The rapid formation of granitic rocks: more evidence

John Woodmorappe

It was once thought that granitic magma was so viscous that it would take hundred of millions of years for granitic rocks to form. However, recent research shows that granitic magmas are orders of magnitude less viscous than previously believed. Furthermore, the physical environment in which silica-rich magmas are segregated, transported and emplaced reveals that granitic magmatism is a rapid, dynamic process. These new findings are entirely consistent with the 6,000-year Earth recorded in Scripture. Granitic magmas may have been generated in the Earth in the 1,600-year period between Creation and the Flood, and emplaced and partly cooled during the Flood. Alternatively, it is possible that the dynamic tectonism associated with the Flood may be adequate to explain granites entirely within the Flood's one-year timeframe, but this needs further investigation.

For more than a hundred years, the generation and cooling of plutonic rocks has been conventionally believed to take millions of years. The entire process of granite formation consists of several steps. To begin with, heat must be injected into the parent rock material (protolith) in order for partial melting to occur. This molten fraction (granitic magma) has to separate and be extracted from the remaining protolith matrix (residuum). The melt must then be transported though the multi-kilometre-thick crust before it pools within a section of crust. Finally, this intruded mass of granitic magma must be allowed to cool and crystallize.

The last two processes, transport through the crust and cooling, have already been shown to occur within a timescale of a few thousand years at most.[1] In summary, magmas do not have to rise in the crust by slow, density-driven diapiric processes, or stoping processes where the magma detaches and absorbs blocks of surrounding rock. Rather the magma can be rapidly squeezed through dikes and other pre-existing conduits. And even granitic bodies of batholithic dimensions can crystallize and cool in only a few thousand years if convective, water-based cooling is available, as surely must have been the case during, and immediately after, the Flood.

Now there are a variety of evidences, recently summarized,[2] which indicate that the first two processes, the partial melting of protoliths and the extraction of granitic magmas, are also fully compatible with a young Earth. A major uniformitarian dogma about the high viscosity of granitic magmas had to fall to make this fact conceivable.

Viscosity—the rate determining variable

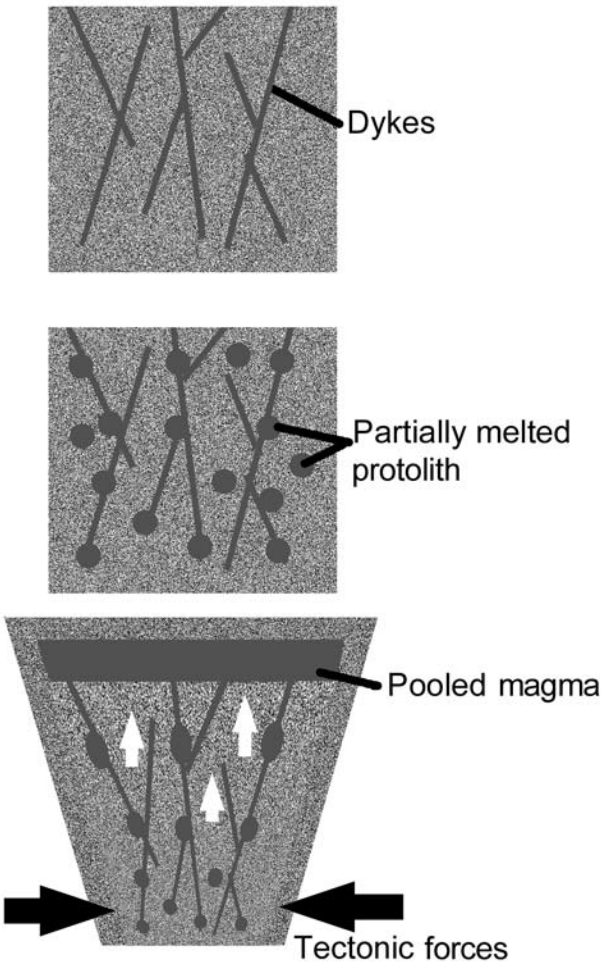
While taking igneous petrology classes over 20 years ago, I was taught as fact that granitic magmas were so viscous[3] that they were almost indistinguishable from solid rock, in terms of their gross physical behaviour. With such a high viscosity it would require millions of years for the magma to differentiate and to rise through the crust. In fact, uniformitarian geologists for the better part of the 20th century had accepted the very high viscosity of granitic magmas as fact.[2] Now it is found to be a myth—as discussed below.

