Devonian – Carboniferous back arc basins in the Bohemian Massif and adjacent areas

The aim of the study was to create a consistent computer model of Variscan plate tectonic evolution of the Central Europe (i.e. 420 – 305 Ma), with special attention given to the Polish part of the Bohemian Massif. Modeling process was performed in Gplates – open source software for plate tectonic reconstructions. The final results were presented in a set of paleogeographic maps and schematic cross-sections.

The plate tectonic theory assumes that outermost part of the Earth, the lithosphere, is divided into several parts (plates) which are in constant motion in relation to each other. Generally, plates can be of continental or oceanic type, however the transitional type is also possible. The oceanic plates are built of dense mafic rocks, and continental ones are characterized by lighter, more acidic rocks.

According to plate tectonic theory, the new oceanic-type crust is formed in rifts zones and consumed in subduction zones. Because of this process, the oldest part of the oceanic crust is of Triassic age. The low density continental crust does not undergo subduction. The engine of plate movements is not well known yet, however there are strong evidences that the suction of subducted slabs is the most important factor. The plate tectonic theory implies three kinds of plates' boundaries, which allow plates' movements. Those boundaries are: divergent, convergent and conservative. The other consequence of the plate tectonic theory are the triple junctions, i.e. the points where three plates meet together. When considering the plates as rigid bodies, their movements can be described by the Euler theorem, which states that any movement on a sphere can be defined as a rotation around a pole (so called Euler pole of rotation). The pole is defined by the intersection of a sphere and its axis. This theorem is used by plate tectonic reconstruction software to calculate plates' positions and their velocities.

Geological structure of the Central Europe is a result of a long and complex history. It is built of four main units of different origin: the East European Craton (EEC), Avalonia (Av), Brunovistulian microcontinent (Bv) and Bohemian Massif (BM). The Avalonia continent drifted away from Gondwana during Ordovician and collided with Baltica and Laurentia around 425 Ma, forming European part of the Caledonides. As a result of these events a wide Rheic ocean was formed between Gondwana and Avalonia. The eastern part of the Avalonian continent spans over north-western part of Poland. The origin and history of Brunovistulian microcontinent is still unclear, however there are growing evidences for circum-Baltican position during Early Paleozoic. Between Bv and EEC the small Malopolska

Block (MB) is present, which is usually interpreted as a sliver of the Baltica continent. The west flank of the Bv is covered by thrust-and-fold belt formed during collision of the Bv with BM, which is composed of three main units (from north to south): Saxothuringia, Tepla-Barrandian and Moldanubicum. The study was focused on the Polish part of Bohemian Massif – the Sudetes Mountains.

The Sudetes extend in northernmost part of the Bohemian Massif and, according to recent view, can be divided into three parts: West Sudetes, Central Sudetes and East Sudetes.

Highly diverse rock complexes of the Sudetes Mts. can be divided in to following groups:

1. Neoproterozoic metamorphosed and unmetamorphosed magmatic and volcano – sedimentary rocks,
2. Cambrian granitoids metamorphosed during Variscan orogeny,
3. metamorphosed Ordovician to Silurian sequences mainly representing volcano – sedimentary filling of the extensional basins,
4. Silurian to Devonian mafic rocks interpreted as a fragments of an ophiolitic complex
5. synorogenic Late Paleozoic sedimentary sequences,
6. syn- and postorogenic granitic intrusions.

The modeling was largely devised to verify several hypothesis that were formulated based on field observations and extensive literature studies:

- two ophiolitic complexes are present within the Bohemian Massif. The older complex, of Cambrian age, represents the remnants of the oceanic plate of the Rheic Ocean and can be identified with Mariánske Lázně Complex, Stare Mesto Unit abd Leszczyniec Unit. The younger complex was formed in the back arc settings during Silurian – Devonian. It is represented by Intrasudetic Ophiolite, pillow lavas of the Rzeszówek – Jakuszowa Unit and mafic rocks of the Stanberg – Horni Benešov Unit,
- the younger ophiolitic complex o is incorporated into oceanic suture, often forming olistoliths,
- the striking resemblance between Moravo–Silesian Zone and Rhenohercynian Zone suggests that those zones were formed in the almost identical settings,
- north-bended arc of the Rhenohercynian Zone and N-S strike of the Moravo–Silesian suggest oroclinal bending of the migrating orogenic front.

