Kontinentales Tiefbohrprogramm der Bundesrepublik Deutschland

Origin of Differential Fluid Pressures in the Course of a Metamorphic Event

ORIGIN OF DIFFERENTIAL FLUID PRESSURES IN THE COURSE OF A METAMORPHIC EVENT:

Fluid inclusion study in basement rocks of the Moldanubian Zone/Central Schwarzwald.

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OBSERVATIONS: Unusual patterns of fluid inclusions have been found in basement rocks of the Central Schwarzwald. Sheared and squashed cavities are very abundant locally. Fluid inclusions are typically arranged along healed microcracks or follow grain and subgrain boundaries. (plates: 1)

Most conspicuous features are:
Wide scatter in salinities from 0.5 to 15 % wt NaCl and in densities from less than 0.2 to 0.9 g/cm^3 (fig. 1, plate 2). $CaCl_2$ is probably present in some inclusions.

Gases: Trace amounts of CO_2 and CH_4 have been found ubiquitously, the latter abundantly in graphite bearing gneisses. Small droplets of a bituminous liquid appear locally in a series of hydrosaline cavities.

Patterns as observed indicate that the fluids and their host rock must have been submitted to a **posttrapping dynamic event.**

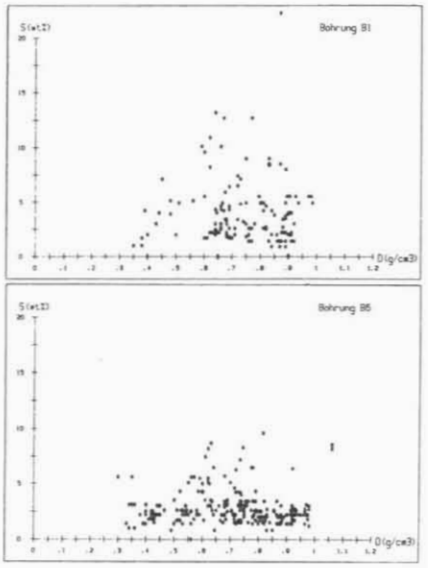


Fig. 1: Broadly scattering microthermic data, salinities versus densities of hydrosaline inclusions from two geothermal research wells (B1 = Hechtsberg, B6 = Geschahse).

Plate 1: Grain boundaries in quartz closely covered by fluid inclusions (80x, Zindelstein)

Plate 2: Closely spaced cavities with hydrosaline solution of different densities (500x, Hechtsberg)

INTERPRETATION: During a metamorphic cycle rocks follow a PT course as depicted schematically in fig. 2.
During all stages fluid inclusions may be trapped in minerals. Up to the time of closure of cavities internal and external pressures are identical. Afterwards, however, the development of pressure inside the inclusion follows its particular isochore defined by the conditions of trapping, whereas the outer pressure is determined by lithostatic PT conditions (rock overburden). Usually the two pressure regimes are not identical.

Prograde path: Development of high internal overpressures in fluid inclusions upon further heating causes cracking of the cavities with leakage of volatiles until pressure equilibrium is attained. Thus contents and PT conditions of hydrosaline inclusions formed during prograde mineral growth will not survive. The PT conditions to be preserved are those of the peak of metamorphism, which has been estimated at about 700°C and 3 to 4 kbars in the Central Schwarzwald.

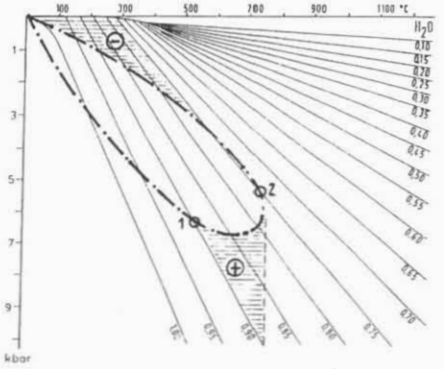
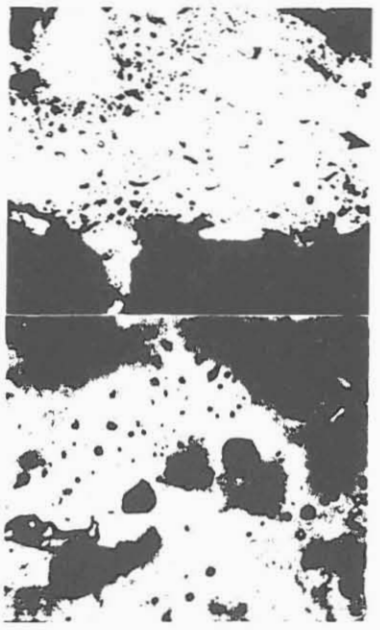


Fig. 2: Development of differential pressures (schematically) during a metamorphic cycle.
[1], [2], fluid trapping on the prograde resp. retrograde branch.



Retrograde path: Presumably the host crystals normally are sufficiently rigid to support the progressive development of internal underpressures in fluid inclusions. Zonal arrangements of fluid cavities, nevertheless, cause centers of hydrolytic weakening thus creating planes of mechanical instability when submitted to external stress. Under tectonic stress fluid cavities are sheared and finally disrupted with mobilization and/or escape of volatiles (plates 1,2) and rearrangement in newly formed inclusions.
In extensional regimes below about 400°C two phase L/V-equilibria must be established in all hydrosaline fluids. Liquid-to-vapour ratios and salt in concentration of residual solutions are controlled by fissure volumes. Healing of cracks in crystals will give rise to very different types of closely associated fluid-filled cavities depending ultimately on the Δ P-regime (whether compression or extension) upon closing of the microsystem.

Although changed in composition and phase ratios, liquids, gases and solutes in these "secondary" fluid inclusions are of primary origin and must preserve certain primary features (e.g. isotope-)ratios.

CONCLUSIONS:

1. Upon cooling **internal underpressures** are developped in fluid inclusions. MaximumΔP is about 1.5 kbars at 300°C (fig. 3).
2. If rocks containing minerals with underpressured fluid inclusions are subject to late deformational stresses the inclusions become centers of mechanical weakness. This results in **liberation of fluids,** promotion of **rock deformation** and **rearrangement of fluid inclusions** with the appearence of low grade fluids.
3. It is **not necessary to assume "flooding"** a low temperature fluids to explain the occurrence of low grade inclusions.
4. The **seismic low velocity** channel below Haslach as well as the **high conductivity zone** correlate with recent regimes of maximum Δ P and might well originate from the **rearrangement of fluids from fluid inclusions.**
5. Processes as described above will occur in all areas of postmetamorphic deformation.

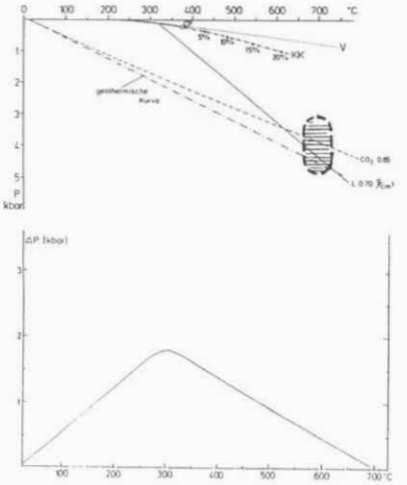


Fig. 3: Negative ΔP up to 1,5 kbars near the 300°C level in gneiss rocks from the target area near Haslach.