1661-8726/08/01S001-3
DOI 10.1007/s00015-008-1296-7
Birkhäuser Verlag, Basel, 2008

Swiss J. Geosci. 101 (2008) Supplement 1, S1–S3

# Orogenic processes in the Alpine collision zone

## Preface to the Special Issue of the Swiss Journal of Geosciences devoted to "Orogenic processes in the Alpine collision zone"

Nikolaus Froitzheim[1] & Stefan M. Schmid[2]
Invited Editors

The papers in this issue further elaborate themes that were presented at the 8th Workshop on Alpine Geological Studies held in Davos on 10–12 October 2007. Ever since a first meeting in Grenoble that took place in 1993, a series of successor Workshops on Alpine Geological Studies has continued in a two-year rhythm: 1995 Basel, 1997 Biella – Oropa, 1999 Tübingen, 2001 Obergurgl, 2003 Sopron, 2005 Opatija. Gradually, the study area encompassed by these meetings was enlarged beyond the Alps in the strict sense. More and more contributions touched on other parts of the Alpine Collision Zone such as the Carpathians, Dinarides or Apennines. Thereby an increasing multitude of various processes leading to collisional mountain building in general could be discussed. Consequently, this present volume captures a part of that same diversity. The 8th workshop in 2007 took place with 117 participants from 14 countries.

Two excursions to the high Alpine area around Davos were carried out before and after the workshop, favoured by clear, warm autumn weather prevailing during the entire conference. The pre-workshop field trip on October 9, guided by Daniel Bernoulli (Basel) and Othmar Müntener (Lausanne), was devoted to the ophiolites at Totalp, where lithologies and structures testify for the exhumation of subcontinental mantle rocks during the opening of the Piemont-Ligurian Ocean in Jurassic times. The second field trip of October 13 was a hike from St. Antönien near Klosters to the Tilisuna area, across the Alpine nappe stack at the Penninic-Austroalpine boundary. It was guided by Thorsten Nagel and Niko Froitzheim (Bonn).

During the three lecture days, 50 oral and 68 poster contributions were presented, organized into the following topical sessions: (1) Alpine oceans: Rifting, break-up, spreading, and paleogeography, (2) Deep structure, lithospheric strength, and mantle dynamics, (3) From subduction to collision, (4) Tectonic and metamorphic processes and the role of HP/UHP metamorphic rocks, (5) Orogenic curvature and kinematics of the Alps-Carpathians-Dinarides, (6) Foreland and hinterland basins: What controls their evolution?, (7) From Neogene to present-day Alps: Neotectonics, brittle tectonics, big tunnels, and finally, (8) Coupling of climate, uplift, erosion, and topography.

Keynote lectures opening the sessions were given by Thorsten Nagel (Bonn), Edi Kissling (Zürich), Onno Oncken (Potsdam), Alfons Berger (Bern), Liviu Matenco (Amsterdam), Francois Roure (Paris), and Sean Willett (Zürich). Ben Reinhardt (Dornach) offered an introduction to the geologic results of and problems encountered along the construction of the Lötschberg and Gotthard base tunnels in a public lecture entitled "Lange Tunnels durch die Alpen: NEAT aus der Sicht des Geologen".

The presentations and discussions during the workshop reflected the recent development of Alpine geology. An increasing part of Alpine geological research deals with the Neogene to recent evolution of the earth's surface and with the interplay of climate and tectonics. For this field of research, the Alps are ideally suited as a natural laboratory because of their limited size, well-constrained boundary conditions, and high density of data. Several presentations dealt with the tectonic continuations of the Alps into the Carpathians and Dinarides and as far as the Balkan Peninsula. The intense, border-crossing research in these areas is proceeding towards a stage where a synoptic picture of the tectonic evolution emerges. Important new findings were also presented by several groups working on bio- and lithostratigraphy in basin sediments around the Alpine orogen. It was remarkable that this particular Alpine Workshop finally managed to bring together geologists working on the tectono-metamorphic history of the Alps with those working on the stratigraphy of adjacent foreland basins.