Why is magma viscosity so significant? It turns out that the viscosity of the granitic magma is ***the*** rate-determining variable that governs how rapidly the magma can be extracted from its partially-molten protolith.[4] In general, and with other factors remaining equal, an order-of-magnitude decrease in the viscosity of granitic magma corresponds to an order-of-magnitude increase in melt-extraction rate from the partially-molten protolith, as well as an order-of-magnitude increase in the rate of transport of granitic magma through the crust.[5]

The physical environment of magma generation

As heat is injected into the protolith and it begins to melt, the minerals with the lower melting points melt first. This leaves cavities within the still-solid material, which is now composed of the remaining higher-melting-point minerals. In other words, the magma first forms myriads of droplets, each of which is surrounded by the remaining, now-porous unmelted-rock matrix. In terms of physical and mechanical behavior, the partly melted protolith is like a sponge filled with small droplets of liquid. The sponge however is kilometres thick—so thick that the bottom can be crushed by the weight of the massive overlying part of this giant 'sponge', squeezing out some of the liquid.

Naturally, it would take a long time for a very viscous liquid to be squeezed out of a sponge and to percolate to the top. However, the time needed would be significantly reduced if the sponge had hollow, vertical pipes driven into it—like the dikes that cut through the crust of the Earth. In this situation the liquid would not have to be squeezed very far before it could flow into a dike and rise to the top. The time needed to extract the magma would be reduced still further if external pressure were applied to the sponge: like squeezing a hand-sized sponge but by tectonic forces on a vastly larger scale. A further reduction in the extraction time, perhaps the greatest effect, would occur if the liquid in the sponge were less viscous. The difference would be



The sequence of granite formation. Protolith may contain pre-existing dykes. As the rock heats, the lower-melting-point minerals melt first; with the pressure of tectonic forces, and the availability of dykes, the liquid can rise quite quickly toward the surface. It then pools and crystallizes. The biggest determining factor is the viscosity of the magma.

similar to the difference in time needed to squeeze tar out of a sponge compared with squeezing water! And of course, if all three effects (dikes, tectonic strain and low viscosity) occur simultaneously, the reduction in extraction time for the granitic magma will be cumulative.

Magma viscosity

Just how viscous are granitic magmas? For the longest time, 'dry' granitic magmas were supposed to have viscosities in the neighborhood of 10^9 pascal seconds (Pa s),[6] in contrast to mafic magmas, which have viscosities of only 10–100 Pa s.[7] However, recent experimental evidence indicates that even relatively dry granitic magmas (1–3% water) are as much as two to four orders of magnitude less viscous (at 10^5–10^7 Pa s) than previously thought.[8] Moreover, a magma containing several percent by weight of water can be at least two orders of magnitude less viscous than a dry magma.[9] It should also be added that the viscosity of granitic magmas, while extremely sensitive to water content, appear to be largely independent of the containing overpressure,[10] but moderately sensitive to temperature.[5] It is unclear at this stage how 'thin' a granitic magma can ultimately be. Extrapolations of experimental data[11] suggest that exceptionally hot and wet granitic magmas can have viscosities as low as 1 Pa s.

Extraction and emplacement times

To appreciate the significance of low viscosity in magmas, let us now consider the time required to extract about 10% by volume of granitic magma from a 1-km layer of protolith. We assume a temperature of about 700°C, and that neither heat flow into the protolith, nor the physical strain on the rock matrix, are limiting factors. With a magma viscosity of 10^{12} Pa s, the extraction of the magma would take 100 million years. Reducing the viscosity to 10^9 Pa s would reduce the time to approximately 20,000 years. Finally, at a viscosity of 10^6 Pa s, the requisite time shrinks to a mere 100 years! This is much less than the 1,600-plus years available between the Creation and Flood, even allowing a considerable margin of error in the estimated time of extraction itself, which could even be shorter than 100 years.

Is there any petrologic or petrographic evidence that granitic magmas have been extracted in timescales of only decades or centuries? Definitely. I will provide just two examples. In some Himalayan leucogranites there is a strong undersaturation of the element zirconium.[12] This indicates that the granitic magma was extracted so rapidly from the remaining matrix (a maximum of 150 years or so), that the zirconium did not have sufficient time to come into equilibrium between the two phases. In a similar situation in Quebec, Canada, based on comparable evidence, the inferred separation time between granitic magma and the residuum is an astonishingly short 23 years.[13]

Sources of heat

Where did the heat come from that melted the protoliths by the time of the Flood? One possible source is the heat stored in the mantle and crust as a leftover of the divine processes during Creation Week itself. These, of course, ordained the Earth as a planet in general, and formed the solid crust in particular. In uniformitarian thinking, the inferred-slow heating of the protolith comes primarily from the heat released by internal radioactive decay. Humphreys[14] has suggested that God accelerated the decay rates of nuclides, such as uranium, by many orders of magnitude. This, he suggested, was an intentional mechanism for generating the prodigious amounts of heat necessary for such things as rapid orogenesis, the rapid melting of protoliths, etc. He also suggests that one of these episodes of accelerated nuclear decay occurred during the first three days of Creation Week. In this scenario the requisite heat buildup would have been sufficient to eventually re-melt a significant fraction of the just-created crust during the ensuing 1,650-year interval between the Creation and Flood. Thus a large reservoir of molten granitic magma would have been generated in the lower crust, waiting to be mobilized, intruded, and partly cooled during the Flood year itself.

