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Transition from Penninic to Austroalpine units in the Bergell Alps: Introduction

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The Bergell Alps are a key area for the understanding of the pre-Alpine and Alpine evolution of the Eastern Central Alps. The present collection of papers summarizes results of recent research projects aimed at studying petrographic and structural features of the Bergell intrusion and the adjacent Penninic and Austroalpine units. Most of the research reported here was supported by various grants from the Schweizerischer Nationalfonds.

The geological interest in the Bergell Alps was ignited during the last century by reports of STUDER (1851) and THEOBALD (1866), but it was not until the early 20th century that this area was studied systematically. Important contributions to the understanding of the Bergell Alps were made by CORNELIUS (1913), STEINMANN (1913), and later by STAUB (e.g., 1918, 1921, 1946) who studied and mapped the area in great detail. Since then, numerous investigators have worked extensively in this part of the Alps (see reference lists in individual papers of this volume); foremost among them is V. Trommsdorff who launched a great number of field projects and introduced many of his students and colleagues to the fascinating geology of this unique area.

The name "*Bergell*" is the German equivalent of "*Bregaglia*" and geographically has two different meanings[1]: it either simply refers to Val Bregaglia, i.e. the southwestern continuation of the Engadine valley, or it designates the whole mountain range ("Bergell Alps") between Val Bregaglia, Valle della Mera, Valtellina, Valmalenco, Val Muretto and Val Forno (cf. maps in this volume). Geologically, "Bergell" refers to a Tertiary pluton in the border region between Switzerland and Italy; it extends from Val Forno in the East to Giubiasco (near Bellinzona) in the West (see Fig. 1 in BERGER et al., 1996, this volume). The Bergell pluton, also known as *Massiccio di Val Masino-Bregaglia* or as *Bregaglia-Iorio Intrusion*, is a calc-alkaline suite of gabbro, diorite, tonalite, granodiorite, and granitic aplites and pegmatites, and occurs in a unique structural setting: It is surrounded by tectonic units comprising the entire stack of Alpine nappes from the Penninic Adula-Gruf nappe to the Upper Austroalpine units and the Southern Alps. The structural relations between intrusives and country rocks thus, provide important constraints on the geological evolution of this area.

Some post-intrusive stages of this geological evolution, had a profound impact on the natural

[1] In this part of the Alps, spelling of geographic names is sometimes confusing because Italian, Rhaetoromanish and German as official languages are spoken with distinct dialects in closely adjoining areas. Readers should refer to the "Schweizerische Landeskarte" which relies on consistent linguistic rules and, besides that, is indispensable for field trips in the area. We recommend the following map sheets (scale 1 : 50'000): #267 San Bernardino, #268 Julierpass, #269 Berninapass, #277 Roveredo, #278 Monte Disgrazia, and #279 Brusio.

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history of the area: Today, after the Late Tertiary uplift and the Quaternary glaciation, Piz Lunghin, a prominent mountain at the northeastern edge of the Bergell Alps, is a major European watershed draining into the Atlantic Ocean (via the Gelgia/Julia and Rhine), the Black Sea (via the En/Inn and Danube), and the Mediterranean (via the Maira/Mera and Po). The extensive glacial erosion further led to the development of clear cultural differences between Val Bregaglia and the Engadine valley; this is documented, for example, by the fact that inhabitants of the Engadine speak the Rhaetoromanish (or Romansh) language, whereas inhabitants of Val Bregaglia speak *Bargaiot*, a distinct Italian dialect which combines Rhaetoromanish and Lombardic elements.

The documented history of Val Bregaglia is very interesting and, as a consequence of the geological evolution, quite different from that of the Engadine. Only a few events shall be mentioned here, however (for a summary, see e.g., POESCHEL, 1943; STAMPA, 1964). The first written reference to the Bergell was made in 46 A.D., when the inhabitants of Val Bregaglia were addressed as *bergalei* by the Roman Emperor Claudius. After conquering other parts of Rhaetia in 15 B.C., the Romans used Val Bregaglia as a short passage from *Clavenna* (now Chiavenna, Italy) across the Septimer or Julier passes to *Curia Rhaetorum* (now Chur, Switzerland). This mountain road was guarded by several watch towers or stations, one of which, *Murus* or *Castellum ad Murum* (present day Castelmur), was located on the strategically important ridge above Promontogno. This prominent geomorphologic landmark, locally known as *Müraia* or *Porta*, consists of Tambo gneisses and has a significant impact on vegetation and climatic conditions in the valley. This ridge was historically important again in the 16th century when Val Bregaglia was divided into two politically and ecclesiastically separate parts, Sotto Porta and Sopra Porta (down river and upriver from ridge, respectively).

The Bergell has become famous not only for its historical monuments, its natural beauty, geology, or climbing opportunities, but also because it was the home of a renowned family of artists, the Giacomettis, including Alberto Giacometti, a leading modern sculptor, Giovanni (Albertos father), and Augusto (a distant cousin of Giovanni), both highly acclaimed painters. An excellent overview of the natural and cultural history of the Bergell Alps can be obtained by visiting the local museums at Stampa (Val Bregaglia), Morbegno (Valtellina) and Chiesa (Val Malenco).

Some aspects of the natural history of the Bergell Alps are assessed in the articles collected in the present volume. Many of the reported geological observations could not have been made without extensive and challenging field work in high Alpine country and remote areas. The eleven articles address various geological topics and are arranged thematically.

In the first paper, SCHMID et al. introduce the reader to the Bergell Alps by presenting a summary of the regional geological situation. This paper, written as explanatory text accompanying the geological-tectonic map attached to this volume, provides a short description of all rock types and tectonic units occurring in the area and also lists abundant references.

