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Tectonic Features within the Cap Rock of the Mogilno Salt Structure, Central Poland

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Cap rocks mantelling upper parts of salt structures are attributed to rock salt dissolution occurring at the salt structure contact with overlying formations in response to circulation of unsaturated brine/ground water within the salt surroundings. They are commonly thought as uniform films protecting salt structures from outer factors. However, seismic and geological studies (e.g. Krzywiec *et al*. 2000, Wilkosz 2005) as well as salt mine catastrophic inundation (e.g. inundation of Wapno Salt Mine, Poland in 1977) have shown that cap rocks have complex structures, they are fractured and faulted, thus, they do not isolate salt series from the surrounding rocks that perfectly. The studies carried out over the Mogilno Salt Structure, central Poland, has proved that tectonic processes exert significant impact not only on a cap rock stability but also on its internal structure.

The Mogilno Salt Structure is one of 11 salt structures in Poland piercing through the Mesozoic cover up to the shallow subsurface (up to about 60 m below the surface). The structure has developed between the Triassic and present, therefore it remains in contact with various Mesozoic and Cenozoic formations. Its cap rock locally borders with Pleistocene deposits, indicating, thus, relatively recent episode of structure's uprise. The cap rock has differentiated thickness (77–190 m), morphology of the surface (± 100 m of relative height difference) and lithology. The latter was revealed by boreholes which evidenced three dominant rock constituents of the cap rock: gypsum, anhydrite and clays, forming altogether varying lithofacies. Additionally allochtonous sediments (gravels, sands, muds and lignite) occur within the cap rock.

This study aimed to analyse tectonic meso-scale structures occurring in the cap rock material in three drill cores. Alas the cores were not spatially oriented, thus only qualitative analysis was possible. The set of tectonic structures documented in the analysed rocks can be divided into two groups according to relative time of their development: (i) inherited tectonic structures and (ii) structures developed in the cap rock *sensu stricto*. The first group includes features developed in salt series during salt flow and they are observed in competent rocks (anhydrite/gypsum) incorporated as blocks into the cap rock. These are stylolites, slickolithes, joints/shear fractures and veins. All structures have varying orientation relative to the core axes dependent on overall block orientation and the stylolites, slickolithes, and veins depict variable geometry and petrographical characteristics throughout the cap rock. Phase changes between anhydrite and gypsum are also evidenced in their structure. The second group includes structures preserved in the gypsum-anhydrite-clay rocks originated due to salt series dissolution and these are represented by joints, shear fractures, shear zones and veins. Due to small area of observations the distinguishing between joints and shear fractures is arbitrary: joint system is attributed to rare fractures cutting the lamination almost vertically and the shear fracture system to those making almost constant angle of 30–50° throughout the cap rock. Joints are dominantly preserved in sulphate rocks and the shear fractures (as well as shear zones) are observed both in sulphate rocks and clays. Some shear fractures has transformed into microfaults as evidenced by slickensides and gypsum coatings with clear fibre lineation and older-vein offset. The latter features are also observed in shear zones which are demonstrated by 10 cm-wide zones of closely spaced fractures that make an angle of about 30° with the shear zone boundary. Generally the angular relationships between all types of fractures and the primary bedding in the cap rock indicate that the fractures developed due to vertical interaction of the salt structure occurring beneath the cap rock and the load overlying it. Timing of their origin can not be deciphered at present.

Progressive growth of gypsum crystals within the fractures (some crystals exceed 10 cm in length) has resulted in formation of continuous veins of varying thickness and locally to substitution of primary clay layers by gypsum ones. This observation indicates that tectonic factors both lead to disintegration of primary structure of the cap rock and to transformation of its lithological composition.

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Quaternary Tectonic Activity of the Central Part of the Polish Carpathian Foredeep, Evidences from Archaeological Open Site at Brzezie near Kraków

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The fossil graben and associated with it the normal faults and joints within the Vistulian and Holocene sediments are the object of considerations here. These structures were observed in the archaeological open site at Brzezie, in the central part of the Polish Carpathian Foredeep (Fig. 1A).

The normal faults cut the Pleistocene gleyed loess, laminated loess, Eoholocene buried soil and the lower part of the Mezoholocene deluvium that includes an archaeological artefacts from the Neolith and early Bronze Age (Fig. 1B). These structures die out within the middle and upper part of the Neoholocene deluvium including archaeological artefacts from the Lusatian culture. The normal faults strike mostly NNE-SSW and dip steeply about 65–850 (Fig. 1C). Some of them, the master normal faults, bound the fossil graben (Fig. 1B). The surfaces of the normal faults are slightly striated. The fault-slip analysis shows that the maximum principal stress axis (σ1) was in subvertical position, the minimum principal stress axis (σ3) was horizontal and WNW-ESE-directed (Fig. 1D). The joints occur within the graben and outside of it. They group into three sets: 1) the NNE-SSW-trending; 2) the WNW-ESE-trending and 3) the ENE-WSW-trending (Fig. 1E). The joints of the two first sets predominate. They form an orthogonal joint pattern, where the joints of the (1) set strike parallel to the normal faults and the joints of the (2) set strike perpendicular to them. Additionally, these joints are closely spaced close to the normal faults. Stewart and Hancock (1990) described the similar relationships between joints and faults and suggesting that the development of joints was connected with the normal faulting. Therefore we believe that jointing was simultaneous with faulting at Brzezie. The basement of the study area is cut by NE-SW-trending faults that represent fragment of the Kurdwanów-Zawichost Fault Zone (Fig. 1A). There are some evidences of sinistral reactivation of this fault zone during the Late Miocene and later (Rauch-Włodarska et al. 2005). The normal faults and joints observed at Brzezie could be caused by activity of the Kurdwanów-Zawichost fault zone during the Pleistocene and Holocene.

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