

Non-Double-Couple Earthquake Mechanisms

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Historically, most quantitative seismological analysis has been based on the assumption that earthquakes are caused by shear faulting, for which the equivalent force system in an isotropic medium is a pair of force couples with no net torque (a “double couple”, or DC). Observations of increasing quality and coverage, however, now resolve departures from the DC model for many earthquakes, and find some earthquakes, especially in volcanic and geothermal areas, that have strongly non-DC mechanisms [Julian *et al.*, 1998; Miller *et al.*, 1998]. Study of non-DC earthquakes can advance our understanding of a variety of phenomena, including tectonic faulting, volcanic and geothermal processes, glacial icequakes, and mine collapses. This presentation summarizes the current state of observations of non-DC earthquakes and analyzes many possible physical non-DC processes.

Contrary to long-standing assumption, sources within the Earth can sometimes have net force and torque components, described by first-rank and asymmetric second-rank moment tensors, which must be included in analyses of landslides and some volcanic phenomena. Non-DC processes that lead to conventional (symmetric second-rank) moment tensors include geometrically complex shear faulting, tensile faulting, shear faulting in an anisotropic medium, shear faulting in a heterogeneous region (e.g. near an interface), and polymorphic phase transformations.

Most microearthquakes at volcanic and geothermal areas have resolvable volume changes [e.g., Foulger and Long, 1984; Julian, 1983; Miller, 1996]. Under natural conditions, volume increases predominate, while at heavily exploited geothermal fields volume decreases and increases are about equally common [e.g., Ross *et al.*, 1999]. The volume changes of most of these earthquakes are smaller than expected for source processes involving combined shear and tensile faulting. If the source processes are of this kind, an additional volume-compensating process, such as rapid fluid flow into opening cracks, is required.

Earthquake source mechanisms do not contain enough information to uniquely diagnose physical source processes, and further information is needed to advance our understanding. The most valuable source of such additional information is provided by accurate relative earthquake locations, which delineate failure-zone geometry and orientation. At some volcanic and geothermal areas in eastern California, hypocenters clearly delineate many small fault planes, for which the source mechanisms imply that some are tensile cracks and some are Riedel shears [e.g., Foulger *et al.*, 2004]. Tensile-failure microearthquakes at one geothermal area were caused by injection of

water at only hydrostatic pressure, an unexpected observation whose explanation may require revision of our ideas about failure mechanisms in rocks.

References

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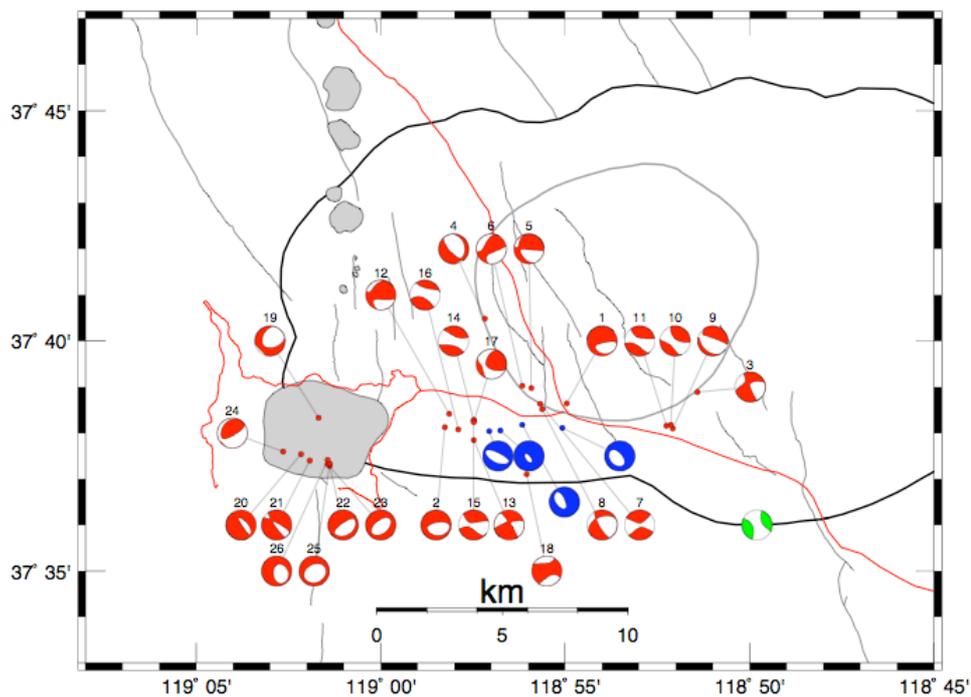


Figure: Examples of earthquake focal mechanisms, many of which are non-DC, from the Long Valley Caldera volcano, California [from Foulger *et al.*, 2004].