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Application of paleokarst studies in dating of tectonic events and morphology formation in an intensively faulted area - (an example from the Carpathian Foredeep, Southern Poland)

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Abstract

In the vicinity of Krakow (southem Poland) the Tertiary sediments, wich fill the Carpathian Foredeep, are protru ded by horsts of Mesozoic limestones creating picturesque landscape. The horsts are cut by deep karst valleys, occasionally filled with Miocene marine clays. This fact has given rise to the long-lasting discussion on the formation of horsts contemporaneously with or ear lier than the development of the Carpathian Foredeep, and on the pre-Miocene versus Pliocene age of the valleys.

Studies of Early Tertiary residual deposits produced by weathering of Mesozoic carbonates contributed significantly to the solution of the dating problems. The results allow to conclude that horsts and valleys were formed contemporaneously, during the Oligocene-Lower Miocene uplift, and were uncovered after the Miocene by removal of the Tertiary sediments. Most part of the studied areas has not been restructurized by the subsequent, Alpine tectonic movements.

Résumé

Près de Cracovie (Pologne méridionale), des horsts de calcaire mésozoïque font saillie dans les sédiments tertiaires qui remplissent l'avant fosse carpatique, ce qui a donné naissance à un paysage pittoresque. Ces horsts sont entaillés par de profondes vallées karstiques, parfois remplies d'argiles marines miocènes. Il en est résulté de longues discussions à propos de l'âge des horsts, contemporains ou antérieurs à la formation de l'avant fosse carpatique, et à propos de l'âge des vallées, pré-miocènes ou pliocènes.

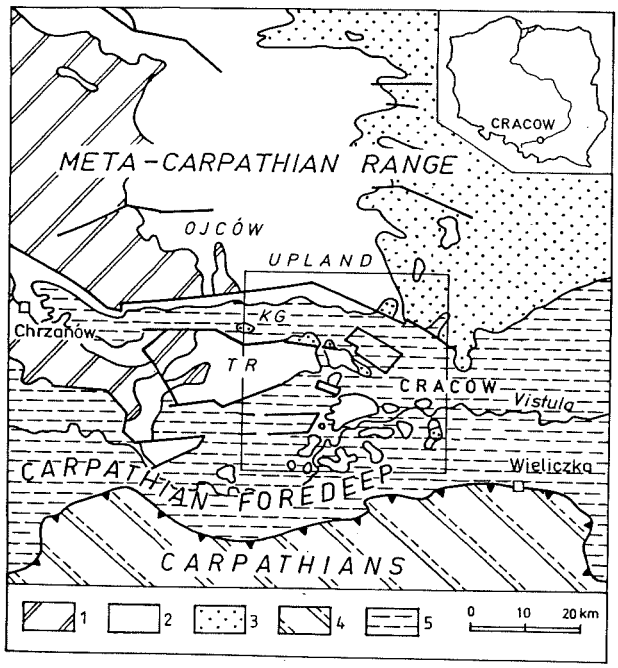
L' étude des dépôts résiduels du début du Tertiaire, produits par l'altération des roches carbonatées mésozoïques, a contribué de façon significative à la solution du problème des datations. Les résultats permettent de conclure que les horsts et les vallées se formèrent simultanément, pendant le soulèvement de l'Oligocène et du début du Miocène; ils furent mis à découvert après le Miocène par enlèvement des sédiments tertiaires. La plus grande partie de la région étudiée n'a pas été restructurée par les mouvements tectoniques alpins ultérieurs.

I. INTRODUCTION

The investigated area is situated in southern Poland, near Krakôw, about 10 km north of the Carpathians. It is composed of Mesozoic and Tertiary deposits (Fig. 1). The Tertiary sédiments (mainly Badenian) fill the Carpathian Foredeep resting upon Jurassic and Cretaceous basement. The prevailing Mesozoic rocks are weathering resistant, massive Oxfordian limestones. In the vicinity of Kraków w these limestones form picturesque hills scattered over the Foredeep. The hills reflect fault tectonics of the Mesozoic complex. These tectonics are proved by the constant thickness of the Oxfordian (see bore-holes D2,Z2,D3 in Fig. 2/1,1I) and by common fault planes within the Oxfordian and Senonian rocks (Fig. 3).

