth's crust the temperatures are sometimes high enough to melt the rocks, particularly if there are applied high pressures due to tectonic forces (earth movements). The theory has been that large 'blobs' of magma are thus generated at 750-900°C, and because they are 'lighter' than the surrounding rocks the 'blobs' rise like balloon-shaped diapirs into the cooler upper crust. There they crystallise as granites.

Young[1] has insisted that an immense granitic batholith like that of southern California required a period of about one million years in order to crystallise completely, an estimate repeated by Hayward.[2] A survey of the technical literature, however, yields estimates of even greater time-spans. Pitcher sums it all up:-

'My guess is that a granitic magma pulse generated in a collisional orogen may, in a complicated way involving changing rheologies of both melt and crust, take 5-10 Ma to generate, arrive, crystallize and cool to the ambient crustal temperature.'[3]

Of course, there is the added time-span from cooling of the granite pluton within the Earth's curst to its exposure at today's land surface by uplift and erosion. Nevertheless, it should be kept in perspective that most recent estimates of these time-spans, including uplift and erosion, rely heavily on radiometric dating determinations and uniformitarian assumptions, and not just on the thermodynamics of crystallisation and heat flow/ dissipation.

So whence cometh the challenge to this hithertofore seemingly impregnable bastion of old-earthers? Surprisingly, the contrary evidence pointing to relatively rapid (the word 'catastrophic' has even been used!) formation of granites has recently been suggested from within the ranks of the 'establishment' itself! The geological fraternity always had a problem within the accepted 'wisdom' anyway — the so-called space problem. How does the balloon-shaped diapir find room to rise through the Earth's crust and then the space to crystallise there (even at 2-5 km depth) in spite of the continual confining pressures? As Petford *et al.* point out,

> *'The established idea that granitoid magmas ascend through the continental crust as diapirs is being increasingly questioned by igneous and structural geologists.* '[4]

In promoting the idea that the long distance diapir transport of granitic magmas is not viable on thermal and mechanical grounds, Clemens and Mawer favoured the growth of plutons by dyke injection propagating along fractures.[5] In other words, the magma is squeezed upwards as thin sheets through long, narrow fractures. Pitcher comments:

> *'what is particularly radical is their calculation that a sizeable pluton may be filled in about 900 years. This is really speedy!'*[6]

Petford *et al.* have gone further, with calculations which show that a crystal-free granitoid melt at 900°C, with a water content of 1.5 weight per cent, a viscosity of 8 x 10^5 Pa s, a density of about 2,600 kg/m^3 and a density contrast between magma and crust of 200 kg/m^3, can be transported vertically through the crust a distance of 30 km along a 6m wide dyke in just 41 days.[7] This equates to a mean ascent rate of about 1 cm/sec. Petford *et al.* then apply their equations to the Cordillera Blanca batholith of north-west Peru and conclude that if its estimated volume is 6,000 km^3, then it could have been filled from a 10 km long dyke in only 350 years. Magma transport must be this fast through such a dyke so that the granitoid magma does not freeze due to cooling within the conduit as it is ascending, and Petford *et al.* therefore maintain that the dyke intrusion of granitoid magma occurs in response to fault slippage within the Earth's crust. They stop short of accepting this 350 year rapid filling of this batholith, because that rate is orders of magnitude greater than the mean cavity-opening rates based on radiometric dates for the associated faults. So Petford *et al.* are constrained by the radiometric dates to conclude that intrusion of the batholith must have been very intermittent, the magma being supplied in brief, catastrophic pulses, while the conduit supposedly remained open for 3 million years.

In a more recent study, Petford has dealt with the question of how, and at what rate, does deep crustal or upper mantle rock melt to form granitic magmas?[8] This is, of course, the first step in the process of formation of granites. Petford suggests that, according to the best theoretical models, melted rock in the lower crust segregates via porous flow into fractures within the source rock (usually metamorphic) above a mafic intrusion (the heat source), the fractures inflating to form veins. Local compaction of the surrounding matrix then allows the veins to enlarge as they fill further with melt, and the fluid-filled veins coalesce to form a dyke (see Figure 1). At a certain critical melt-fraction per cent of the source rock, a threshold is reached where the critical dyke width is achieved. Once that critical dyke width is exceeded, *'rapid (catastrophic) removal of the melt*

