Geophysical Research Abstracts, Vol. 7, 02393, 2005
SRef-ID: 1607-7962/gra/EGU05-A-02393

# Fault zone properties and fault classification: the role of fault history

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For a wide variety of practical purposes, e.g. tunneling and underground excavation, exploration of hydrothermal ore deposits, geothermy and hydrocarbon exploitation, the study and prediction of anatomy of fault zones and its relevant parameters is of particular interest. Relevant properties of fault zones include a wide range of parameters including lithology, tectonic evolution, depth of fault activity within the crust, permeability and porosity, final stage of the stress and hydrological regimes and nature and origin of circulating hydrothermal fluids. Generalized models of fault zones in bedrocks distinguish between fault cores with anastomosing zones of cohesion-less rocks and mechanically stiff shear lenses and damage zone surrounding fault cores. The width ratio of fault cores and damage zones has been used to classify fault zones as these basically influences the hydrological regime and technical properties (Caine et al., 1996, Geology, 24, 1025–1028) and ore mineralization. The influence of variable lithologies, particularly the presence of thicker beds of carbonates can significantly change discussed parameters. Based on extensive field work, fault classification models have been tested and extended by application on major regional fault zones and structurally controlled ore deposits in Eastern Alps, Inner Carpathians and Altyn Mountains. Here, I report results from the study of three further parameters. These include:

(1) The ***tectonic history of fault zones*** controls the width of both fault core and damage zone as well as the ratio of widths of core and damage zones. I distinguish between: (i) In *shear/brittle fault zones* shear zone formation predate the stage of brittle/rigid behavior. Such fault zones tend to have a narrow fault core as well as a narrow damage zone. Such Shear-fault zones often limit major metamorphic complexes. The proportion of smectitic clay minerals seems to lower compared to purely brittle fault zones.

In normal shear/fault zones, the damage zone is largely confined to the hanging-wall block, which may also represent the site of major ore mineralization. (ii) *Purely brittle fault zones* comprise much wider fault cores and damage zones compared with shear/fault zones with a displacement in a similar order of magnitude. Such faults seem to have a much higher proportion of smectitic clay minerals as these minerals form directly from country rocks at shallow crustal levels.

(2) In terms of the **predominant tectonic regime** (normal, reverse and strike-slip), the hydrological regime is largely different as it controls the orientation of the open extensional and largely closed shear-extensional fissures. In such terms, reverse faults are unproblematic for geotechnical properties as the tensional fissures are subhorizonal, often not interconnected and therefore not much water is to expect. By contrast, strike-slip faults have subvertically oriented tensional fissures oblique to the strike of the fault which allows the circulation of descending and ascending water. The vertical interconnectivity of these open fissures is high. As in such zones, the fault core is often an aquitard, hot waters can be expected under specific circumstances. Detailed studies on Carpathian ore deposits show that overstep in strike-slip fault systems appear to particularly well suitable for formation of major hydrothermal ore deposits. By contrast, normal faults also tend to have vertical open fissures, particularly in the hangingwall block, but these terminate upwards. So, access of descending water is limited.

(3) The **depth of fault formation** is another parameter controlling the specific fault zone and fault rock properties at a specific level, particularly of fluid-rock interaction. Among several parameters, the depth of boiling of ascending water heavily influences fault zone properties. Below and at the level of boiling, opening of fractures is controlled by the effective pore pressure, and hydrofracturing is an important mechanism of fault propagation. Below and at the depth of boiling of ascending hydrothermal fluids, ore mineralization is particularly pronounced, and cohesionless rocks are transformed to hard rock by precipitation and cementation, forming generally cataclasites by sealing mechanisms. Such situations are widespread in epithermal gold systems, particularly when volcanic activity interferes with oversteps in strike-slip fault systems as Neogene, volcanic-hosted and fault-controlled ore deposits of Inner Carpathians.