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ON THE ALLEGED HORIZONTAL DISPLACEMENTS WITHIN MESOZOIC DEPOSITS OF THE CRACOW UPLAND (SOUTH POLAND)

(Pl. I and 7 Figs.)

W sprawie domniemanych połogich przemieszczeń w osadach mezozoicznych Wyżyny Krakowskiej

(Pl. I i 7 fig.)

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Abstract: The article deals with overlaps occurring within Upper Jurassic limestones in the southern part of the Cracow Upland. A similarity of overlaps and sloping tectonic ribs has been found. The origin of overlaps is associated with en echelon arrangement of steeply inclined joint fractures as well as with their intersection with horizontal discontinuity surfaces, mainly bedding planes. On the basis of a mesostructural analysis a normal-dep-slip style of tectonics and the lack of compressional structures of the thrust type have been found.

Key words: overlaps, tectonic ribs, horizontal displacements, Mesozoic deposits, Cracow Upland.

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Treść: W pracy poruszono problem okapów skalnych występujących w wapieniach górnej jury, w południowej części Wyżyny Krakowskiej. Stwierdzono podobieństwo okapów do połogich żeber tektonicznych. Genezę okapów związano z kulisowym ułożeniem stromych pęknięć ciosu i przecinaniem się ich z połogimi powierzchniami nieciągłości – głównie uławiceniem. Na podstawie analizy drobnych struktur w badanym regionie stwierdzono głównie zrzutowo-normalny styl tektoniki i brak oznak reżimu kompresyjnego typu nasuwczego.

INTRODUCTION

The problem of horizontal or sloping displacements within Permo-Mesozoic deposits of the Cracow Upland has frequently been discussed. The majority of investigators (Kuźniar, Żelechowski, 1927; Nowak, 1927; Bobrowski, 1950:

Gołąb, 1951; Tokarski, 1954; Gradziński, 1955) are of the opinion that such displacements of rock patches do really exist and that their geological importance is considerable. Origin of these displacements is being confined to compressional mechanical regime (horizontal compression of the N – S direction), caused by thrusting of the Flysch Carpathians onto their foreland.

According to Nowak (1927) there was even decollement of the Mesozoic sedimentary cover, enabled by "independent movement on the Permian clays". On the contrary, Dżułyński (1953) and Bogacz (1967) strongly neglect the possibility of horizontal displacements, such as compressional thrusting and folding. Both these authors consider faults as main factors that have influenced the tectonics of the Cracow Upland. These are normal-slip or oblique-strike-slip faults (Bogacz 1967). Mesoscopic structural studies carried out by Krokowski (1977) do not confirm the existence of sloping, almost horizontal displacements. Vertical or sloping mass transfer recorded in Permo-Mesozoic deposits of the Cracow Upland could have been caused by feathered faults, related to normal-slip fractures of the higher order or, could relate to intrabed slips, enabled by tilting of blocks and flexural bends (cf. Dżułyński, 1953, p. 403).

