Paleogene of the Eastern Alps - an introduction

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The Paleogene was a period of dynamic global and regional changes. Plate tectonics led to the closure of the Tethys, the opening of the Northern Atlantic, and the separation of Antarctica. A remarkable incision at the Cretaceous/Paleogene boundary led to subsequent faunal and floral radiations. The biotic development during the Paleogene was influenced by dramatic climatic and eustatic sea-level changes. Starting in the Campanian, the eustatic sea-level curve reveals a general regressive trend during the Paleogene, except for two remarkable highs in the Early Eocene (Ypresian) and the Early Oligocene (Rupelian).

In the Eastern Alps, the interplay of tectonic, atmospheric, and eustatic sea-level changes is expressed by changing distribution patterns of depositional environments during the Paleogene. One of the main tectonic processes was the subduction of the European Plate under the Adriatic Plate within the Penninic Ocean, representing a prominent phase in Alpine orogeny. Finally, the Tethys Ocean vanished completely during the Eocene. The narrowing and uplift of the Alpine orogen formed an archipelago separating the Paratethys in the North and the Mediterranean Sea in the South.

This volume presents a modern overview of this significant period in the Eastern Alps and a great variety of hitherto unpublished data is introduced. It comprises 18 papers covering a wide range of earth science fields: geodynamic, palaeogeographic, and palaeotopographic evolution; facial development; litho- and biostratigraphy; systematic palaeontology and palaeoecology of several organism groups (calcareous nannoplankton, foraminifera, molluscs, Bryozoa, echinoids, palynoflora).

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TECTONIC UNITS OF THE EASTERN ALPS

Definition, nomenclature, and understanding of tectonic units of the Eastern Alps are frequently inconsistent and partly still a matter of debate. The Molasse sequence, for example, means to a sedimentary geologist the beginning of sediment input from the uplifted Alps into the Alpine Foreland by the beginning of the Oligocene; in terms of geodynamics, however, the Molasse sequence starts during the Late Eocene and is related to particular subduction processes.

A broad summary on this topic is given by KURZ, FRITZ et al. From the footwall to the hanging wall (from N to S, or NW to SE), the authors differentiate: (1) The continental European Plate including the Molasse Zone. (2) The Helvetic units and the Waschberg Zone, representing detached parts of the European Plate. (3) The Valais units of Northpenninic palaeogeographic origin. The Rhenodanubian Flysch Zone as part of the Valais palaeogeographic realm is still a matter of discussion; WAGREICH assumed that the depositional area of the Rhenodanubian Flysch was situated within the Penninic domain. (4) The Brianconnais units, representing a microcontinent of Middlepenninic palaeogeographic origin. (5) The Ligurian-Piemontais-Southpenninic units with oceanic lithosphere. (6) The Austroalpine unit, including the Lower, Middle, and Upper Austroalpine units as well as the Juvavic unit, and the Gosau Basin on top of the Austroalpine nappe stack. (7) The Southalpine unit juxtaposed along the Periadriatic Fault.

PALAEOGEOGRAPHY AND GEODYNAMICS

The Eastern Alps result from the still active convergence between Africa and Europe. Although the Alps represent one of the best studied orogens, the problems addressed in the former chapter are even more evident for geodynamic interpretations and palinspastic reconstructions. The Penninic Nappes of the Tauern Window, for example, are metamorphic rocks that formed a remarkable sedimentary unit during deposition. They are, however, frequently neglected in palaeogeographic reconstructions.

The Paleogene evolution of the Eastern Alps started with the consolidation of the Austroalpine nappe complex during the Late Cretaceous. Subduction of the Penninic oceanic domain took place during the Late Cretaceous and the Paleogene, followed by a collision between the Penninic and the Austroalpine units. The Paleogene orogeny was primarily controlled by subduction, collision and closure of the Penninic oceanic domains, followed by cessation of Flysch sedimentation in the Eocene and the deposition of Molasse sediments. Subduction and collision are also documented by high-pressure metamorphism in the internal zones of the Eastern Alps as well as by Late Oligocene magmatism along the Periadriatic Lineament. Oblique collision finally resulted in the formation of strike-slip faults parallel to the strike of the orogen, and the initiation of orogen-parallel extrusion at the end of the Oligocene, which continued during the Miocene. Based on structural, petrological, geochronological, sedimentological and stratigraphic data, KURZ, FRITZ et al. reconstructed the Paleogene geodynamic and palaeogeographic evolution of the Eastern Alps.

