

Alteration at the base of the Verrucano-hangingwall along the Glarus thrust, eastern Switzerland

Hürzeler Jean-Pierre*, Schmid Stefan*, Abart Rainer**.

* Institute of Geology and Paleontology, Department of Geosciences, University of Basel, Switzerland.

**Institute of Petrology and Mineralogy, Free University of Berlin, Germany.

Along the Glarus thrust different lithologies that are part of the footwall are in contact with one single but lithologically rather heterogeneous siliciclastic lithological unit forming the hangingwall, referred to as "Verrucano". In the northern part of the thrust North Helvetic Flysch, Blattengrat Units and Sardona Units in the footwall are in contact with a facies of Verrucano that contains abundant lithic clasts from metamorphic, volcanic and granitoid sources. In contrast, in the south the Mesozoic para-autochthonous cover of the Aaremassif was cut by a Verrucano-hangingwall of mostly volcanoclastic composition. Pre-existing fold structures in the footwall were decapitated along a sharp tectonic contact. The decapitated Cretaceous to Jurassic carbonate units from the footwall can be found further north as tectonic slivers along the thrust and are referred to as "Infrahelvetic slices". The infrahelvetic carbonates have been preserved largely undeformed in the central parts of the Infrahelvetic slices but become progressively more tectonized towards the margins. The oxygen isotope signal of the Infrahelvetic slices is between 23 and 26 ‰ $d^{18}O(V-SMOV)$. This indicates that they are derived from primary marine carbonates, which largely have preserved their diagenetic signature. In contrast, the carbonate at Lochseiten locality ($d^{18}O(V-SMOV) = 19$ to 21 ‰) is in oxygen isotope equilibrium with the North Helvetic Flysch in the footwall; the oxygen isotope signature of a precursor carbonate, if any, is completely obliterated. This was interpreted by Abart et al. (2002) as evidence for upwards directed fluid flow across the thrust, which also caused chemical and isotopic alteration of the basal portions of the Verrucano in the hanging wall. The compacting and dehydrating Flysch units in the footwall were identified as the fluid source. Despite the fact that the Cretaceous carbonate units in the footwall of the southern section of the thrust do not have any potential for dehydration, it was anticipated from field observation, that the base of the Verrucano in the hangingwall was chemically and mineralogically altered. This motivated a systematic study of bulk rock chemical compositions, mineralogical and stable isotope patterns along sub-vertical profiles across the thrust. Sampling localities were chosen to cover all different types of footwall-hangingwall-Lochseiten calc-tectonite arrangements and to allow for sampling of at least several meters in both footwall and hangingwall lithologies. The sampling localities are shown in figure 1.

Bulk rock compositions show systematic changes from within the Verrucano towards its base. The calcite impregnation of the lowermost Verrucano, which was described by Abart et al. (2002) can, for instance, be explained by calcite dissolution in the footwall limestones as is indicated for the Grauberg locality by an increase in the SiO_2 and Al_2O_3 contents in the uppermost footwall limestone. This alteration trend indicates removal of calcite by dissolution and associated passive enrichment of white mica. For the lowermost Verrucano a depletion of Na_2O and a concomitant enrichment of K_2O can be observed. The decreasing trend of alkali contents toward the thrust plane at the base of the Verrucano cannot be explained by passive dilution

due to the infiltration of carbonate from below, because this would imply constant element ratios between the alkali metals and among the alkali metals and the other immobile elements. Element ratios vary, however, substantially along the profiles indicating selective addition or removal of individual components.

Mineral modes were estimated from normative calculations based on independently determined bulk rock and mineral compositions. The modal calculations made for the Graue Hörner profile reflects well the observations made in thin sections. Alkali feldspar is successively replaced by muscovite and sericite, whereas albite is formed in quartz-muscovite-albite domains that develop in deformation shadows of larger clasts. Normative albite decreases dramatically only in the last decimetres above the thrust. In the sampling profile from Piz Grisch in the southern section of the exposed portion of the thrust the estimated mineral modes are extremely heterogeneous. This reflects the lithological and chemical heterogeneity of the Verrucano in this outcrop where a volcanoclastic and a marly facies are interlayered on a decimetre scale.

Along a several hundred metres long subvertical profile Arkay et al. (1997) demonstrated that illite crystallinity is significantly lower in the footwall flysch than in the hangingwall Verrucano. This was interpreted as evidence for transported metamorphism. Unfortunately the sampling intervals were so large that local variations at the thrust could not be detected. This motivated detailed sampling and analysis of illite and chlorite crystallinity in the immediate vicinity of the thrust in this project. Despite of the small number of analysed samples, they seem to indicate a persistent trend of decreasing illite crystallinity within the Verrucano down to the thrust plane. Such a trend has been observed over the bottommost four metres of the Verrucano at the Lochseiten locality and over the bottommost 40 metres at Piz Grisch.