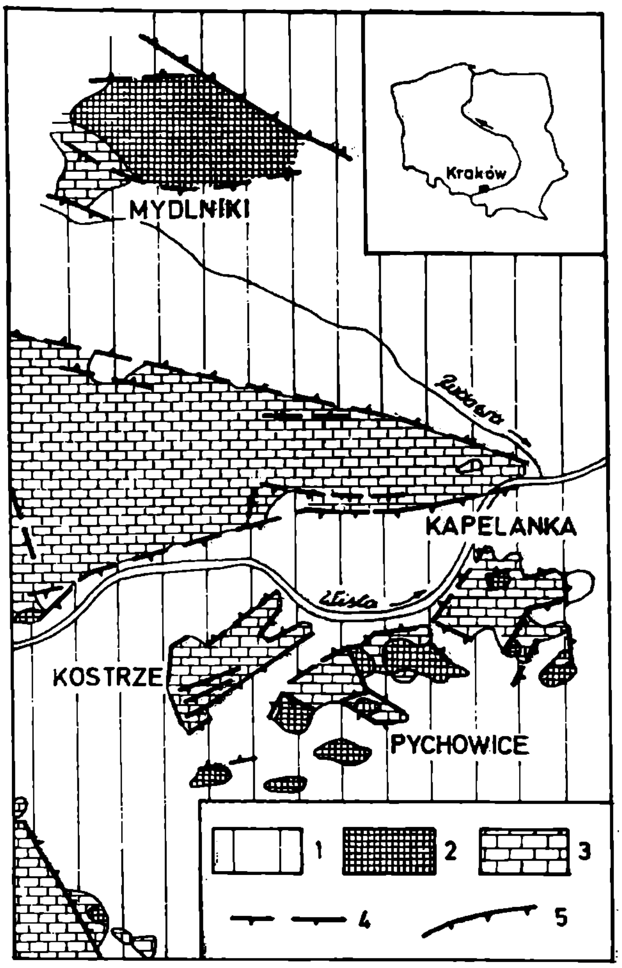

Fig. 1. Geological sketch of the vicinity of Kraków (according to Gradziński, 1974). *1* – Miocene (clays), *2* – Cretaceous (conglomerates, limestones, marls), *3* – Upper Jurassic (limestones); faults: *4* – probable, *5* – certain

Fig. 1. Szkic geologiczny okolic Krakowa (według Gradzińskiego, 1974), *1* – miocen (iły), *2* – kreda (zlepieńce, wapienie, margle), *3* – jura górna (wapienie), *4* – uskoki prawdopodobne, *5* – uskoki stwierdzone

In the light of the above review, the origin of the alleged intrabedding displacements remains unsolved. Kuźniar and Żelechowski (1927) described one of the walls of the abandoned quarry at Kapelanka, Kraków (Fig. 1). Overlaps of this wall, forming beds overlying the lower ones, were interpreted as having been caused by horizontal displacements, enabled by stresses generated by the overthrusting Carpathians. Dżułyński (1953), however, related the origin of these overlaps to exploitation processes, protruding along joint surfaces. The old concept of Kuźniar and Żelechowski (1927) was supported again by Gradziński (1955) who noticed a certain regularity in the arrangement of overlaps. This regularity is due to the presence of an overlap on a wall and a step on the other wall, parallel to the former one. A similar interpretation was expressed by Jaroszewski (1968).

GEOMETRY AND ORIGIN OF OVERLAPS

Bedding planes of Jurassic limestones in the vicinity of Kraków do not reveal slickensides which could have proved horizontal or sloping mass transfer. On the contrary, on sloping discontinuity surfaces there occur stylolites displaying vertical orientation of rods (Fig. 2). Slickenside structures and sliccolites occur on steeply inclined (60 – 70°) surfaces (Fig. 2) and indicate the normal dip-slip style of tectonics of the region.

Steeply-dipping and vertical, NNE-trending surfaces reveal a strike-slip component. To reconstruct the orientation of main strain directions (elongation, shortening and intermediate, denoted *X*, *Z* and *Y*), a projection of movement planes of slickensides and sliccolites (Figs. 3 and 4) was drawn, by using the method of Arthaud (Arthaud, 1969; cf. Mercier et al., 1973; Jaroszewski, 1974). A movement plane is described by tectonic striae or rods of sliccolites, as well as by normals to surfaces of slickenside or sliccolite planes. Poles of movement planes of slickenside structures occur on the circumference of the diagram (Fig.

