THE COALIFICATION MAP OF THE ALPS BETWEEN THE RIVERS INN, ISAR AND RHEIN (AUSTRIA AND SWITZERLAND)

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Coalification studies at the Technical University of Aachen, the University of Basel and the University of Frankfurt over the last sixteen years are summarised. Since the first use of vitrinite reflectance (VR) measurements in the study area in 1980, VR studies are the most advanced technique of our multi-methodological determinations of diagenesis and low temperature metamorphism. The coalification map is based on more than 2300 VR measurements, including data from literature and data from research wells. The data set gives one of the largest VR-compilations in an area of 1250 km^2 of sedimentary cover units. Data are presented by contour mapping, expressed as isorank areas of VR, using the MSDOS-program »Surfer« and the Mac-program »Spyglass«. This map shows no tectonic interpretation (nappe limites, faults, folds). In a second map the coalification pattern is calculated for each tectonic unit, therefore the VR-values are indicating a tectonic interpretation. Combined with some cross sections through the nappe system, VR-data give a three dimensional view of the rock maturity distribution and crosscutting relations between deformation (D) and metamorphism (M).

The main results from rock maturity mapping are:

1) There are three main »heating events« (M1 to M3) within the Austroalpine system.

2) In the highest tectonic units, in the Silvretta nappe and the Krabachjoch nappe, peak metamorphism (M1) occured pre-D1 (thrusting and folding). At the master fault a very conspicuous metamorphic inversion is typical. Both nappes are showing an allochthonous maturity pattem. Hyperthermal coalification gradients in Permo-Triassic formations in the Upper Austroalpine are the effect of diastathermal metamorphism in connection with crustal thinning during Permian graben tectonics and Triassic aborted extensional deformation, related to rifting in the Hallstatt-Vardar ocean.

3) Jurassic heating during onset of rifting in the Ligurian-Piemontais ocean domain alone can not explain the rank-pattern in Permo-Triassic sediments, but may have caused a burial recoalification of Permian to Jurassic sediments. Cretaceous D1-thrusting and folding and D2-normal faulting and D3-folding causes a dramatic deformation of isorank lines. Positive coalification anomalies are related to anticlinal structures and low rank anomalies to synclines.

4) Alpine heating under dynamothermal conditions (orogenic metamorphism, M2) is required for sediments younger than Norian: **4a)** The overall observed great change in the slope of coalification at the level of the Norian sediments yielded information about the existence of a second important re-coalification event. **4b)** In cross sections through the nappe edifice, coalification increases from the top to the base of the Upper Austroalpine nappe sheet. **4c)** If the rank slope in the uppermost unit is extrapolated to the lower nappe pile, the recorded VR-data from Norian to Cretaceous sediments fit into this gradient. **4d)** Numerical modeling clearly demonstrates that the coalification pattern in the Upper Austroalpine can only be the result of a minimum of two heating processes.

5) Syn- to post-nappe tectonic heating at the southern rim of the Northern Calcareous Alps indicated by coalification near the vitrinite-graphite jump can not be explained by burial. M3-heating occured during and after D1- to D2-thrusting in the north and extensional D2-faulting in the Silvretta area. Late Cretaceous heating is evident, because M2 and M3 show metamorphic inversion at the base of the Upper Austroalpine.

6) In the Oberhalbstein area, stockwerk-tectonics controls the coalification pattern. **6a)** At the base of the middle stockwerk, at the Turba mylonite-cataclastite zone, a progressive conspicuous metamorphic hiatus is evident. This is one of the major new tectonic structures discovered in the study area, and can be followed for about 90 km from the Bergell intrusion to the N until Klosters. **6b)** In the middle stockwerk, incipient metamorphism (M2) occured syn- to post-D1 and pre- to syn-D2, but pre-D3.

7) In the north, post-nappe tectonic diagenesis (sub bituminous to semi-anthracite rank) has obliterated disconformities at nappe thrusts between the Helvetic, the North and South Penninic units. This maturity pattern is related to post-Rupelian metamorphism (M5).

8a) In the western part of the Lechtal nappe, maturity inversion over the Penninic nappes is proved. The same pattern is obvious at the imbrications of the Lechtal nappe and the Arosa zone. **8b)** The Arosa zone is also marked by diagenetic inversion to the Rhenodanubic flysch. Therefore, the Northern Calcareous Alps first overthrusted the Arosa zone (D1) and then together the North Penninic flysch (after M3 during D3).

9) In Penninic nappes to the south of the Lechtal nappe the situation is different. In the whole area a post thrust and melange tectonic heating (M4) overprinted the nappe wedge. This maturity pattern is disturbed in the Penninic and Helvetic units by Tertiary D3- to D5-deformations and is therefore of pre-Rupelian time. Tertiary D1- and D2-structures do not deform the coalification pattern.

10) In the North Penninic units, a thinning of coalification zones is evident in the area of Chur. A not well mapped shear zone is located.

11) The Alpine M1- to M5-maturity pattern is transported onto the Molasse showing a maturity inversion.

Five heating events (M1 to M5) are causing different maturity patterns.