Although the idea of accelerated radioactive decay is interesting, we creationist scientists must not 'put all our eggs in one basket'. Other models for rapid protolith melting need to be examined that do not require any acceleration of radioactive decay as sources of heat. There is, in fact, a model[15] for rapid crustal melting which meets this specification. It is attractive because it is very simple and can generate copious volumes of molten granitic crust. It requires no more than heat transfer between mafic magma and sialic crustal material. Mafic magmas usually have temperatures around 1,200°C prior to crystallization. On the other hand, granitic magmas commonly flow at temperatures as low as 700°C and material of granitic composition can be partially molten at about 850°C.[16]

Now consider what happens when a large volume of basaltic magma intrudes into solid granitic crust. As the heat leaves the mafic magma, and it starts to crystallize, the surrounding granitic crust will absorb the heat and begin to melt. Very significantly, such melting can occur quickly, even for granitic crust of batholithic dimensions. Consider, for instance, a 500-m thick basaltic sill injected into solid granitic crust. In only 90 years or so, 60% of the basalt will have crystallised such that the sill will no longer undergo internal convection. Within the same period of time, a layer of granitic magma will be generated from the crust, varying in thickness from 500–1,400 m, depending upon the initial conditions of the mafic magma.[17]

Within the one-year Flood?

We can take the implications of the studies cited in this report even further, when we remember that they have all been conceptualized and developed within the basic uniformitarian mind set. Could protolith melting and granite-melt extraction occur, to an appreciable extent, within the Flood year *itself*? Heat flow is one of the major factors in these studies that limits melt-extraction to 100 years (see Figure 16 of Rutter and Neumann[18]). However, it is unlikely that such a thermal limit existed in the recently-created Earth, as was discussed earlier. It is certainly worth exploring whether appreciable amounts of granitic magma of exceptionally low viscosity and exceptionally high water content could be extracted from a partially-molten protolith in a year or less. Further, we need to explore the effect of very high strain rates, which must have existed as a result of catastrophic tectonism during the Flood. The physical pressures resulting from such strain rates would be applied directly to the partially-molten rock matrix. Appropriate studies could determine whether or not such strain rates are possible, even for brief periods of time, and reveal whether granite petrogenesis in one year is a realistic proposition.

However, this question is rather moot. Regardless of whether or not significant quantities of granitic magma were generated during the Flood year itself, it is clear, from recent reports, that the entire process of granitic petrogenesis could have occurred on an Earth that was only several thousand years old:

> 'As a result, dynamic models that operate on timescales of months to centuries are replacing the once-prevailing view of granitic magma production as a slow, equilibrium process that requires millions of years for completion.'[19]

It would be difficult to make the implications any clearer for a young Earth. Furthermore, the abolition of the long-held uniformitarian myth about granite formation constitutes nothing less than a revolution in geology. What other uniformitarian myths are we even now tacitly accepting that are likewise ready to fall?

Conclusion

The viscosities of silica-rich granitic magmas are orders of magnitude less than has been conventionally believed for over a hundred years. Consequently, the millions of years, previously believed necessary to form granitic rocks, are no longer required. The underlying physical processes involved in the segregation, transport and emplacement of granitic magmas operate on a timescale of months to centuries. Besides magma viscosity, important factors controlling the rate of emplacement include tectonic deformation of the crust, the protolith structure after partial melting, and the emplacement of magma by dike networks. Granitic magmatism is a rapid, dynamic process. Granitic rocks may have been generated in the Earth in the 1,600-year period between Creation and the Flood, and emplaced and partly cooled during the Flood. Alternatively, it is possible that the dynamic tectonism associated with the Flood may be adequate to explain granites entirely within the Flood's one-year timeframe, but this needs further investigation.

