Crystal isotope stratigraphy; time constraints on magmatic processes

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Sr isotopic variations from cores-to-rims of feldspar in young volcanic rocks have proved to be very common and attest to crystallisation in an open system [e.g.1]. Isotopic profiles in the context of mineral and rock textures have typically been interpreted as reflecting magma mixing – either magmas that are variably primitive vs. contaminated, or magmas that originate from distinct mantle sources. When several crystals are analysed from a single rock they typically appear to share common process experiences, yet in detail they show a complex variety suggesting that crystals are continuously recycled from different mush/cumulate zones within a given magma storage and delivery system. Although fewer in number, isotopic profiling studies of plutonic minerals have revealed comparable variations – for which similar intepretations have been made [e.g.2].

What can this tell us about timescales of magmatic processes? Firstly the processes reflected in isotopic profiling must occur over timescales more rapid than those over which such information would be diffusively equilibrated – this translates into <10 kyr (probably much less) in most cases. Secondly, isotopic profiles across "event boundaries" (unconformities, due to dissolution) can be modelled as consistent with residence times ≤ a few hundred years. Higher-resolution trace element diffusion modelling has determined residence times in some systems to be years-to-decades [3,4]. The likelihood is that magma mixing events are reflected in geophysical signals, which occur on timescales of days to years. If so, crystallisation rates must be faster than many of the published values (perhaps much faster if driven by decompression).

References

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