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NEOGENE LANDSCAPE EVOLUTION OF THE EASTERN ALPS

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The modern geomorphological evolution of the Eastern Alps started with the termination of the Eo-/Oligocene collision. A first uplift impulse in Early Oligocene times is reflected by a sudden increase in sediment discharge and the production of coarse clastic material. Only the central and eastern Northern Calcareous Alps (NCA) remained lowlands and were covered by sediments which were not removed until early Miocene times. The shape of the Eastern Alps and their geomorphological evolution were sustainedly influenced by Early to Middle Miocene lateral tectonic extrusion, which stretched the Eastern Alps for more than 50 per cent in E-W direction. Tectonic extrusion was combined with an abrupt lowering of relief and sediment discharge. Middle Miocene sedimentation covered large areas along the eastern margin of the Eastern Alps so that the Pannonian basin extended further to the west than today for several tens of kilometers. In Late Miocene to Pliocene time elevations and relief increased, and the sediments of the eastern margin were removed. Late Pliocene to Pleistocene glaciation led to a fundamental morphological recast of the higher parts of the Eastern Alps and substantial peak uplift.

Provenance analysis of marker pebbles indicate that the large NE-directed catchment of the Paleo-Inn river originally extended much further to the S than today and even crossed the Periadriatic lineament. This river system persists since Early Oligocene times until present with relatively limited change. In the eastern part of the Eastern Alps, N-directed rivers dominated most of the Oligocene and the earliest Miocene time discharging their load on top of the central and eastern NCA. In Early Miocene times, a pattern of large-scale, ENE- and SE-trending faults was established in the course of lateral tectonic extrusion, which led to a complete reorganization of the river network and the overall geomorphological evolution in the eastern Eastern Alps.

In Neogene times, cannibalism of S-directed catchments on the expense of the N-directed rivers prograded from W to E, according to the maturity of S-directed river profiles. Marker pebbles record the first exposure of the Tauern core complex in Middle Miocene time, and fast relief increase in that area.

The gross structure of the modern macrorelief of the Eastern Alps was established during Early to Middle Miocene lateral tectonic extrusion. The modern mesorelief is strongly influenced by glacial erosion dynamics. The microrelief reflects the activity of post-glacial processes. The different temporal and spatial scales of relief-forming processes require quite different tools for a holistic quantitative reconstruction of the geomorphological evolution. Our work focuses on the evolution of the meso- and macrorelief, and thus on processes in the time-scale of millions of years.

For an analysis of the mesorelief, numerical DEM analysis, neotectonic movements, fault plane solutions, geodetic uplift data and sediment budgets of open and semi-enclosed catchments have been considered. The macrorelief of the past was reconstructed by considering differential exhumation in the orogen, precise provenance analysis of clastic material, lithospecific thermochronology on pebble material, sediment discharge rates, and structural data. The combination of apatite and zircon fission track data and sediment budget calculations of circum-Alpine basins enables to estimate long-term denudation rates with a temporal resolution of 1 Ma. Regional climate change in the eastern Alps during the Oligo-Miocene period appears to follow the global changes only in a very damped manner. Therefore, denudation rates rather reflect changes of relief in response to vertical movements, than climatic changes. Estimated changes in relief, combined with palinspastic restorations and reconstructions of paleogeology and river network led to the presentation of paleogeograhic 3D models of the post-collisional evolution of the Eastern Alps.

DEM analysis enables to distinguish several geomorphological domains defined by geometric characteristics. The most rugged domain with high relief encounters the crystalline region west of the Brenner line, the western NCA, the Tauern window and the area to its south, and the Niedere Tauern. This region matches with Miocene apatite fission track ages, maximum Pleistocene glaciation and maximum recent uplift. Typically, it shows U-shaped valleys and a local relief up to 3000 m. Elevations above the regional and local average are more frequent than below (negative skewness of elevation frequency curves).

A region of high to intermediate relief and relics of the early Oligocene Dachstein paleosurface characterizes the central and eastern NCA. After sediment coverage and removal, this area experienced episodic surface uplift since ca. 10 Ma. Preservation of the paleosurface was only possible in areas, where thick Triassic limestones enabled subsurface erosion by karstification.

Intermediate to low relief with relics of the early Miocene Nock paleosurface is found in the Gurktal Alps east of the Tauern window and neighbouring regions. Here, glacial landscape overprint is of minor importance. The preservation of modified paleosurface remnants is due to only late and moderate uplift (not before Pliocene time) and, probably, sediment burial before that time. Apatite fission track ages are Paleogene. Elevation frequency curves show positive skewness.

In conclusion, the relief evolution was mainly governed by Neogene geodynamics and, only in the second place, by the exposed lithologies. Presently, there is an excellent match between measured surface uplift, elevation, and Pleistocene ice thickness, which may suggest that isostatic rebound after ice melting is responsible for the recent vertical movements. However, subsidence (in the eastern part of the Eastern Alps) and uplift (in the western part) relative to a reference point in the Bohemian massif also match positive resp. negative isostatic anomalies indicating deep-seated causes for vertical movements. In our opinion, recent movements are governed by isostatic response to crustal (and lithospheric) thickness, to ice load and release, as well as to tectonic pressure as evidenced from neotectonic analysis.

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