The geological-tectonic map is a new compilation by BERGER and includes many observations from recent field work of several investigators. This map displays the main part of the Bergell pluton only, i.e. without the narrow extension towards Bellinzona. It was compiled from unpublished maps enclosed in various diploma and Ph. D. theses (conducted mainly at ETH Zürich). Where such maps were not available, the geological maps of STAUB (1921), WENK and CORNELIUS (1977), and MONTRASIO and SCIESA (1988) were used. To facilitate viewing of the map, Quaternary rock formations were not distinguished further.

BERGER et al. use their new structural observations to show that ascent and emplacement of the Bergell pluton took place during the last stages of the Alpine orogeny, in an environment characterized by ongoing regional north-south shortening. This syn-emplacement deformation was followed by post-emplacement regional compression which affected the pluton after its solidification and led to its rapid exhumation.

HUBER and MARQUER report structural observations in the southern part of the Tambo and Suretta nappes. For this area, located just north of the Bergell Pluton, the authors propose a tectonic model consisting of four deformation phases. According to their description, there is a link between formation of the Turba mylonite and the strongest deformation phase (D2) which produced the main schistosity. Based on cross-cutting relationships between Turba mylonite and Bergell granodiorite, the authors suggest that their D2 is pre-granodiorite and probably synchronous with the Bergell tonalite intrusion.

PUSCHNIG describes regional and local structures in the tectonic units occurring at the northeastern border of the Bergell intrusion. His field observations indicate that some structural features are restricted to the vicinity of the pluton and thus related to the emplacement. According to the author, overprinting relationships between these local structures and those observed on a regional scale allow to deduce a sequence of eight deformation events near the Bergell pluton which serves as an important time marker.

HANSMANN reviews the geochronological data for the Bergell pluton. He provides a historic overview of age estimates made before the time of isotopic dating. The author then discusses the available isotopic data, including the most recent age determinations on zoned allanite, and provides a complete listing of all data. Some of the older isotopic data are revised and their significance assessed in view of the latest findings. An entire chapter is devoted to the Gonfolite Lombarda, a clastic sedimentary sequence which, exposed near Como and containing boulders of Bergell intrusives, yields important temporal constraints on uplift and erosion of the pluton.

HANDY et al. discuss the evolution of the lower Austroalpine-Penninic suture in view of new radiometric data for two generations of white mica and riebeckitic amphibole. Microstructural observations permit ascribing growth of these minerals to specific deformation events. According to the authors, their data allow to determine the age of the eo-Alpine subduction and nappe stacking and the subsequent extensional uplift.

MÜNTENER and HERMANN report field observations for the western Val Malenco. They document that both mantle and lower crustal rocks were intruded by a Permian gabbro, the Fedoz gabbro, which welded the subcontinental mantle to the lower continental crust. This intrusion and the associated heat supply caused granulite-facies metamorphism and partial melting in the lower crustal rocks. The Malenco lower crust-mantle complex was later subjected to various deformation events and the Alpine metamorphism. It has to be mentioned that the term *Fedoz gabbro,* as used throughout this volume, refers to an uniform pre-Alpine rock type which – due to Alpine tectonics – is now occurring in two different tectonic positions, i.e. in the Margna nappe and in the Malenco unit. Using *Fedoz gabbro* for both occurrences emphazises pre-Alpine aspects.

HERMANN and MÜNTENER present a reconstruction of the Jurassic Adriatic continental margin. They recognize a penetrative deformation in the Malenco lower crust-mantle complex and attribute it to the late Permian extension which post-dates the Fedoz gabbro intrusion but is distinct from the Jurassic rifting. The Malenco unit was in Jurassic time situated between the Forno ocean floor sequence and the Margna continental margin. Because the Malenco unit contains a wide range of rock types in addition to ultramafic rocks, the authors suggest that the location of the Alpine tectonic boundary between Penninic and Austroalpine units is revised.

ULRICH and BORSIEN report new petrographic and chemical data for the Fedoz (meta) gabbro occurring at Lago Pirola / Alpe Zocca, i.e. in the Malenco unit and compare its composition to that of the Forno metabasalts. The authors observe a tholeiitic differentiation trend for the Fedoz gabbro. Their field observations and chemical data further suggest that the residual melt separated into two immiscible melts which intruded older gabbroic rocks of the same differentiation series.

TROMMSDORFF and CONNOLLY present a thermal model based on simple heat conduction for the contact aureole produced by the Bergell tonalite. Their thermodynamic calculations for the Malenco serpentinite are able to reproduce the observed succession of mineral assemblages as well as the mineral compositions. According to their calculations, a large solid volume reduction is associated with final antigorite breakdown, leading to the formation of extensional veins filled with olivine + talc.

POZZORINI and FRÜH-GREEN report systematic oxygen, hydrogen and carbon isotope variations in the Ventina Ophicarbonate Zone. These rocks exhibit constant carbon isotopic compositions which, in combination with field observations, strongly suggest that the ophicarbonates were formed on the seafloor. Highly variable hydrogen and oxygen isotopic compositions, on the other hand, provide evidence for infiltration of fluids that were probably derived from the surrounding rocks during regional and particularly during contact metamorphism.

The papers collected in this special issue of the Swiss Bulletin of Mineralogy and Petrology should not be considered as final reports, but rather as a summary of our current knowledge on a unique area of the Eastern Central Alps. We hope that the present volume provides an incentive for further research. Many secrets of the Bergell Alps still await to be unveiled.

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