Geochemical constraints on element mobility and volume flux in brittle shear zones of the KTB-pilot hole

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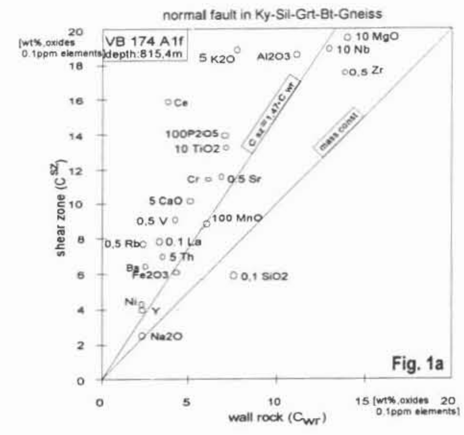
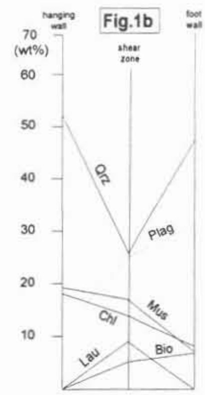
Deformation of upper crustal rocks is frequently restricted to discrete brittle shear zones where fault gouge and cataclasites are widespread reflecting high strain magnitudes. Within these zones pervasive fluid infiltration along newly formed fractures support diffusion-controlled deformation mechanisms (formation of retrograde mineral phases as well as pressure solution). These are powerful in changing both the volume (mass) and the geochemical composition of the shear zone compared to its wall rock. As primary strain marker are generally lacking in cataclasites, conventional strain analysis is not feasible. In this study combined geochemical (XRF,e.g.Fig.1a), mineralogical (XRD,e.g.Fig.1b) and microscopic analysis have been carried out on 13 shear zones and wall rock taken from the KTB-pilot well.

Realistic mass balances of altered rock provide a correction of possible volume or mass dilatations. Therefore GRESENS (1967) developed a procedure supplemented by GRANT (1986) applying the isocon-method (see also ALTENBERGER 1991). Concentration of wall rock and shear zone elements will be multiplied by a scaling factor and plotted in x-y-diagram. An isocon with a slope of 45° describes a reference of constancy in mass and volume.For mass and volume balances another reference is calculated using the immobile elements (e.g.Ti, Zr, Nb, Y, Mn).

In this study, changes in density between cataclasites and wall rock are minor (max. 1.8%). Thus mass and volume can be treated in the same way.





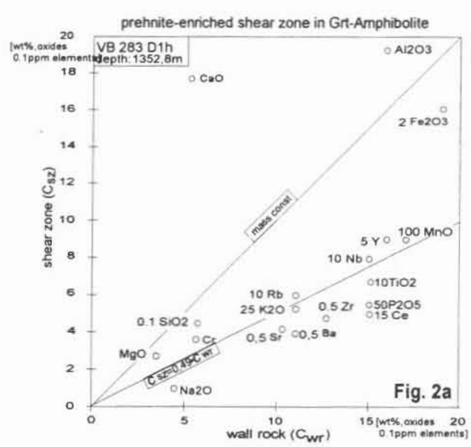
Geochemical data from various ductile shear zones indicate widely different behaviour (gain/loss of major and minor elements and of volume; O'Hara 1990; Tobisch et al. 1991; Glazner and Bartley 1991). The brittle shear zones of the KTB-pilot well record a similar behaviour. By using the isocon method 3 general cases can be distinguished.

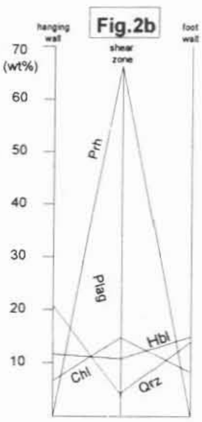
1) Volume loss of the shear zone is indicated by an increase in immobile elements (e.g.Fig.1a). The volume loss of 29% in this shear zone is largely related to the remarkable depletion in quartz (50%). This assumption is confirmed by the amount of depletion in SiO_2 (-46%). Elevated CaO content might be explained by the growth of laumontite.

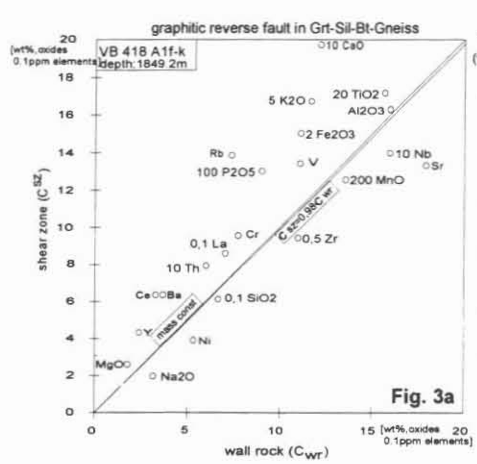
2) Volume gain has led to a decrease in immobile elements (e.g.Fig.2a) which is a characteristic feature of prehnite-enriched shear zones of metabasites. Enrichment of CaO (+600%) and Al_2O_3 (+150%) is due to synkinematic formation of prehnite. Gain in volume amounts to 104%.

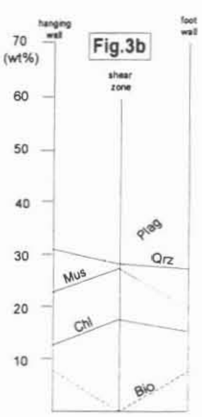
3) Volume constancy (e.g.Fig.3a). Altough the volume of the graphitic reverse fault in paragneiss (VB 418 A1f-k) does not vary, the amount of several elements has changed.

Replacement of plagioclase by white mica (Fig.3b) implies that K+ and the other potassium groupe elements such as Ba and Rb were released from the fluid phase and added to the shear zone. Simultaneously Na+ became a mobile element within the shear zone which could be removed by the fluid.









The different behaviour of the shear zones investigated is probably related to the difference in host-rock rheology. Within the more brittle metabasites fluid-filled shear and tensional fractures are likely to be stable for extended periods. Consequently, the precipitation of new minerals like prehnite is a common phenomenon. The gneisses, on the other hand, are weaker and fractures herein are less stable. By two ways, quartz contributes to strain softening and increasing ductility of the gneisses:

a) crystal plastic deformation; starting of recrystallization is especially widespread in the semibrittle graphitic shear zones.

b) pressure solution creep; provided that high fluid/rock ratios were given, pressure solution should have been very effective in removing quartz from the shear zone and thus dramatically reducing its volume.

SUMMARY AND CONCLUSIONS:

- Volumetric strain is different in metabasites (volume gain) and gneisses (volume loss or volume constancy)
- Volume loss in gneisses is largely controlled by pressure solution of quartz
- Volume gain in metabasites is due to their brittle behaviour
- Despite of nearly volume-constant deformation, the content of mobile elements (particulary of the alkalis) varies from the wall rock to the shear zone.

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