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Geology and evolution of the Proterozoic-Paleozoic basement in the Alps: an introduction

by *Urs Schaltegger*[1]

Why should we bother about the early Paleozoic and Proterozoic evolution of the Alpine basement? There are too many unresolved problems concerning Alpine and Variscan orogenic evolutions that should be treated with priority! Any extrapolation further backwards remains purely speculative and is thus not interesting.

This provoking comment of one of my colleagues (we will not mention his name here!) was the start for this special volume of the Swiss Bulletin of Mineralogy and Petrology. The volume could be realized by a combined effort of colleagues from Austria, Germany, Italy and Switzerland, in order to summarize the state of knowledge on this topic in various areas of the Alps, and/or to present new evidence for the story of the Alpine region going beyond the Variscan orogenic cycle! It is thus the logic extrapolation and extension of VON RAUMER and NEUBAUER'S (1993) treatise on "Pre-Mesozoic Geology in the Alps". It is a matter of fact that the Alpine basement displays a nearly continuous outcrop of the Variscan orogen and is the best place to study Variscan and pre-Variscan orogenic processes, despite the Alpine overprint. This is a further argument to focus our interest onto the Alpine area and its Paleozoic-Proterozoic evolution.

Looking through this special volume, the reader realizes the emphasis put on the evolution of the Silvretta and Ötztal crystalline complexes (Austria/Switzerland), reflected by research papers of HOINKES et al., POLLER, KLÖTZLI-CHOWANETZ et al., KÖPPEL et al. and SCHALTEGGER et al. The focus on this area is fortuitous and just reflects a common research interest of several university institutes in Europe. Proterozoic-Early Paleozoic terranes are, in contrary, spread over the entire Alpine basement, from Austroalpine and Penninic units of the Eastern Alps (SCHULZ, and VON QUADT et al., this vol., in addition to the manuscripts mentioned above) to the central and western Alps (EISELE et al., this vol.) and Southern Alps (BORIANI and VILLA, ZURBRIGGEN et al., this vol.).

The investigation of geological processes in the far past demands the application of quantitative techniques in petrology, structural geology, geochemistry and geochronology. With the help of these methods we are able to correlate between terranes that have been disrupted, overprinted, moved around and reassembled by subsequent orogenic processes. Far-field correlations in geology often use distinct magmatic events of large regional importance. The Proterozoic-Early Paleozoic terranes within the Alpine basement host rocks formed during two important magmatic phases on the former Gondwana continental shelf:

(a) oceanic magmatism of late Precambrian to Ordovician age took place in both divergent and convergent settings. The resulting rocks are ophiolitic assemblages (MÉNOT et al., 1988), continental tholeiites (VON RAUMER et al., 1990), and members of ocean-island or island-arc systems (EISELE et al., VON QUADT et al., SCHALTEGGER et al., this vol.; ABRECHT et al., 1995; STILLE and TATSUMOTO, 1985). Geochemical characterization is the only way to distinguish between the different settings, which leads into all the problems of dealing with polymetamorphic rocks. This oceanic stage probably started at around 530 Ma and ended at ca. 470 Ma (ABRECHT et al., 1995; GEBAUER and SÖLLNER, 1993; GEBAUER et al., 1988; MILLER and THÖNI, 1996; OBERLI et al., 1994; VON QUADT, 1992; VON QUADT et al., SCHALTEGGER et al., this vol.). At the same time, granites and migmatites were formed on a continental mass, remnants of which can be found in Silvretta and Ötztal units (KLÖTZLI-CHOWANETZ et al., POLLER, this vol.) or in the Bohemian massif (e.g. KRÖNER et al., 1994).

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(b) A second phase of continental acid magmatism is of paramount importance, forming vast orthogneiss terranes spread over the entire Alpine basement. As recent studies show (BUSSY and VON RAUMER, 1994; POLLER et al., 1997; SCHALTEGGER, 1993; SERGEEV and STEIGER, 1993; ZURBRIGGEN et al., this vol.), it spans an age range from ca 460 to 430 Ma in the Upper Ordovician and coincides with acid volcanism in Upper Austroalpine units (LOESCHKE and HEINISCH, 1993).

KÖPPEL et al. (this vol.) use the Pb isotopic approach to model source compositions and mantle/crust ratios of some of group a and b rocks in the Silvetta nappe, demonstrating the presence of a continental mass that has been structured and mainly formed during the Cadomian orogenic cycle, a conclusion that also can be derived from Nd isotopes (SCHALTEGGER et al., this vol.). What about the isotopic age results at around 1 Ga, published by STILLE and TATSUMOTO (1985), SCHENK-WENGER and STILLE (1990), and MAGGETTI and FLISCH (1993)? This problem is addressed in the manuscript by VON QUADT et al. (this vol.): Their 870 Ma whole-rock isochron of amphibolites from the Tauern Window is assumed not to represent any geological event since no zircon U–Pb data exist that could substantiate an event at that time. There is only one exception, i.e. the 870 Ma-old SHRIMP U–Pb zircon age by GEBAUER et al. (1988) from the Gotthard massif. A mantle event has generally been invoked to explain ages around 0.9 Ga. On the other hand, there are plenty of indications for the existence of ca 0.6–0.65 Ga-old protoliths in the Alpine basement, one of them being dated by SCHALTEGGER et al. (this vol.) in the Silvretta unit.

The assembly of all the Proterozoic–Early Paleozoic terranes was subsequently covered by sediments of a passive continental margin during the Devonian and acted as substratum for the Variscan orogenic evolution. Knowledge of the pre-Variscan lithologies and structures is therefore crucial for the understanding of the Variscan (and Alpine) processes, especially for the onset of Variscan collision and its temporal definition. Variscan overprinting of Proterozoic–Early Paleozoic assemblages is the topic of the manuscripts by SCHULZ, BORIANI and VILLA, and ZURBRIGGEN et al. (all this vol.).

In a conclusive remark, I would like to address two aspects: (1) What is the importance of Proterozoic–Early Paleozoic terrane studies for the younger orogenic cycles, and (2) what has to be done in future in order to proceed to a more coherent picture of Proterozoic–Early Paleozoic units in the Alpine basement?

(1) The characterization of the former Gondwana continental margin is a pre-requisite for reconstruction of the Devonian plate assembly at the onset of Variscan orogenesis. It may answer the question whether there has been a microcontinent between the two large continental plates (Laurasia and Gondwana), for which we find evidence in the Silvretta nappe (POLLER; SCHALTEGGER et al., this vol.) and in the Southern Alps (ZURBRIGGEN et al., this vol.). It may also help to determine where, when and how Variscan orogeny started, an enigmatic problem for the Alpine basement.

(2) Correlations are only meaningful, if we do not compare apples with pears: We need exactly coeval rock suites within the same geodynamic setting to be compared. This asks for integrated studies comprising precise geochronology with optimum precision of ±1 to 2 million years, achievable with state-of-the-art U–Pb techniques, involving procedural Pb blanks on the picogram and subpicogram level, as well as reliable geochemical and isotope geochemical data. The relationship between sedimentary facies and magmatism has to be established, which may give important information on the geodynamic setting, even in polymetamorphic terranes. This may be achieved by looking at relic fossils even in high-grade rocks (see HANEL et al., 1997), dating detrital zircons and establishing a Nd isotope "stratigraphy" of the metasediments. All this is hard to achieve and it still needs lots of effort to get there.

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