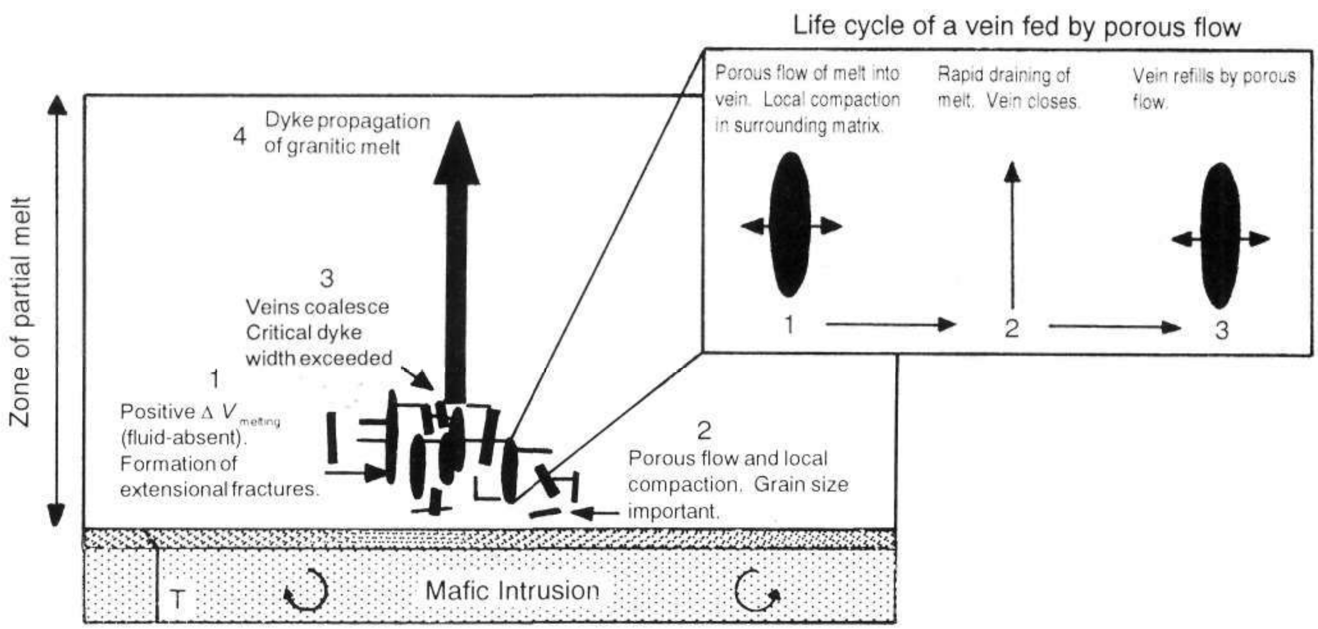

Figure 1. *Schematic representation of a possible sequence of events (1-4) resulting from fluid-absent melting reactions in a protolith above a mafic (intrusive) heat source in the lower crust. Veins fill by porous flow, with some local compaction (insert).*

from source' occurs. The veins collapse abruptly, only to be then refilled by continuing porous flow of more melt from the continuously applied heat to the source rock. Thus the process is repeated, the granitic melt being extracted and then ascending through dykes to the upper crust in rapid and catastrophic pulses.

> *'In the physical model presented here of rapid melt extraction followed by ascent of relatively small magma batches at rates orders of magnitude faster than chemical diffusion, the only significant magma reservoir will exist at the level of emplacement, provided that is that space can be made fast enough in the upper crust to accommodate the ascending magma batches.*"

Rapid provision of the required space within the upper crust would not be a problem within the context of a catastrophic global Flood that involved catastrophic plate tectonics.[10] However, Petford only postulates a maximum vein filling rate of about 2.5 m/yr for a grain size of 5 mm and a porosity of 50 per cent, a rate that seems comfortably slow enough for his uniformitarian time-scale.

But now just to hand is an independent test of the slow (diapir) versus fast (dyke) models for emplacement of granitic magmas, based both on laboratory work **and** field observations. Brandon *et al.* chose the mineral epidote for study because it has a magmatic origin in some granitic rocks and its stability in granitic magmas is restricted to pressures of >600 MPa (a depth of 21 km).[11] Their experimental work has now shown that epidote dissolves rapidly in granitic melts at pressures of <600 MPa. Indeed, for temperatures appropriate for granitic magmas (700-800°C) they found that epidote crystals (0.2-0.7 mm) would dissolve in a low-pressure granite melt within 3-200 years. Therefore, if magma transport from sources in the lower crust is slow (>1,000 years), epidote will not be preserved within upper-crustal batholiths. Yet the authors are able to point to granitic rocks of the Front Range (Colorado) and the White Creek Batholith (British Columbia) in which epidote crystals are found, 0.5 mm wide crystals (in the case of the Front Range occurrence) that would dissolve at 800°C in less than 50 years. Brandon *et al.* state:

> *'Preservation of 0.5 mm crystals therefore requires a transport rate from a pressure of 600 to 200 MPa of greater than 700 m year."*[12]

They went on to calculate a maximum ascent rate of 1.4 x 10^4m (or 14 km) per year for the epidote-bearing White Creek Batholith granitic magma. Therefore, since epidote is found preserved in granitic magmas crystallised at shallow crustal levels, then granitic magma transport from the lower crust must be fast (very much less than 1,000 years). Furthermore, since the modelling of ascending diapirs indicates such magma transport rates are slow (0.3-50 m per year) and ascent times are 10,000-100,000 years,[13,14] then the preservation of epidote crystals not only implies magma transport was rapid, but that the transport was via dykes rather than diapirs.

What all this means is that much progress is currently being made by some establishment geologists (not all agree yet) with a catastrophic model for the ascent of granitic magmas. While their findings are drastically reducing the time-scales involved, even for granitic melt production in the lower crust, there is still some way to go for our apparent granite problem to be fully solved. Yet since their calculations are invariably always placed within a uniformitarian, radiometrically-determined, millions-of-years context, there appears to be no intrinsic obstacle to successful transposition of these findings to a total catastrophic context, such as catastrophic plate tectonics within a global Flood. This is not to ignore the cooling of the granite magma once it has been rapidly transported into place from deep in the curst, but as Pitcher reminds us,

> '.. . *it is salutary to note that his* [Spera[15]] *estimates of the time taken for solidification of a typical pluton from liquidus to solidus temperatures varies greatly with the assumed water content, decreasing ten-fold between 0.5 and 4 wt %* [weight per cent] *water.*'[16]

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