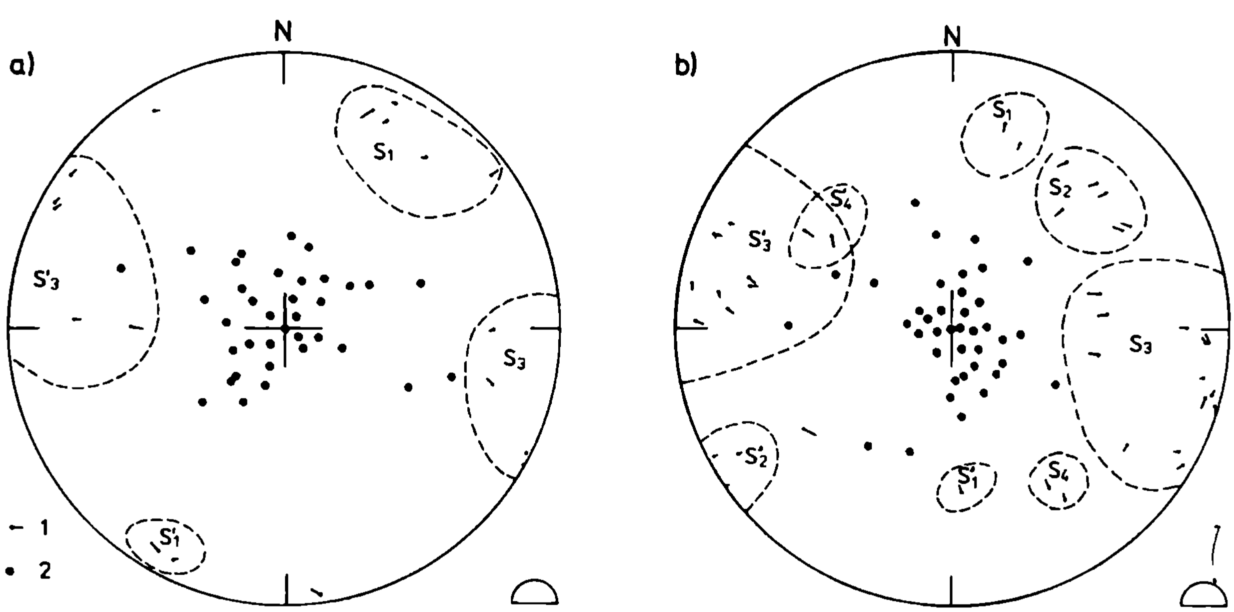

Fig. 2. Diagrams of slickenside structures, slicolites and stylolites: *a* – Kapelanka, *b* – Rząska – Mydlniki Wapiennik, *1* – slickenside structures, and sliccolites, *2* – stylolites

Fig. 2. Diagramy struktur ślizgowych, slikolitów i stylolitów: *a* – Kapelanka, *b* – Rząska – Mydlniki Wapiennik, *1* – struktury ślizgowe i slikolity, *2* – stylolity

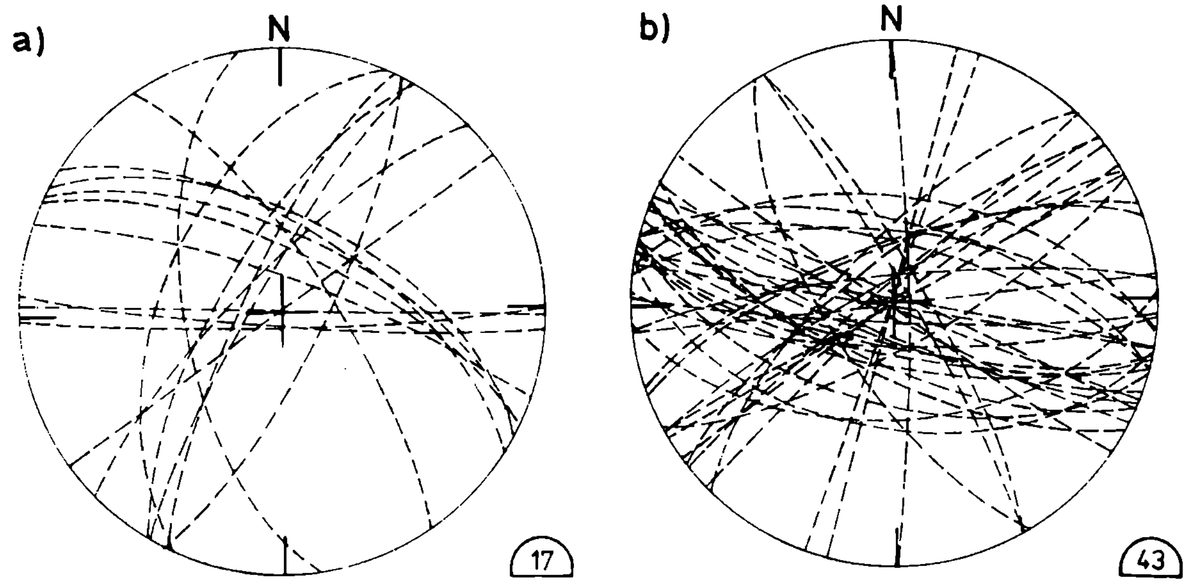

Fig. 3. Diagrams of planes of movement of slickenside structures and sliccolites within Upper Jurassic limestones: *a* – Kapelanka, *b* – Rząska – Mydlniki Wapiennik