II. DATING PROBLEM

Broad depressions between the hills are filled with Badenian marine clays. The same clays were also occasionally reported from deep karst valleys cutting the horsts. This fact has given rise to the long lasting discussion on the age of horsts and valleys. The discussion may be summarized in two structural models of the Carpathian Foredeep. In the first one, horsts and valleys were formed before the Badenian. After the Miocene they were only uncovered by removal of the Tertiary sediments. The second model, preferred till now, assumes almost complete peneplanation of pre-Miocene basement during die Paleogene, Late Alpine age of faults and Pliocene age of valleys. The origin of faults is explained by means of tension resulting from



flexural bending of the Carpathian Foreland in the Badenian, during formation of the Foredeep.

The solution of the dating problems was possible owing to studies of residual deposits produced by weathering of Mesozoic carbonate rocks. The discussed deposits locally underlie Miocene marine sediments filling varions karst structures cut in the Oxfordian limestones. They contain exclusively redeposited Senonian and Oxfordian microfossils. Most common are residual clays originating from destruction of Senonian marls, accompanied by green (sometimes red and green) clays and white sands. The clays and sands may contain Oxfordian Oints and also debris and pebbles of Oxfordian limestones. The mineralogical composition of clays is dominated by smectites which are commonly accepted as typical of the Oligocene residual deposits. The author's studies point out that sedimentation of examined deposits lasted through the Early Miocene until the Carpathian.

Figure 1: Localization of the studied area: 1 - pre-Jurassic sediments, 2 - Jurassic, 3 - Cretaceous, 4 - Cretaceous and Palaeogene of the Carpathians, 5 - Tertiary; KG - Krzeszowice Graben, TR - Tenczynek Ridge

