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Field data and numerical models on the emplacement of sill complexes

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There is increasing evidence that many, perhaps most, shallow magma chambers develop from sills, and many of the large chambers from clusters of sills. While individual sills have received great attention in the literature, sill complexes have received comparatively little attention. Sill complexes, however, are common in many areas worldwide, including active volcanic areas as well as in many sedimentary basins. Here we present field and geophysical data on sill complexes from sedimentary basins and, in addition, new field data on sill complexes from active volcanic areas. We combine these observational results with new numerical models on the emplacement of (a) individual sills and (b) sill complexes. Commonly, the individual sills are concave in geometry. Depending on the subsequent loading, stresses may concentrate at the margins of the solidified sills so as to rupture the chilled selvage (glassy margin) of the sill. This rupturing may have important implications for the potential of the sill acting as a fractured reservoir for various types of crustal fluids (such as oil, gas, groundwater). When the lateral dimensions of the sill become comparatively large in proportion to its depth below the free surface, the surface effects tend to have large effects on the geometry and location of the stress concentration around the sill. In particular, the stresses tend to concentrate close to and at the surface. This has clear implications for unrest periods in volcanoes that are supplied with magma from shallow sill-like magma chambers. We made many numerical models as to the formation of and local stresses around sill complexes. Some of the main results may be summarised as follows. First, in a sill complex the topmost sill is most likely the oldest one. Second, the sill with the largest lateral dimensions tends to dominate the local stress field around the sill complex as a whole, irrespective of where within the complex that sill is located. In particular, the surface stresses and deformation depends primarily on, and is related to, the regions above the lateral ends (tips) of the largest sill. Third, a sill that forms when a dyke becomes deflected along a contact can be either symmetric (double deflected) or asymmetric (single deflected). Numerical models indicate that if the contact along which the dyke is deflected into a sill is inclined, then there is a greater tendency to form a single-deflected sill than if the contact is horizontal. Field observations and numerical models also indicate that the most favourable condition for sill emplacement is a contact where there is an abrupt change from a comparatively soft rock (such as a pyroclastic rock) to a stiff rock (such as a lava flow). These conditions are commonly met in sedimentary basins, rift zones, and stratovolcanoes.