This volume captures some highlights of the 2007 Davos Workshop. 16 articles cover a multitude of Alpine-type working areas and processes active in collisional mountain building. We wish to acknowledge the financial contributions of the Schweizerische Nationalfonds and the Swiss Academy of

[1]Steinmann-Institut für Geologie Mineralogie und Paläontologie, Universität Bonn, Meckenheimer Allee 171, 53115 Bonn, Germany. E-mail: niko.froitzheim@uni-bonn.de
[2]Geologisch-Paläontologisches Institut, Universität Basel, Bernoullistr. 32, 4056 Basel, Switzerland. E-mail: stefan.schmid@unibas.ch

Sciences towards the organization of the 8th Workshop on Alpine Geological Studies in Davos and the publication of this series of articles. We are also grateful to the editors of the Swiss Journal of Geosciences who agreed to host this Special Issue, particularly Stefan Bucher who assisted the technical aspects of editing, and the three supporting Swiss Earth Science Societies (Swiss Geological Society, Swiss Palaeontological Society and Swiss Society of Mineralogy and Petrology) who, via their budgets, also substantially contributed towards the production costs.

A first series of papers focuses on the role of **sedimentary processes during orogeny**. The evolution of foreland and internal basins of orogens in general is discussed in a review paper by **Roure**, mostly by discussing industrial seismic data from basins in the Alpine-Mediterranean area and in America. This illustrates the influence of inherited structures such as platform-basin transitions and former rifts which are inverted during collisional deformation. In the case of intramontane basins, the paper illustrates the influence of tectonic escape, strain partitioning during oblique convergence, and post-orogenic collapse. Another and more specific study focussing on synorogenic basins is that of **Mikes et al.** who provide a provenance study for the Bosnian Flysch in the Dinarides, forming an intensely folded stack of Upper Jurassic to Cretaceous mixed carbonate and siliciclastic sediments sandwiched between the Adriatic Carbonate Platform and the Dinaride Ophiolite Zone. The authors conclude that Middle Jurassic intraoceanic subduction of the Neotethys was shortly followed by exhumation of the overriding oceanic plate. Following mid-Cretaceous deformation and thermal overprint, the depocentre of the Bosnian Flysch is reported to have migrated further towards SW, receiving increasing amounts of redeposited carbonate detritus from the Adriatic Carbonate Platform margin. The third contribution focussing on the importance of understanding sedimentary processes during orogeny is that of **Ortner et al.** who analyse and discuss Late Jurassic sediments and structures in the western part of the Northern Calcareous Alps. By doing so the authors discuss two competing processes that occurred along the same continental margin: (1) Chaotic breccia deposition near a major normal fault scarp that is part of a pull-apart basin associated with strike slip movements in their working area and (2) synchronous gravitational emplacement of exotic slides and breccias (Hallstatt mélange), triggered by Late Jurassic orogeny reported for the eastern part of the Northern Calcareous Alps. **Veselá & Lammerer** show that the geometry and sediment type of Latest Carboniferous to Triassic rift basins in the Western Tauern Window can be reconstructed in spite of strong Alpine deformation and metamorphism. This interdisciplinary study introduces formation names, presents U-Pb zircon data from meta-volcanic rocks that help constraining the age of the sediments, and shows how the sedimentary basins predetermined the geometry of Alpine thrusts.

The discussion on the mechanism of the **formation of the arc of the Western Alps** is enriched by a tectonic synthesis by **Dumont et al.** who present and review data on the multi-stage orogeny in the French external Alps (Dauphiné Zone). The authors show that Eocene or older deformation was followed by N to NW-oriented basement thrusting so far only reported for more internal parts of the Western Alps. The classical main WNW-directed compression represents a third event, indicating a rapid transition from northward-directed Alpine collision to the onset of westward thrusting that formed the Western Alpine arc. The fourth event is coeval with final uplift of the external massifs, producing strike-slip faulting and local rotations and significantly redeforming earlier structures.

A series of papers focuses on the **metamorphic evolution of the Alps**. Starting with the Palaeozoic evolution of migmatites from the Ötztal nappe, **Thöny et al.** using textural relations and microprobe analysis were able to separate pre-Variscan, Variscan, and Eo-Alpine parageneses and determined P-T conditions for these stages. U-Pb dating of monazites from the leucosomes on the microprobe yielded results in favour of an Ordovician-Silurian (441 ± 18 Ma) age of migmatization. The article of **Wiederkehr et al**. represents a combined structural and metamorphic study of Bündnerschiefer series at the front of the Adula Nappe in the eastern part of the Lepontine dome of the Central Alps. The authors demonstrate that these rocks experienced a Tertiary-age pressure-dominated metamorphism, characterized by the occurrence of Fe-Mg carpholite. This was followed, after isothermal decompression, by isobaric heating, leading to the temperature-dominated Lepontine metamorphic event. The authors discuss the heat source of Barrow-type metamorphism, arguing that such heating was caused by radioactive decay of accreted continental material. **Rütti et al.** report on the structural and metamorphic evolution of the Leventina Nappe that represents one of the lowermost exposed structural units of the Alpine nappe edifice and is also part of the Lepontine dome. However, maximum metamorphic pressure conditions did not exceed 8 and 10 kbar for the northern and southern parts of the nappe, respectively. These pressures, and temperatures between 550 °C and 650 °C, are interpreted to be related to the under thrusting of the thinned European margin into the crustal accretionary prism that initiated during late Eocene to early Oligocene times.