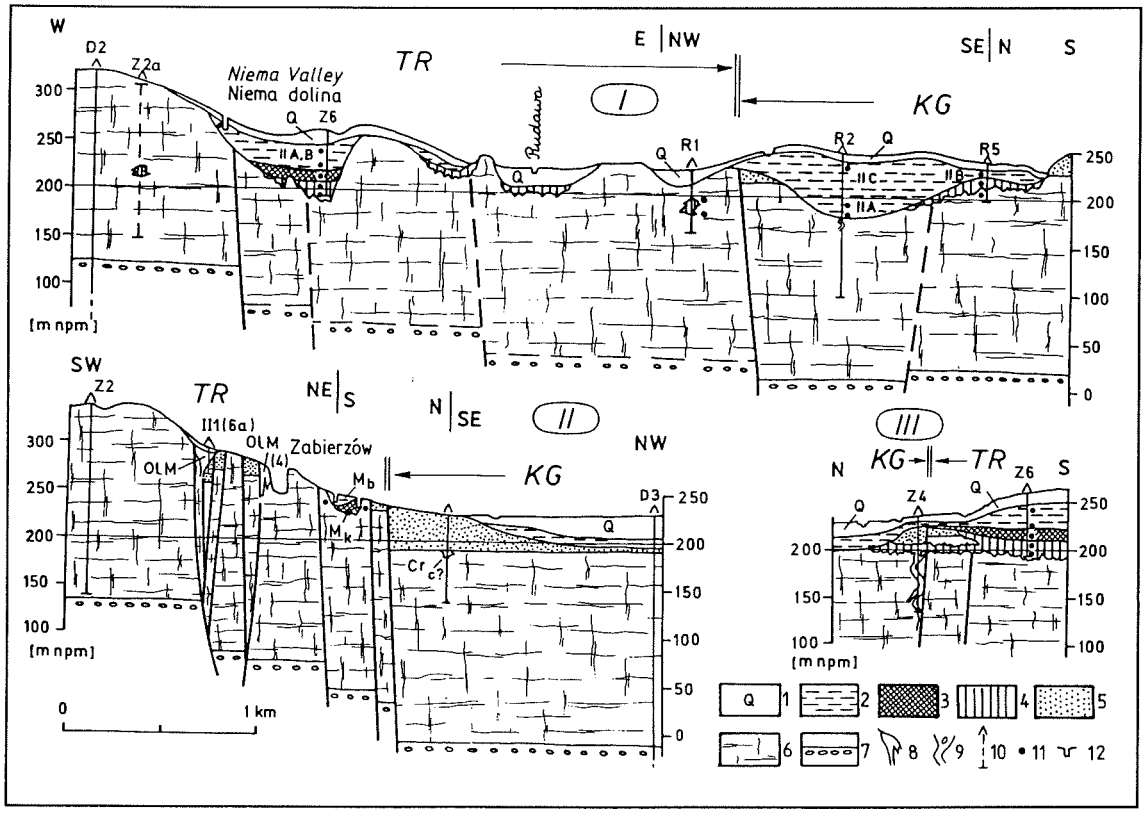


Figure 2: Cross-sections through Tenczynek Ridge (TR) and Krzeszowice Graben (KG) (see Fig. 1).
1 - Quaternary, 2 - Badenian, 3 - Karpathian, 4 - Oligocene-lower Miocene, 5 - Cretaceous (Turonian, Santonian,Lower Campanian), 6 - Oxfordian, 7 - Callovian (top part), 8 - sink-holes, 9 - karst conduits, 10 - drilling projected on the cross-section plane, 11 - sampling depth, 12 - dug well. Cr_c - Cenomanian calcareous conglomerates with marine fauna (clastic dyke).

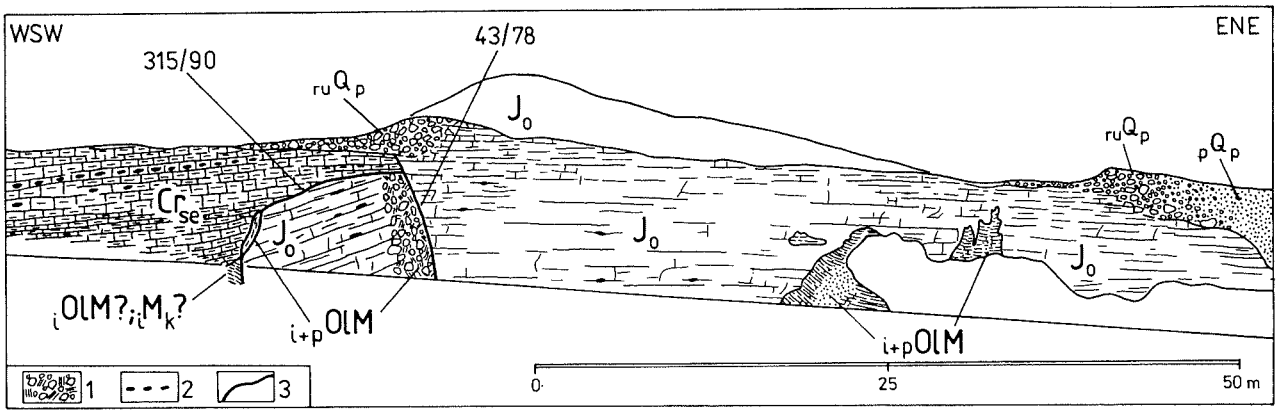


Figure 3: Sketch of Oligocene-lower Miocene outcrop at Kraków, Telewizyjna Str. 1 - karstified fault breccia, fissures filled with green clays and sands; 2 - flints; 3 - intersection of the fault plane with inclined wall of the outcrop. 315/90, 43/78 - orientations of the fault planes (direction of dip/angle of dip).
J_o - Oxfordian; Cr_{se} - Senonian; OlM - Oligocene-lower Miocene; M_k - Karpatian; Q_p - Pleistocene.
Lithology: i - clays; p - sands; ru - limestone rubble.

