Triassic ‘ophiolites’ and related rocks in Eastern Carpathians (Romania)

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In the Eastern Carpathians (EC), ultramafics (lherzolites and harzburgites) to FeTi gabbros, dolerites and volcanics occur in three areas, from north to south: Rarău, Hăghimaş and Perşani Mts. They are embedded in the Lower Cretaceous Wildflysch formation, as both centimetre-sized clasts in breccias, and meter- to kilometre-sized blocks. The volcanics comprise highly-depleted (HDBA), depleted (DMORB) and normal (NMORB) basalts/andesites, to enriched type mid-ocean ridge basalts (EMORB). Additionally, ocean island basalts (OIB), calc-alkaline basalts/andesites (CABA) and trachytes occur. Many volcanics have a distinct supra-subduction zone signature. No direct geological field relation could be established among the isolated occurrences. Thus, it is difficult to assign ultramafics, Fe-Ti gabbros and basalts to a coherent ophiolite assemblage. Nevertheless, we will use the term ‘ophiolites’ for a part of the rocks, because several basalt groups indicate an oceanic origin and ultramafics with basaltic dykes occur.

Based on primary interfaces between volcanics and sediments such as radiolarites and limestones, a Middle to ?Late Triassic age of the Eastern Carpathians “ophiolites” and a separation from the Southern Apuseni Mts. ophiolites and island arc volcanics are envisaged. In all cases where we observed interfaces with basalts, the sediments proved to be Triassic.

In the Rarău area (northernmost part of the EC), Ladinian and Lower Carnian red cherts are in direct contact with basaltic rocks of NMOR- and EMOR-type, respectively. One olistolith shows a succession of CABA, Werfenian sandstones and shales, and Upper Anisian–Lower Ladinian limestones. In the Perşani Mts. (southernmost part of the EC), a direct contact of basaltic rocks and limestones displaying a Late Triassic facies is exposed.

When combining the basalts ages with the geochemical grouping, it is clear that at least one or more samples from the following groups are Triassic: OIB, CABA, and EMORB. For the NMORB and HDBA this is also probable since Mid-Triassic radiolarites were previously found in close vicinity. No stratigraphic assignment can be made for the moment for the UMs, Fe-Ti gabbros and the DMORBs, but none of these shows any close connection to Jurassic or Lower Cretaceous sediments. Taken all the arguments together, it is highly probable that a vast majority of the magmatic rocks, maybe even all, are of Triassic age.

For long time, the Eastern Carpathians “ophiolites” were believed to have been formed in the Eastern Vardar Ocean (Main Tethyan Suture Zone), being thus partly time-equivalent to the Middle to Late Jurassic ophiolites and island arc volcanics found in the Southern Apuseni Mts. and in the basement of the Transylvanian Depression. Most of the ‘ophiolites’ were believed to be thrust on top of the Eastern Carpathian Bucovinian nappes during the Mid-Cretaceous orogeny forming the so-called “Transylvanian nappes”.

Based on the new data, a model is developed, which accounts for the existence of a Triassic ocean connected with the Meliata-Hallstatt Ocean. This ocean closed most likely in the Late Triassic to Early Jurassic. During the closure ultramafics and basic magmatic rocks together with sediments were obducted, subsequently eroded and transported as blocks of different sizes into the Lower Cretaceous Wildflysch basin.

Lake Ohrid Basin (FYROM/Albania): a seismogenic landscape

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The Former Yugoslavian Republic of Macedonia and Albania share the Lake Ohrid Basin (40°54’ – 41°10’ N, 20°38’ – 20°48’ E) stretching over a length of c. 30 km and a width of c. 15 km. Clearly the strike of the basins (N-S) does not correspond to the strike of the major tectonic and geological units (NW-SE). This already gives evidence that the basin is formed due to a younger deformation stage. In addition, the area meets all criteria of an active, seismogenic landscape with linear step-like fault scarps on land and within the lake. In general, the faults and fault scarps are getting younger towards the basin centre, as depicted on seismic and hydroacoustic profiles. Post-glacial (or Late Pleistocene) bedrock fault scarps along the steep flanks of Mokra and Galicica Mountain chains are long-lived reflections of repeated surface faulting in tectonically active regions, where erosion cannot outpace the fault slip. Others like wind gaps, wineglass-shaped valleys and triangular facets, are accompanying morphological features of a tectonically active area. Additionally, mass movement bodies within the lake and also onshore (rockfalls, landslides, sub-aquatic slides, homogenites, turbidites) are likely to have been seismically triggered. Multichannel-seismic studies reveal evidence for wedge-like growth strata incorporating mass movement bodies, rather pointing to sudden earthquake-triggered events than to fault creep. Earthquakes larger than magnitude M 6.0 at Lake Ohrid may also be accompanied by secondary effects like liquefaction, seeps, dewatering structures, rock falls and landslides and others. These morphotectonic observations correspond to focal mechanisms of earthquakes in the greater Lake Ohrid area. An integrated multidisciplinary approach was chosen to investigate the neotectonic history of the basin, using tectonic morphology and a variety of geophysical and remote sensing methods.

Tectonic evolution of the Lake Ohrid and Prespa Basins (FYROM/Albania)

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The region of the Lake Ohrid and Prespa Basins is located at the Greek/ FYROM (Former Yugoslav Republic of Macedonia)/Albanian border. The neotectonic and landscape evolution of the southern Albanian fold-and-thrust belt and the Albanian-FYROM extensional back-arc area (basin and range type) are directly linked to subduction and subduction roll-back within the Hellenic trench system. The initiation of the Ohrid Basin is estimated between 2 and 8 million years. The deformation can be divided in three major deformation phases (1) NW-SE shortening from Late Cretaceous to Miocene with compression, thrusting and uplift; (2) uplift and diminishing compression during Messinian - Pliocene; (3) vertical uplift and (N)E-(S)W extension from Pliocene to recent associated with (half-) graben formation. This latter phase of an orogenic collapse is related with a seismogenic landscape with linear step-like fault scarps on land and offshore, wineglass shaped valleys and triangular facets. The geomorphology also points to rotated and tilted blocks. Seismic and hydroacoustic data of Lake Ohrid show that the faults and fault scarps, in general, are getting progressively younger towards the basin centre. A tectonic multi-proxy approach (palaeostress analysis, remote sensing) has been made to reveal the stress history of the region. Furthermore, apatite fission-track (A-FT) analysis and t-T-paths modelling was performed to constrain the thermal history, and the exhumation rates.

For fission-track analysis apatites were separated from a suite of granitoid rocks from basement units and from flysch- and molasse-type deposits of Paleogene to Neogene age. Apatites show a range of the apparent ages from 56.5±3.1 to 10.5±0.9 Ma. The spatial distribution of ages suggests different blocks with a variable exhumation and rock uplift history. Fission-track ages from molasse and flysch sediments of the basin fillings show distinctly younger ages. Generally, the Prespa Basin reveals A-FT-ages around 10 Ma close to normal faults, whereas modelling results of the Ohrid Basin suggest a rapid uplift initiated around 1.4 Ma associated with uplift rates (? rock uplift rates or surface uplift rates?) on the order of 1 mm/a. As a conclusion we observe a westward migration of the extensional basin