If the illite crystallinity were employed as a geothermometer using the calibration of Kisch (1991), the observed crystallinity variation would indicate a temperature decrease of about 30°C within the basal 40 metres of the Verrucano at the Piz Grisch locality and of about 70°C within the basal 4 metres of the Verrucano at the Lochseite locality. Such a temperature regime is very unlikely, and we ascribe the variations in illite crystallinity to a downward increase in the intensity of illite (re)crystallization during thrusting. Illite formation during the decomposition of feldspar (Abart and Ramseyer 2002) and the re-crystallization of "old" (detrital) white mica in high strain zones are two possible mechanisms that may explain the progressive downward decrease in illite crystallinity at the base of the Verrucano.

The clear decreasing trend of chlorite and illite crystallinity, the bulk chemical and stable isotope signatures as well as the observed patterns in mineral modes indicate only a rather localized alteration zone developed in the base of the Verrucano during thrusting. The zone of intense deformation, mineral reaction, fluid circulation and chemical alteration appear to coincide spatially testifying to the intimate feedback among these processes.

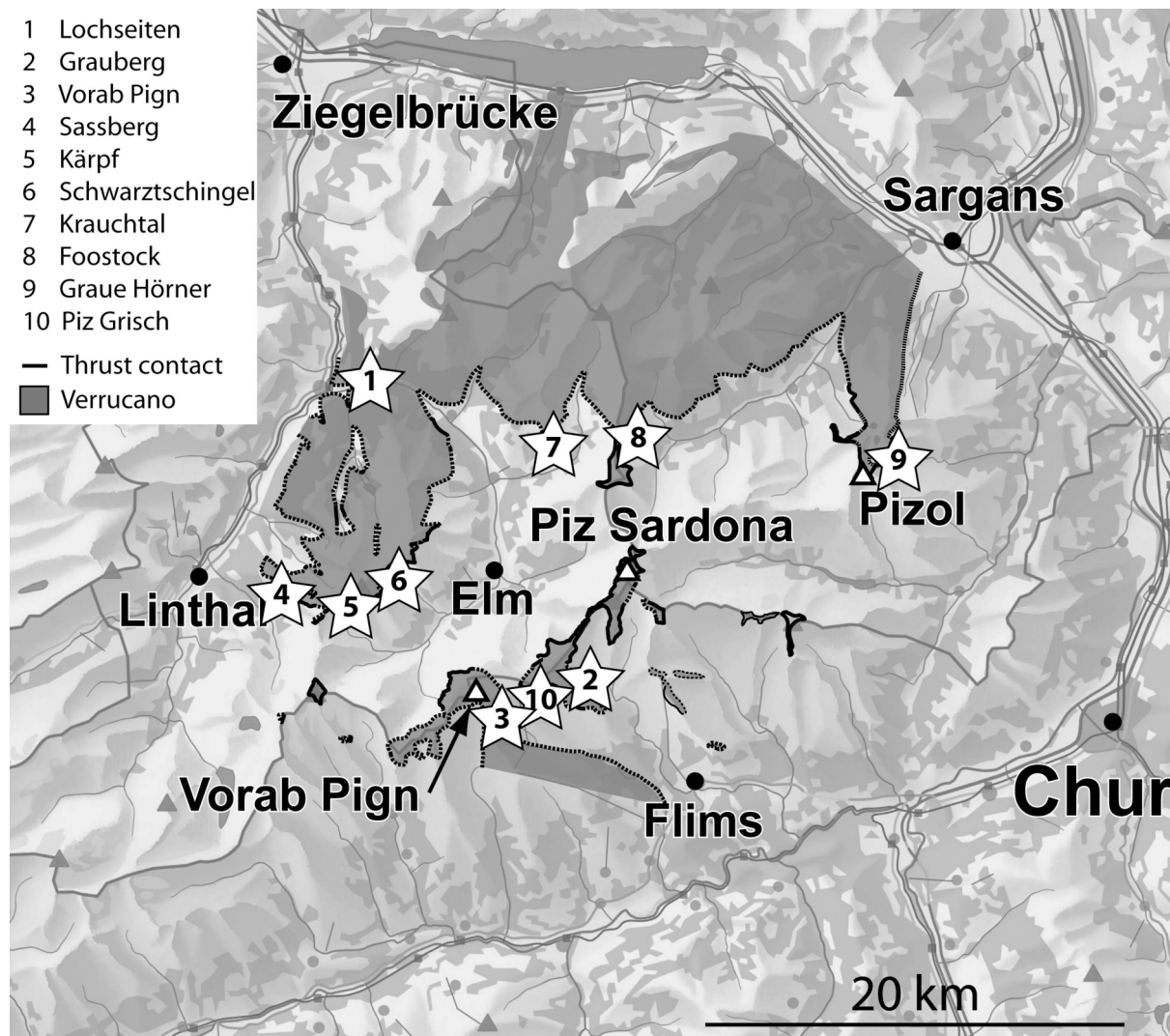


Figure 1. Overview of the different outcrops at the Glarus thrust.

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