Geophysical Research Abstracts
Vol. 20, EGU2018-10480, 2018
EGU General Assembly 2018

Sill geometry as a record of palaeostress states

Tara Stephens (1), Richard Walker (1), David Healy (2), Alodie Bubeck (1), Richard England (1), and Ken McCaffrey (3)

(1) School of Geography, Geology and the Environment, University of Leicester, Leicester, LE1 7RH, United Kingdom (tls15@le.ac.uk), (2) School of Geosciences, King's College, University of Aberdeen, Aberdeen, AB24 3UE, United Kingdom, (3) Department of Earth Sciences, Durham University, Durham, DH1 3LE, United Kingdom

Sills constitute a major component of magma transport networks in the shallow crust, yet palaeostress analyses in volcanic regions typically focus on dykes. The predominance of intrusive complexes hosted in layered media has led to many models that rely on layering to cause dyke-to-sill transitions. These models require a local rotation of $\sigma3$, from horizontal (for dykes) to vertical (for sills). This rotation is assumed to reflect a low deviatoric stress state (i.e. $\sigma1 \approx \sigma2 \approx \sigma3$) which can facilitate dilation and intrusion of pre-existing discontinuities (i.e. bedding, faults, joints) via mode I dilation. Many natural examples of sills and dykes, however, display combinations of mode I and mixed mode (extensional shear) opening.

Here we present the results of detailed field analyses of two sill complexes: the Loch Scridain Sill Complex (LSSC), Isle of Mull, UK; and the San Rafael Sub Volcanic Field (SRSVF), Utah, USA. Sills in the LSSC have consistent low-angle dips between 1° and 25°: they cut vertical basement bedding and foliation, and horizontal bedding in the overlying sedimentary and volcanic cover sequence. Sills in the SRSVF also have consistent dips between 1° and 25°, and cut gently dipping beds of sandstones, siltstones, and mudstones; notably, regional-scale sills cut formation boundaries at a low angle. In both cases the sills either cut, or are cut by dykes, and we have observed no clear feeder dykes in either region. LSSC and SRSVF sills display low-angle opposing dips, which generally give a bimodal dip distribution. In some instances intersecting sills of opposing dips cross-cut or are linked, and accommodate coaxial vertical uplift of the host rock.

The sills cut bedding and formation boundaries, and cut or abut against steeply dipping faults, fractures, and foliation. From this, we infer that the magma pressure was not greater than the horizontal stress during emplacement. To better constrain the stress state, we combine traditional palaeostress analyses with mechanical models of slip tendency and dilation tendency. We also present depth-independent mechanical models that use the local intrusion attitude to derive the stress ratio and relative driving pressure at the time of emplacement; combined with modelled and observed opening angles, we can determine whether the sills in a complex relate to a single regional stress state, or are the product of local variations. Our results indicate that the studied sills in the LSSC record periods of near-radial horizontal shortening, related to the interplay of the regional tectonic stress and volcano construction-induced stress. Sills in the SRSVF appear to relate to previously unrecognised periods of tectonic shortening, and potentially, the reactivation of major regional-scale faults. In both examples, the sills do not require bedding, and bedding is not the primary control on their geometry.