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LATE CRETACEOUS EXHUMATION HISTORY OF AN EXTENSIONAL ALLOCHTHON (GRAZ NAPPE COMPLEX, AUSTRIA)

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The eastern margin of the Graz Nappe Complex defines a large scale extensional shear zone. Two different P-T-D paths extracted from northern and southern areas at the eastern margin of the Graz Nappe Complex (Strassegg and Naintsch area, Fig. 1) were estimated using conventional thermobarometry, fluid inclusion and structural studies.

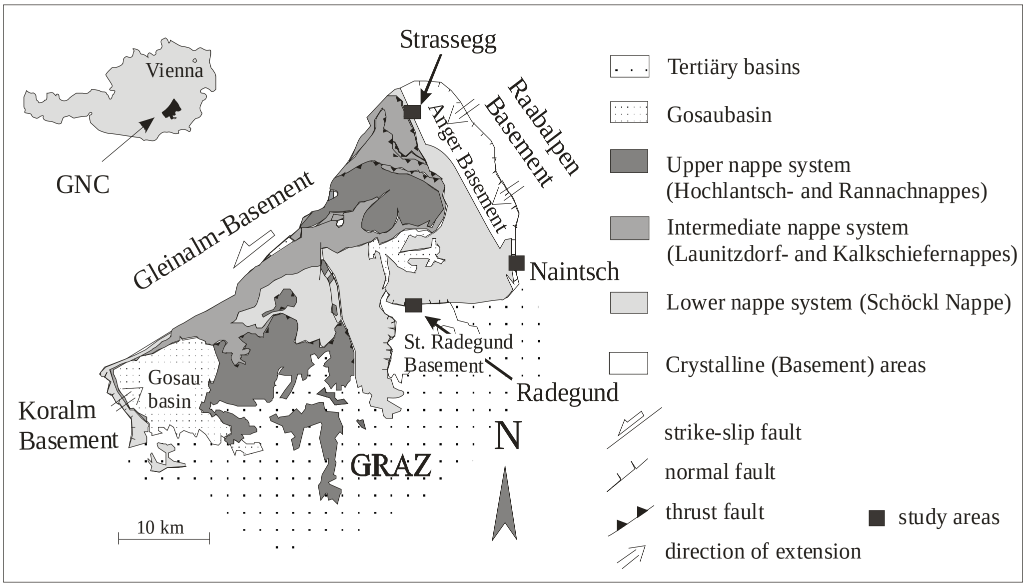

Fig. 1 Simplified geological map of the Graz Nappe Complex including the locations of the study areas.

Both study areas are comparable by their tectonic evolution and show nearly same deformational stages. Within the Strassegg area three different quartz vein generations were distinguished, which record various stages of progressive deformation and metamorphism. After peak of metamorphism around 6 kbar and 500°C, a P-T-deformational path shows "pseudo-isochoric" cooling down to ca. 3 kbar and 300°C (Fig. 2a). Late stage deformation under sub-simple shear divergent conditions and normal faulting is related to horizontal extension and steepening of the P-T loop by isothermal decompression (ITD) to below 1 kbar. Finally rocks cooled isobarically (IBC) at shallow crustal level. This retrograde decompressional path was associated with a change in fluid regime by unmixing of a single parent metamorphic fluid, leading to the coexistence of CO_2-H_2O-NaCl-rich and H_2O-NaCl-rich fluids that caused precipitation of sulfides and gold. Ore precipitation took place along "pseudo-isochoric" cooling down to 8-9 km (2.5-3 kbar). Latest H_2O-NaCl-rich fluids represent fluid infiltration by shallow crustal faults.

Data from the Naintsch area reflect a more steepened isothermal decompressive path (Fig. 2b). Fluid inclusions consist of H_2O-NaCl-$CaCl_2$±$MgCl_2$ chemistry. Thermobatrometric data give peak metamorphic conditions around 580-600°C and pressures around 7 to 9 kbar based on garnet-biotite thermometer and garnet-biotite-muscovite-plagioclase barometer. This data show higher peak metamorphic conditions compared to the Strassegg area.

Fluid Inclusion microthermometry of extensionally quartz vein generations and thermobarometric data from garnet-biotite schists, which host the quartz veins, reflect nearly isothermal decompression followed by final isobaric cooling. Additionally, garnet growth within this area is documented by major element zoning patterns and rotated inclusion trails of ilmenite inclusions, which are distinguished by different growth stages (Fig. 2b).