Based on the available geological information (maps, cross sections, etc.) the region of Central Europe was divided into several smaller units (terranes). The following units were distinguished: Malopolska Block, Brunovistulicum, Saxothuringia, Tepla–Barrandian, Góry Sowie Block, Orlica–Snieznik Unit, Moldanubian Unit and Rhenohercynian Zone. Except Moldanubian Unit and Rhenohercynian Zone, all distinguished units should be understood as a unit of continental crust characteristic. According to the recent models, the Moldanubian Unit was formed as a result of deformation of the transitional type crust by diapiric intrusions. The Rhenohercynian Zone, in turn, should be interpreted as a suture zone composed of diverse, metamorphosed and tectonically engaged rock sequences.

Each unit was characterized by individual number (Plate ID) and other attributes, like age of appearance and disappearance. The Plate ID numbers were used to create text file describing rotation of each unit. Based on collected information the conceptual model was defined and incorporated into Gplates software. In the next step, the model was manually adjusted to achieve the most realistic output. Also, at this stage several divergent concepts of the Bohemian Massif evolution were tested. During this process, different versions of the model were developed to carry out velocity analysis and agreement with the compiled geological information. The final model is characterized by rather stable and uniform velocity distribution, which does not exceed those observed currently on the Earth and documented in the past.

The performed modeling showed that complicated structure of the Bohemian Massif could be explained as a result of a closing of two oceanic units, i. e. Rheic Ocean and Rhenohercynian Ocean. The Rhenohercynian Ocean was formed along Avalonian – Baltican part of the Laurussia continent and existed during Late Silurian – Early Carboniferous times. During the Late Devonian, as a result of consumption of the Rheic Ocean, the Armorican Terranes collided with Avalonian Island Arc. The collision resulted in stress regime change in the back arc basin (the Rhenohercynian Ocean) from extensional to compressional, which is marked by deposition of synorogenic sediments (for example Bardo or Świebodzice Unit). The Tepla – Barrandian Unit, which is interpreted as a part of Avalonian Island Arc, rotated clockwise and collided with the Saxothuringian southern margin. The rotation led to the formation of a north-bended orocline. The Renohercynian Zone and Moravo – Silesian zone are interpreted as the same oceanic suture placed in the northern and eastern part of the orocline, respectively. The Moldanubian Zone was formed as a result of burial and exhumation of the southern passive margin of the Saxothuringan Terrane, during its collision with Tepla – Barrandian Unit. The closure of the Renohercynian Ocean led to the formation of an accretionary prism with abundant mélanges complexes and olistoliths (e.g. Kaczawa Unit). The Brunovistulicum Terrane did not belong to the Avalonian Island Arc, however its dextral movement along present day Kraków – Lubliniec Fault during opening of the back arc basin and then northward migration and clockwise rotation during its closure, had a major impact on the orocline formation. As a result of the collision of the Brunovistulicum with the Bohemian Massif the Moravo – Silesian thrust-and-fold belt was formed.

Based on the presented model following statements were made

1. pillow lavas of the Rzeszówek – Jakuszowa Unit represent an equivalent for the Intrasudetic Ophiolite,
2. the Nowa Ruda Massif, and probably Braszowice - Grochowa Massif, could be interpreted as a huge olistolith transported above Góry Sowie Block,
3. bodies of the Wojcieszów Limestone, also identified as a olistoliths or olistolplaques within Lower Paleozoic slates (mainly Radzimowice Slates), were formed on the Gondwana passive margin and later transported to the deeper part of the basin. As a more resistance to the erosion, today they form a characteristic klippen belt in the Kaczawa Mountains landscape,
4. mélanges in the Kaczawa Unit are interpreted as a typical complexes of an accretionary prism.

Remarkably, the model does not allow to conclude on origin of the Góry Sowie Block. Based on the collected data, the Góry Sowie Blok might belong to the Armorican Terranes as well as to the Avalonian Island Arc. During the modeling, both hypothesis were tested, however with no success. Taking under consideration recent advances on the formation of Orlica – Śnieżnik Dome and its resemblance to the Góry Sowie Block, it might be assumed that Góry Sowie Block is also a part of Saxothuringian Terrane and had undergone similar evolution.

The model itself has several incoherencies which arise as a result of software limitations, lack of available data or necessary simplifications. Nevertheless, the model gives a reliable insight into the evolution of the Bohemian Massif. The most significant advantages of the presented approach are the possibility of incorporation different types of data during modeling, as well as quantitative analysis of the final model.