The southern margin of the Northern Calcareous Alps (i.e., the southern shelf of the Penninic Sea) was characterized by a narrow carbonate shelf during the Paleocene,

being part of the Gosau Basin. Towards the north, this basin showed a general deepening, with deep-marine depocenters and structural highs formed along an active continental margin. Slope deposits of the Gosau Group formed the southern margin of the Rhenodanubian Flysch Zone. WAGREICH assumes that deposition of Gosau sediments ended between the Late Paleocene and the Early/Middle Eocene due to compressional tectonics and overthrusting. During the Early/Middle Eocene, this overthrusting led to a transition from Gosau basins to strike-slip/piggyback basins (e.g., Lower Inn Valley). For the Paleocene to Eocene, WAGREICH suggests an active continental margin setting with slope basins influenced by strike-slip faulting and a northward propagation front of deformation and thrusting.

The Rhenodanubian Flysch Zone formed the deep-marine northward continuation of the Gosau Basin. This position makes it relevant for the syn-collisional history of the Eastern Alps. Considering the debatable internal basin structure and the origin of sediments, TRAUTWEIN et al. reconstructed the palaeogeographic and geodynamic evolution of the Rhenodanubian Flysch Zone. Based on provenance analyses, they differentiated between a southern main flysch basin and a northern basin. The thermal evolution reveals that the different subunits of the Flysch Zone were buried to different depth levels.

The tectonostratigraphic subdivisions of the metamorphic Penninic Nappes, that are particularly exposed in the Tauern Window, represent a crucial problem for the geodynamic evolution of the Eastern Alps. New results on the palaeogeography and tectonomorphic development based on structural, lithological and metamorphic evidence are presented by KURZ, NEUBAUER et al. They suggest that high-pressure metamorphism and nappe stacking took place during the Paleogene with a main deformational phase during the Eocene.

From Paleocene to Late Eocene times the northern shelf of the Penninic Ocean corresponds to the Helvetic Zone (RASSER & PILLER), the southern part of the Molasse Zone (ZAGORSEK) and the Waschberg Zone (KRHOVSKY et al.). By the end of the Eocene, the Molasse Basin was established north of the Alpine orogen. During the Oligocene, its southern margin is represented, for example, by sediments of the Lower Inn Valley (ORTNER & STINGL; SCHERBACHER et al.; LÖFFLER & NEBELSICK). The northern margin is characterized by predominantly siliciclastic sediments along the Bohemian Massif (KAISER et al.; HARZHAUSER & MANDIC).

The Waschberg Zone is a peculiar nappe system showing facies relations to the Molasse Zone and the Carpathians. Restricted water circulation patterns in the Oligocene of this unit can be traced through most of the Paratethys (RÖGL et al.; KRHOVSKY et al.).

During the Oligocene, the E-W extension of the Eastern Alps was less than 30% its present-day dimension, which developed during Miocene lateral extrusion. Based on petrologic and thermochronologic data, KUHLEMANN et al. reconstructed the development of the Oligocene to Miocene topographic relief.

SEDIMENTOLOGY AND STRATIGRAPHY

The Paleogene was a time of active tectonics and eustatic sea-level changes, both influencing sedimentary processes. WAGREICH found that Paleocene to Early Eocene deep-water sedimentation in the Northern Calcareous Alps was largely controlled by local subsidence and sediment supply, but not by eustatic sea-level changes. He reconstructed the main provenances and depositional basins as well as their tectonic control.

Comparable relations were studied in the Paleogene Helvetic Zone by RASSER & PILLER, who found particular facies patterns along the Helvetic shelf in Austria and Bavaria. Comparisons of the eustatic sea-level with the relative sea-level changes, as revealed by ferruginisation and glauconitisation in carbonate sediments, led to the reconstruction of the subsidence history.

The Paleocene/Eocene boundary in the Gosau Group of Gams/Styria was studied and discussed by EGGER & WAGREICH. Based on calcareous nannofossils, they found a complete succession from the Paleocene to the Lower Eocene in this area.

The Rhenodanubian Flysch Zone is usually characterized by sediment input from the Alpine orogen. Based on provenance analysis of Cretaceous to Paleogene sediments, however, TRAUTWEIN et al. identified two main sediment sources and depositional areas: one basin to the south with sediment input from the Austroalpine Unit and another to the north taking up sediments from the European margin.