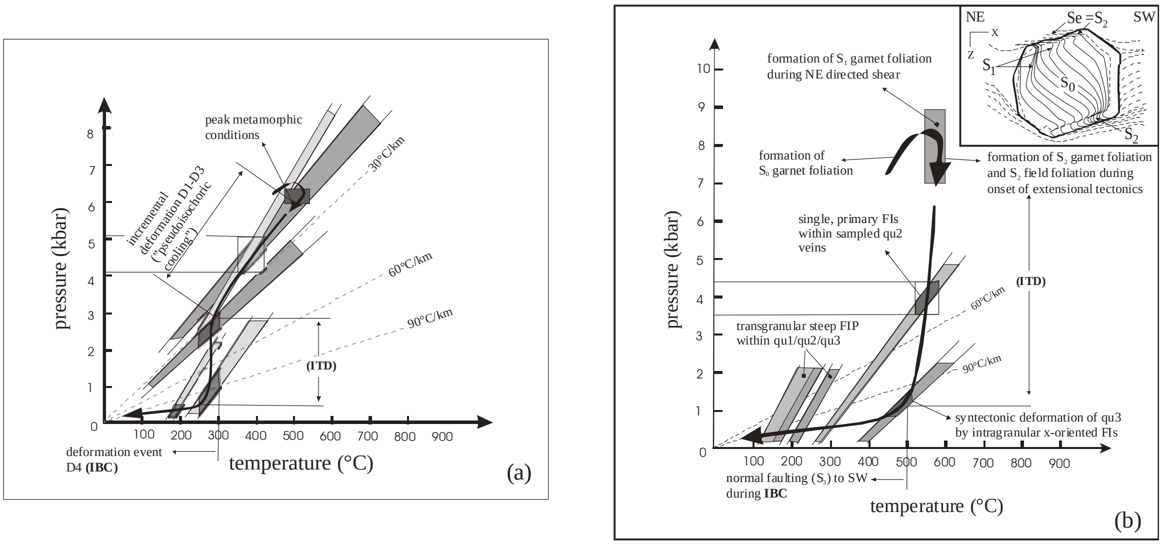

Fig.2: P-T-D path, deformation events (D1-D4) and quartz vein generations (Qu1-Qu3) based on structural and fluid-inclusion data at Strassegg (a) and Naintsch (b).

Differences in the P-T evolutionary paths between Naintsch and Strassegg are explained by exhumation from different crustal levels (Fig. 3):

(1) P-T-D paths indicate that the rocks at Naintsch exhumed from a deeper structural level. The pressure difference of peak metamorphic conditions (conditions of onset of deformation) is about 2kbar; however, the temperatures are very similar. This may reflect inclined paleothermal isogrades during onset of exhumation.

(2) Both P-T-D paths show pronounced branches of ITD followed by IBC. A rise of the local paleo-geotherm by heat advection during rock exhumation is implied. Rocks were exposed rapidly close to the surface (ITD) and then cooled slowly (IBC). The thermal effect of this exhumation is seen in narrow metamorphic field gradients with increasing of temperatures from ca. 300°C (hangingwall) to ca. 550°C (footwall) over few kilometres.

(3) Although both P-T-D evolutionary paths show ITD followed by IBC, the decompression path at Naintsch is much steeper and started from higher pressures. This corresponds with the position of the studied areas within the extensional shear zone. Rocks in the footwall (Naintsch) cooled more rapidly and evolved ITD whereas in hangingwall rocks (Strassegg) a pseudo-isochoric branch is preserved. The overall shape of the extensional corridor provides another argument for exhumation from different levels. The corridor, best defined as domain between Lower Austroalpine Raabalpen Basement and Upper Austroalpine GNC (Fig. 1), is very narrow in the south (Naintsch: ca 1500m) and widens to the north (Strasseg: ca 6000m). This goes along with the width of paleo-thermal isogrades, which are much more condensed in the south.

(4) The shift from ITD to IBC seems to correlate with the flow geometry of rocks. Early extensional phases with sub-simple convergent shear can be related to vertical rock movement and consequently ITD. Late phases with sub-simple divergent flow translate to horizontal extension which may correlate with IBC.

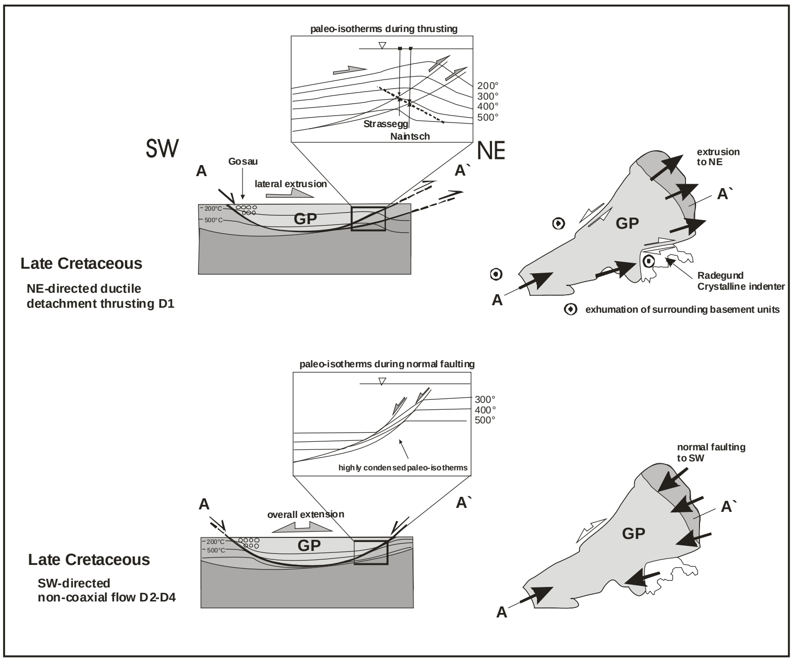

Fig.3: Qualitative structural model representing the evolution of the GNC prior to the onset of extensional tectonics during Late Cretaceous. (a) Profiles define isotherms after thrusting during updoming of the surrounding Basement Units and NE directed flow. Box shows the assumed crustal location of the study areas, indicated on a hypothetical paleo-isotherm with nearly same temperatures but differences in pressures. (b) Highly condensed isotherms as a consequence of SW-oriented extension.

Combining available data from Late Cretaceous structural elements we argue for a large scale extension – extrusion corridor that evolved prior to the well known Miocene extrusion tectonics in the Eastern Alps.

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