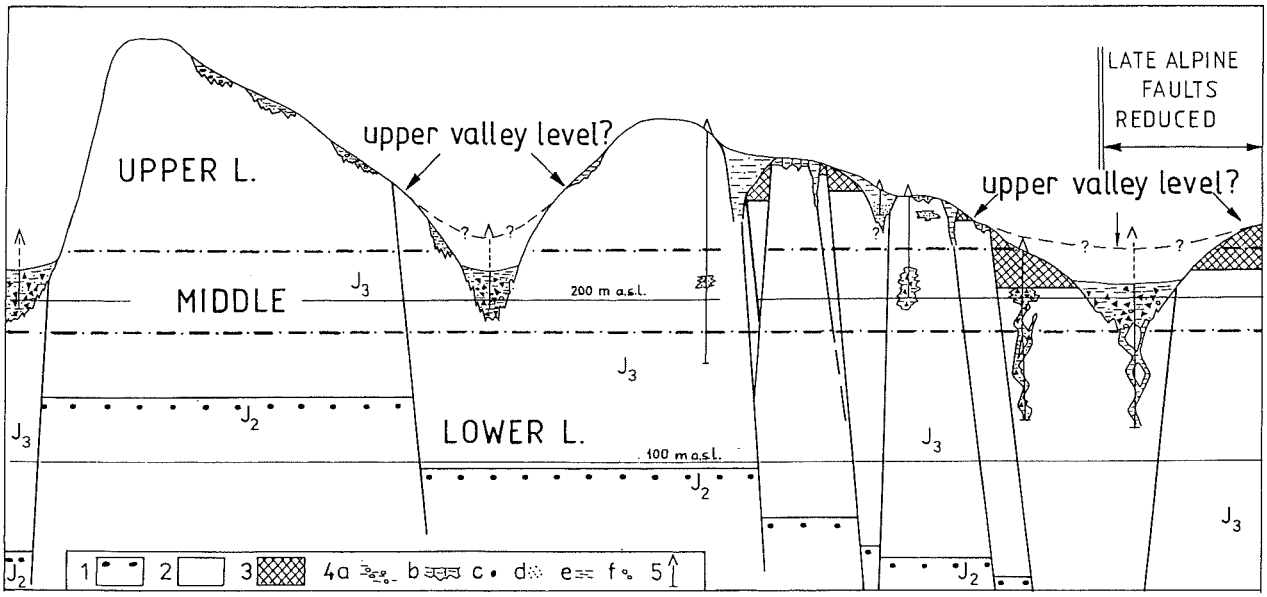


Figure 4: Levels of Oligocene-early Miocene karst near Kraków south from Krzeszowice Graben.
1 - Callovian (top part); 2 - Oxfordian; 3 - Cretaceous; 4 - Oligocene-lower Miocene: a - weathering clays after Oxfordian limestones, b - weathering clays after Cretaceous marls, c - flints, d - sands, e - clays, f - limestone pebbles; 5 - boreholes.

III. KARST LEVELS

The studied deposits belong to three karst levels characterized by different altitudes of the localities, relation to principal morphological features and the prevailing source of material. The levels were drawn schematically in Fig. 4 based on the Crue cross sections (for example Fig. 2). Only the right margin of the scheme has been based on the section, in which reduction of the Late Alpine tectonic effects was done.

The upper level includes diverse weathering deposits derived from both - Upper Cretaceous and Oxfordian source beds - and accumulated in vertical, frequently joint- or even fault-controlled karst forms (sinkholes, pockets etc.) (Fig. 2/1I, 3). Horizontal karst conduits

are rare. It is possible that the deposits from some small outcrops exposed in the slopes of the valleys are relies of material which filled the upper valley level.

In the most interesting middle level prevail clays rich in Oxfordian flints and rare pebbles of the Oxfordian limestones. These deposits were found in the bottom of some valleys. In the author's opinion they fill sub-Miocene karst paleovalleys, in most cases exposed recently because of the removal of their Tertiary infillings. Their unexposed fragments were localized by drilling in some places (Fig. 2/1). The most obvions is the case of Gacki water well (Fig. 5). Thick Tertiary sediments (green clays with flints and Badenian marine clays) were drilled between two outcrops of Oxfordian on the axis of the recent valley. One can be sure that, before the Badenian, this valley ran straight from NE to SW.

The Oligocene - early Miocene age of the valleys is confirmed also by the presence of horizontal caves and karst conduits developed at the level of valley bottoms. The caves and conduits are filled with green clays, sands and flints encountered in five bore-holes (like Z2a and R1 in Fig. 2/1). Results of drillings point out to the depth of the paleovalleys exceeding 90 meters (Z2a, Fig. 2/1). Recently, the caves and deposits which fill the paleovalleys fall between the rather altitude range of 50 m (180-230 m a. s. 1.) whereas the altitude of the top of Jurassic sequence is 280 m. It allows us to conclude that the studied area has not been essentially restructured after Middle Alpine tectonic events. Altitudes apparently different from those quoted above are rare and reflect the Late Alpine movements.

