

## **THE DACHSTEIN PALEOSURFACE AND THE AUGENSTEIN FORMATION IN THE NORTHERN CALCAREOUS ALPS – A MOSAICSTONE IN THE GEOMORPHOLOGICAL EVOLUTION OF THE EASTERN ALPS**

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The central and eastern Northern Calcareous Alps (NCA) are characterized by remnants of the Dachstein paleosurface, which formed in Late Eocene (?) to Early Oligocene time and which is preserved with limited modification on elevated karst plateaus. In Oligocene time, the Dachstein paleosurface subsided and was sealed by the Augenstein Formation, a terrestrial succession of conglomerates and sandstones, which are only preserved in small remnants on the plateaus, some in an autochthonous position. From Early Miocene times on, the Augenstein Formation was removed by erosion. Since the early Late Miocene, the largely denuded paleosurface, meanwhile fragmented by a pattern of conjugate strike-slip faults, was uplifted. Individual blocks were uplifted to different elevations between 1700 and 3000 m.

The Augenstein Formation consists of conglomerates and sandstones. The pebbles nearly exclusively derive from Paleozoic to Early Triassic sequences of the Greywacke zone and its equivalents and the siliciclastic base of the Northern Calcareous Alps and their equivalents. Polycrystalline quartz pebbles are the predominating components in the Augenstein conglomerates and derive from phyllites, in which they form nodules precipitated from material mobilized by pressure solution. The frequency of the quartz pebbles shows that phyllites and other low-grade schists were widespread in the source area, as it is the case in the present counterparts. Other pebble lithologies are quartzites, sandstones, conglomerates, lydites, rhyolites, greenstones, and mostly black carbonates. Metamorphism attains no higher grade than greenschist facies. The quartzites are very variable and can be correlated with lithologies both in the Variscan and post-Variscan series. Red quartzites and metasandstones can easily be correlated with the typical Early Triassic Buntsandstein formation in the western part of the NCA. Therefore, these pebbles are frequent in the western Augenstein occurrences, which are closest to the possible source areas.

Zircon fission track (FT) data from pebble populations and sandstones show different sources. A Permian cluster represents typical Late-Variscan ages. Zircons forming a Jurassic cluster derive from a region which was affected by a Mesozoic thermal event, probably due to crustal thinning which led to the formation of the Penninic ocean. The Late Cretaceous clusters are typical cooling ages to the Cretaceous metamorphic event which affected large parts of the Austroalpine realm. All these age groups are typical of the Austroalpine mega-unit, the pre-Cretaceous ages from higher, the Cretaceous ages from deeper structural levels. Eocene to Oligocene age clusters of zircons are due to clear, euhedral crystals and come from a volcanic source (e.g., Periadriatic volcanic edifices which topped the intrusives exposed at the present erosion level). The youngest cluster (33 Ma from Steinernes Meer) shows that the basal Augenstein beds in this locality is 33 Ma old (Early Oligocene) or slightly younger. In fact, conglomerates in the Molasse zone started to become important around 30 Ma, after a prominent uplift pulse of the Alps.

The Augenstein formation has been nearly completely destroyed by erosion. There is good reasoning that it partly attained thicknesses in excess of 1 km.

(1) A mass budget calculation assuming reasonable erosion rates in the source area results in a total volume of solid rock of 4760 km<sup>3</sup>, corresponding to an equivalent of uncompacted Augenstein sediment in the order of 6350 km<sup>3</sup> containing an average pore volume of 25 %. This is equivalent to an average sedimentation rate of 0.063 mm/a (over 10 Ma) and an average sediment thickness

of 635 m (depositional area of Augenstein formation was approximately 10,000 km<sup>2</sup>). Uneven distribution of the Augenstein sediments - there is geological reasoning that they wedged out towards the east - result in local thicknesses of clearly >1 km in the central parts of the NCA.

(2) In a sample from the Dachstein plateau, apatite shows shortening of fission tracks. This indicates post-sedimentary thermal overprint. Thermal modelling of the track length distribution indicates temperatures in excess of 50 °C. The assumption of a realistic geothermal gradient of 20-25 °C/km and a mean surface temperature around 16 °C results in burial of 1.36-1.7 km for T<sub>max</sub> = 50 °C, and of 1.76-2.2 km for T<sub>max</sub> = 60 °C.

### **Geomorphological and geological situation during Augenstein sedimentation**

On the basis of the pebble content, the heavy mineral spectra and the zircon and apatite fission track data, we propose a scenario for the paleogeological and paleogeomorphological situation during Augenstein sedimentation, which is based on the palinspastic reconstruction of Frisch et al. (1998; Tectonophysics 297: 1-15). These authors showed that the Eastern Alps had a considerably shorter E-W extent prior to the prominent Early to Middle Miocene lateral extrusion process, which led to more than 50 % E-W stretching in Miocene time.

Our reconstruction considers large parts of the central and eastern Eastern Alps south of the NCA to have been continuous terrains of the weakly metamorphosed Variscan sequences and its post-Variscan siliciclastic cover. This area supplied the Augenstein formation to the north on the one hand, and the Csatka formation in the Bakony Mountains (via the Paleo-Drau river system) to the east on the other.

The source area of the Augenstein sediments is considered to have formed an intermediate-relief scenery, which is constrained by the following: (1) The overall geomorphological situation between the mountainous western Eastern Alps and the Pannonian basin suggests intermediate reliefs for the Augenstein source area. (2) Apatite fission track data from the source area and from the clastic material of the Augenstein formation indicate shallow incision of rivers. Towards the end of the Augenstein sedimentation, the source area stabilized and formed a hilly paleosurface, which is preserved today in remnants (Nock paleosurface).

Sedimentation of the Augenstein formation was terminated in Early Miocene time by the orogenic collapse (ca. 21 Ma), which generally lowered the relief of the Eastern Alps, and the formation of fault-bounded longitudinal (E-W) depressions (ca. 18 Ma), which prevented further river transport of material from S to N.