References

1. Snelling, A.A. & Woodmorappe, J., The cooling of thick igneous bodies on a young Earth, in; Walsh, R.E. (Ed.), *Proceedings of the Fourth International Conference on Creationism*, Technical Volume, Creation Science Fellowship, Pittsburgh, pp. 527–545, 1998. See also Woodmorappe, J., Granites … they didn't need millions of years of cooling, *Creation* **21**(1):42–44, 1999, for a popular-level summary.
2. Petford, N. *et al*., Granite magma formation, transport and emplacement in the Earth's crust, *Nature* **408**:669–673, 2000.
3. See <http://xtronics.com/viscosity.htm> for a good tutorial on the nature and measurement of viscosity. The viscosity of a mafic magma (at 10–100 Pa s) is comparable to honey, chocolate syrup, or ketchup. A dry granitic magma has a viscosity (at 10^7 Pa s) comparable to that of tar or pitch. (The viscosities of the common substances are at room temperature.)
4. Rutter, E.H. and Neumann D.H.K., Experimental deformation of partially molten Westerly granite under fluid-absent conditions, with implications for the extraction of granitic magmas, *J. Geophysical Research*

100(B8):15697–15715, 1995.

5. Baker, D.R., Granitic melt viscosities: empirical and configurational entropy models for their calculation, *American Mineralogist* **81**:126–134, 1996.
6. Rutter and Neumann, Ref. 4, p. 15709.
7. Scaillet, B. *et al*., Viscosity of Himalayan leucogranites, *J. Geophysical Research* **101**(B12):27696, 1996.
8. Baker, Ref. 5, p. 128.
9. Schulze, F. *et al*., The influence of H_2O on the viscosity of a haplogranitic melt, *American Mineralogist* **81**:1155–1165, 1996. At a high temperature (1300°C) and water-material content of 4 (% by weight), the granitic magma may have a viscosity of only $10^{3.5}$ Pa s (p. 1159).
10. Baker, Ref. 5, p. 132.
11. Hess, K.-U. and Dingwell, D.B., Viscosities of hydrous leucogranitic melts: A non-Arrhenian model, *American Mineralogist* **81**:1297–1300, 1996.
12. Harris, N., Vance, D. and Ayres, M., From sediment to granite: timescales of anatexis in the upper crust, *Chemical Geology* **162**:161, 2000.
13. Sawyer, E.W., Disequilibrium melting and the rate of melt-residuum separation during migmatization of mafic rocks from the Grenville Front, Quebec, *J, Petrology* **32**(4):701–738, 1991.
14. Humphreys, D.R., Accelerated nuclear decay: a viable hypothesis? in: Vardiman, L., Snelling, A.A. and Chaffin, E.F., (Eds), *Radioisotopes and the Age of the Earth: A Young-Earth Creationist Research Initiative,* Institute for Creation Research, El Cajon, and Creation Research Society, St. Joseph, pp. 333–379, 2000.
15. Huppert, H.E. and Sparks R.S.J., The generation of granitic magmas by intrusion of basalt into continental crust, *J. Petrology* **29**(3):599–624, 1988.
16. Huppert and Sparks, Ref. 15, p. 614.
17. Huppert and Sparks, Ref. 15, pp. 614–615.
18. Rutter and Neumann, Ref. 4, p. 15712.
19. Petford *et al.*, Ref. 2, p. 669.

John Woodmorappe has an M.A. in geology and a B.A. in biology, from a midwestern US state university. He is a science educator by profession. He is the author of *Studies in Flood Geology*, *Noah's Ark: A Feasibility Study*, and the recently released *The Mythology of Modern Dating Methods*.

Erratum TJ 15(1)

John Woodmorappe, *Contra* Rb-Sr dating: an isotope fractionation mechanism for the nonradiogenic origin of excess strontium-87.

In Table 1, on page 119 the numbers in Column 8, ^{88}Sr Abundance, are incorrect and should read as follows:

A. Isotopically Normal to Heavy Strontium

Number of Fractionations	^{88}Sr Abundance
0	0.825800000
1	0.826318996
2	0.826836453
3	0.827352376
4	0.827866767
5	0.828379631
10	0.830921161
20	0.835891669
50	0.849934471
100	0.870654088
150	0.888388234
200	0.903539668
300	0.927517299
500	0.957884958
1000	0.987326432
3000	0.999788499

B. Isotopically Normal to Light Strontium

Number of Fractionations	^{88}Sr Abundance
0	0.825800000
-1	0.825279464
-2	0.824757382
-3	0.824233752
-4	0.823708569
-5	0.823181832
-10	0.820524692
-20	0.815091775
-50	0.797813503
-100	0.765560422
-150	0.728693444
-200	0.686992612
-300	0.589295036
-500	0.356929776
-1000	0.024164883
-3000	0.000000002