Geophysical Research Abstracts, Vol. 7, 05633, 2005
SRef-ID: 1607-7962/gra/EGU05-A-05633

How local stresses control volcanotectonic processes in composite volcanoes

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No dyke-fed volcanic eruptions take place unless the local stress field within the volcano is favourable to feeder-dyke formation. If the stress field is unfavourable to dyke propagation at any location along its potential pathway to the surface, the dyke becomes arrested, and an eruption is prevented. Recent studies indicate that most dykes never reach the surface; that is, most potential feeder-dykes become arrested in some layers and never reach the surface to feed eruptions. Similarly, no caldera-fault formation can occur, or slip on existing ring faults, unless the local stress field within the host rock favours the formation or reactivation of a dip-slip fault at the appropriate location.

Since most volcanic eruptions are fed by dykes (here the term "dyke" includes inclined sheets), and since most collapse calderas are associated with ring faults, it is clear that in order to forecast the volcanotectonic processes leading to eruptions and caldera subsidence, we must understand the local stresses in volcanoes. The local stresses, in turn, depend on the loading conditions (the tectonic regime, the magma-chamber geometry and its excess pressure) and, in particular, on the mechanical properties of the layers that constitute the volcano. A composite volcano is composed of numerous layers (strata) commonly with contrasting mechanical properties. Some layers, such as basaltic lava flows or welded pyrolastic units, may be very stiff (with a high Young's modulus), whereas other layers, such as young and non-welded pyroclastic units, are often very soft (with a low Young's modulus).

Here I present the results of new numerical models on the local stress fields in composite volcanoes. The results show, first, how the variation of the stress field ahead of

dyke tips depends on the mechanical layering, and why most dykes become arrested and never reach the surface. Second, they show the surface stresses above arrested dykes, and indicate the conditions that must be satisfied for arrested dykes to induce tension fractures or normal faults at the surface of a composite volcano. Third, the results show what stress conditions must be satisfied for ring faults to form or slip. In particular, the new models explain why ring faults form and slip so rarely during unrest periods. The numerical results also explain why the ring faults of most collapse calderas, although they are dip-slip faults, have neither the dips of ordinary normal faults nor those of ordinary reverse faults, but are rather close to vertical.

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