Another series of papers significantly contributes towards elucidating **the timing of orogeny based on radiometric methods and the manifold geodynamical consequences**. In the Western Alps, and using Lu-Hf geochronology, **Herwartz et al.** determined ages of ca. 42 and ca. 45 Ma for prograde garnet growth in eclogites from the Balma ophiolite unit on the southern side of the Monte Rosa massif, i.e. from a much debated piece of the internal Western Alps, derived from lithologies that record a former continent-ocean transition. The authors present isotope and trace element data in favour of a MORB character of the protoliths and they discuss the far-reaching paleotectonic implications of these data. **Kurz et al.** combine $^{40}Ar/^{39}Ar$ dating with micro-structural analyses for dating different stages of the eclogite-facies evolution in a part of the basement exposed in the Tauern Window of the Eastern Alps. They discuss isotopic signature and micro-tectonic processes that took place after

peak pressure conditions were reached at 39 Ma and during exhumation until some 31 Ma ago. By showing how deformation during exhumation results in the resetting of the Ar isotopic system, they contribute towards a better understanding of the methods that may lead to unravelling the timing of subduction processes in the Alps.

Since some time, it is widely recognized that **thermochronological data on exhumation processes** enrich our thinking on driving forces and dating of exhumation. The article by **Luth &Willingshofer** presents a set of maps displaying the cooling history of the Eastern Alps, based on the existing thermochronological database. These maps highlight the diachronous exhumation of deep structural levels in a framework of combined east-west extension and north-south shortening in the eastern Alps. **Danišík et al.** show, using low-temperature thermochronological methods, that a Cretaceous-age granite in the Western Carpathians records a distinct thermal event during the Middle to early Late Miocene, likely related to mantle up welling, magmatic activity, and increased heat flow in the Carpathian-Pannonian region. Thereby the authors show that the Miocene thermal event had a regional character and affected large parts of the basement outcrops in the Western Carpathians north of the Pannonian basin.

Two articles address processes related to **orogen-parallel extension in the Eastern Alps and the formation of the Pannonian basin.** A fault slip analysis on the Neogene evolution of the Austroalpine basement units east of the Tauern Window in the context of orogen-parallel lateral extrusion and focussing on the Koralm basement is presented by **Pischinger et al.** Together with the stratigraphic evolution of the Styrian and Lavanttal Basins and related subsidence histories the authors reconstruct the late tectonic evolution and final exhumation of a part of the Eastern Alps that is adjacent to the Pannonian basin. **Fodor et al.** provide new up-to-date U-Pb radiometric data that imply an Early Miocene crystallization age for the Pohorje pluton located at the southeastern margin of the Eastern Alps, confirming interpretations based on K-Ar geochronology. The new data imply a temporal coincidence with magmatism in the Pannonian Basin system. K-Ar ages and zircon fission track data combined with structural investigations indicate rapid cooling of the pluton, interpreted as related to lateral extrusion of the Eastern Alps and/or back-arc rifting in the Pannonian Basin

Finally, two articles are devoted to the **tectonic evolution of the Carpathians, Dinarides and Balkanides,** i.e. orogens in Southeastern Europe that bridge an important gap between the Alps and the Hellenides and their extension into Turkey. **Ustaszewski et al.** present a restoration of the major tectonic units of the Alpine-Carpathian-Dinaridic system for Early Miocene times. They show how severely the late-stage tectonic evolution has modified the configuration that existed at the end of collision. The mid-Miocene to recent evolution is dominated by block rotations that resulted from the combined effect of ongoing indentation of Adria and subduction retreat in the East Carpathians. The authors further present vertical and horizontal seismic tomography sections of the mantle under the area, and discuss the relations between lithospheric slabs imaged under Alps and Dinarides. **Tückmantel et al.** provide new structural data on a yet badly understood part of the Balkanides in the northwestern part of the Rhodope metamorphic province. Alpine, amphibolite-facies gneisses in the area of Rila valley in western Bulgaria were exhumed by several distinct phases of extensional deformation. The most pronounced faulting occurred in the Eocene to Early Oligocene when a major normal fault exhumed rocks from the ductile middle crust to the surface, as evidenced by syn-rift deposits in the hanging wall.