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Explaining the discrepancy between forced fold amplitude and sill thickness.

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Understanding the behaviour of Earth's surface in response to movement and emplacement of magma underground is important because it assists calculation of subsurface magma volumes, and could feed into eruption forecasting.

Studies of seismic reflection data have observed that the amplitude of a forced fold above an igneous sill is usually smaller than the thickness of the sill itself. This observation implies that fold amplitude alone provides only a lower bound for magma volume, and an understanding of the mechanism(s) behind the fold amplitude/sill thickness discrepancy is also required to obtain a true estimate of magma volume. Mechanisms suggested to explain the discrepancy include problems with seismic imaging and varying strain behaviour of the host rock. Here we examine the extent to which host-rock compaction can explain the fold amplitude/sill thickness discrepancy. This mechanism operates in cases where a sill is injected into the upper few kilometres of sedimentary rock that contain significant porosity. Accumulation of sediment after sill intrusion reduces the amplitude of the forced fold by compaction, but the sill itself undergoes little compaction since its starting porosity is almost zero. We compiled a database of good-quality 2D and 3D seismic observations where sill thickness has been measured independently of forced fold geometry. We then backstripped the post-intrusion sedimentary section to reconstruct the amplitude of the forced fold at the time of intrusion. We used the standard compaction model in which porosity decays exponentially below the sediment surface. In all examples we studied, post-sill-emplacement compaction can explain all of the fold amplitude/sill thickness discrepancy, subject to uncertainty in compaction model parameters.

This result leads directly to an improved method of predicting magma volume from fold amplitude, including how uncertainty in compaction parameters maps onto uncertainty in magma volume. Our work implies that host-rock deformation at the time of magma intrusion is less important than post-intrusion pure-shear compaction in response to ongoing sediment accumulation. This inference could be tested in cases where an independent direct measurement of the porosity-depth profile overlying the sill is available to better constrain compaction model parameters.