Sedimentation, however, was not only influenced by eustacy and tectonics. RÖGL et al. studied environmental changes of the Oligocene Ottenthal Formation (Waschberg Zone) that were strongly influenced by orbital cyclicity.

The sedimentary facies of the Late Eocene to Early Miocene of the Waschberg Zone was summarized by KRHOVSKY et al. They work out the influence of tectonic movements and changing palaeoenvironmental conditions of the Paratethys sea on the facies development. FUCHS et al. revise the lithostratigraphy and biostratigraphy of the Mid-Oligocene Thomasl Formation (Waschberg Zone) and discuss its affinities with the adjacent Molasse Zone and the Carpathians.

Carbonate sediments in the conspicuously siliciclastic-dominated Oligocene of the Molasse Zone were studied by KAISER et al. They were deposited on a mixed carbonate-siliciclastic ramp at the southern margin of the Bohemian Massif. A combination of siliciclastic grain size analyses and carbonate facies analyses allowed the reconstruction of the sedimentary environments and the development of the ramp. Finally, miogypsinid biostratigraphy allowed exact dating of this sequence.

A basin analysis of the Lower Inn Valley is presented by ORTNER & STINGL. They studied the interplay between sedimentation and tectonics in this area and formalized the lithostratigraphic units. The authors worked out the influence of sea-level changes, subsidence and sediment input on a wide range of sediments, from deep marine marls to littoral deposits.

The Oligocene topographic relief of the Eastern Alps was studied by KUHLEMANN et al. Their study reveals, in which way the topographic relief determined the sedimentary regime of the Oligocene to Miocene.

PALAEONTOLOGY

After the mass extinction event at the Cretaceous/Paleocene boundary, major climatic and sea-level changes governed several biotic turnovers during the Paleogene. In the Eastern Alps, Alpine orogeny additionally led to sustainable changes by providing a high environmental variability. This makes the Eastern Alps a prolific area for complex palaeontological studies, yielding basic information on biostratigraphy, palaeoenvironmental changes, and palaeobiogeography, that help understanding the evolution of the Eastern Alps.

The Danian echinoid fauna of the Waschberg Zone contains taxa surviving the Cretaceous/Paleocene boundary (KROH). Based on the study of 1200 specimens, the author described 19 taxa, most of which have not yet been reported from Austria. The faunal affinities to other occurrences and the idea of Early Paleocene taxonomic reorganization of echinoids is discussed.

The Gosau Basin of the Krappfeld area represents an exceptional development. It is part of the Central Alpine Gosau Basin and reveals affinities with the Paleogene of the Southern Alps. ZETTER & HOFMANN describe rich palynomorph assemblages from the Early Eocene of this area with at least seven new taxa. The authors assume that species diversity and composition reflect the Eocene Thermal Maximum and discuss the mechanisms of pollination and diaspore dispersal in terms of vegetation dynamics.

A particularly rich bryozoan fauna in the Late Eocene of the Molasse Zone was found by ZAGORSEK. He described 121 Bryozoa taxa, including three new species and one new genus. The fauna shows high similarities with those of Hungary and the Waschberg Zone as well as with present-day bryozoan associations from the British Islands and the Mediterranean Sea. An environment of a cool-water and/or deep-water basin is interpreted.

Palaeoenvironmental implications of Early Oligocene benthic foraminifera from the Lower Inn Valley are discussed by SCHERBACHER et al. The composition of foraminiferal assemblages allowed estimations of water depth, temperature, organic matter fluxes as well as oxygenation and seems to mirror a transgression-regression cycle. The cycle is linked to the subsidence of the basin combined with eustatic sea-level fluctuations. A correlation with the Paleogene successions of the Slovenian Basin is discussed.

A palaeoenvironmental analysis based on microfacies and molluscs was conducted by LÖFFLER & NEBELSICK for the historically well-known Lower Oligocene of the Lower Inn Valley. The taxonomic structure of molluscs is dominated by thermophilous elements and allows reconstruction of the water depth. The trophic analysis combines the mollusc assemblages and carbonate facies.

Profound palaeobiogeographic reconstructions based on molluscs are shown by HARZHAUSER & MANDIC. The authors give a thorough systematic work on gastropods and bivalves from the Late Oligocene of the Lower and Upper Austrian Molasse Zone and worked out the influence of geodynamic processes on the faunal spectrum. The composition of the fauna displays high similarities with those of Bavaria and Hungary and furnishes a strong influence from the Proto-Atlantic-Boreal Region, while elements from the Western Tethys are exceptionally rare.

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