The lower level is represented by vertical systems of fissures and conduits found in the Oxfordian limestones, under the cover of Tertiary clays and even Senonian maris (Fig. 2/111). The system extends down more than 100 m below the top of the Mesozoic sequence. The fillings of these forms are green (and occasionally red) clays and sands found in tectonic depressions, commonly below the bottom of paleovalleys.

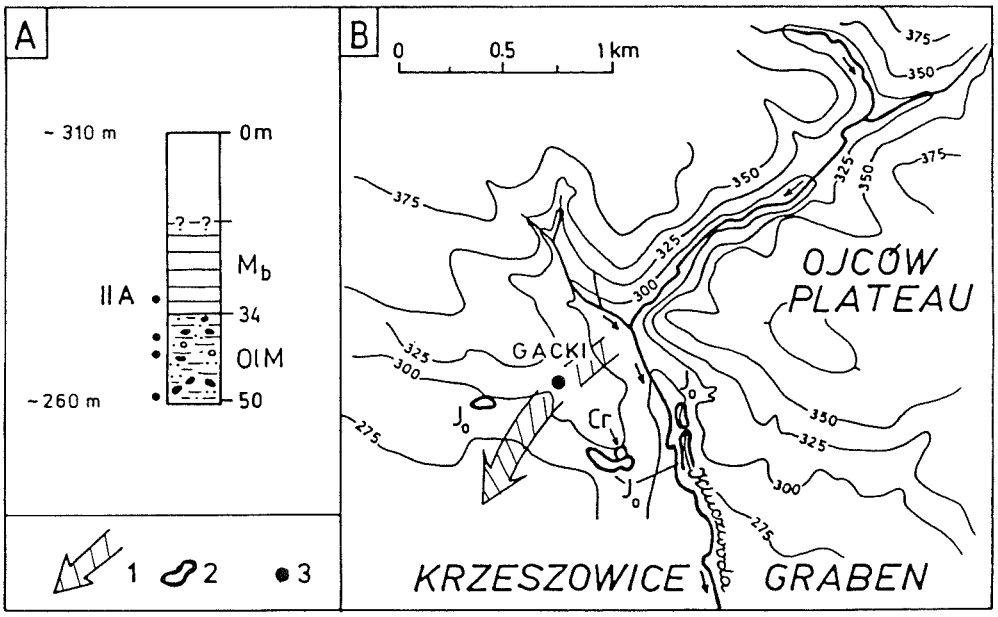


Figure 5: Sequence of sediments filling the Kluczwoda paleovalley (A) and its localization (B).
1 - Kluczwoda Valley before Badenian; 2 - outcrops; 3 - Gacki water well. Cr - Cretaceous (Turonian, Lower Campanian); M_b - Badenian. Other explanations as in Fig. 3 and 4.

IV. CONCLUSIONS

Results of the studies on Oligocene - early Miocene deposits allow us to say that both structural models of the Carpathian Foredeep are not complete. The tectonic history of the studied area is multiphase but generally the first, older model was better. Horsts and valleys were formed contemporaneously during the Oligocene - early Miocene (Middle Alpine) uplift, and were uncovered after the Miocene by removal of the Tertiary sediments.

Vertical erosion has begun during the Oligocene as a result of the uplift of the Meta-Carpathian Range which, at this time, included also the Foredeep. Broad bending

of the Range resulted in tension, which caused the formation of numerous faults. Simultaneous faulting and erosion prevented the Jurassic limestones from thickness reduction in grabens and activated the cutting of antecedent gorges. They led to the development of valley systems running from the Meta-Carpathian Range to the south, across the latitudinal horsts.

The deep karst valleys were accompanied by underground drainage systems. Complicated fault tectonics locally forced the development of lateral karst conduits beneath the Cretaceous maris (Fig. 2/III). Their infillings may be confused with Lower Cretaceous karst deposits, which are in fact absent in the vicinity of Kraków.

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