Fig. 3. Diagramy płaszczyzn ruchu struktur ślizgowych i slikolitów w wapieniach górnej jury: *a* – Kapelanka, *b* – Rząska – Mydlniki Wapiennik

4) and form a number of sets of high concentration. These correspond to appropriate sets of slickenside structures (Fig. 2) which could be interpreted as complementary and conjugated sets, displaying normal dip-slip kinematic properties. The sets of poles of movement planes (Fig. 4) represent intermediate direction *Y*. Directions of shortening and elongation run along movement planes and are vertical and horizontal, respectively. Strain systems relate to stress systems, the maximum stress of which is oriented almost vertically while the two remaining

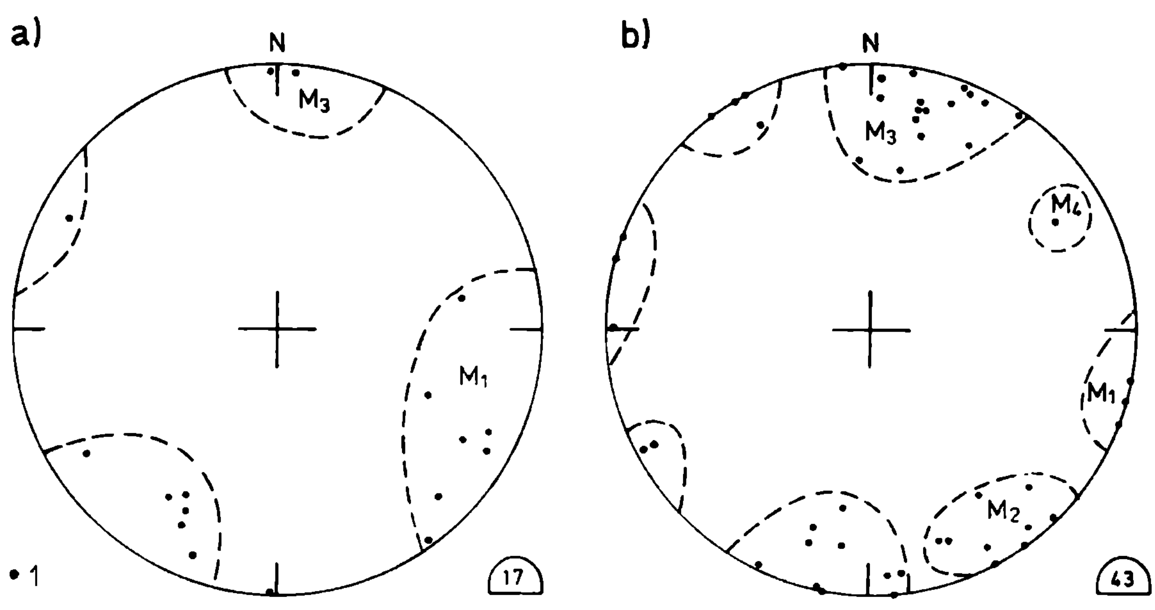

Fig. 4. Diagrams of normals to planes of movement of slickenside structures and sliccolites: *a* – Kapelanka, *b* – Rząska – Mydlniki Wapiennik. *1* – poles of planes of movement

Fig. 4. Diagramy biegunów płaszczyzn ruchu struktur ślizgowych i slikolitów: *a* – Kapelanka, *b* – Rząska – Mydlniki Wapiennik. *1* – bieguny płaszczyzn ruchu

stresses are alomost horizontal. The σ_2 stress is described by poles of movement planes.

In the investigated area directions of slickensides and sliccolites are concordant with those representing joint fractures (Figs. 2, 4 and 6). The concordance of joint and fault orientation within Mesozoic deposits of the Cracow-Silesian Region has already been noticed by Dżułyński (1953), Kozioł (1953) and Krokowski (1977). Similar orientation of slickenside structures and joint indicates that

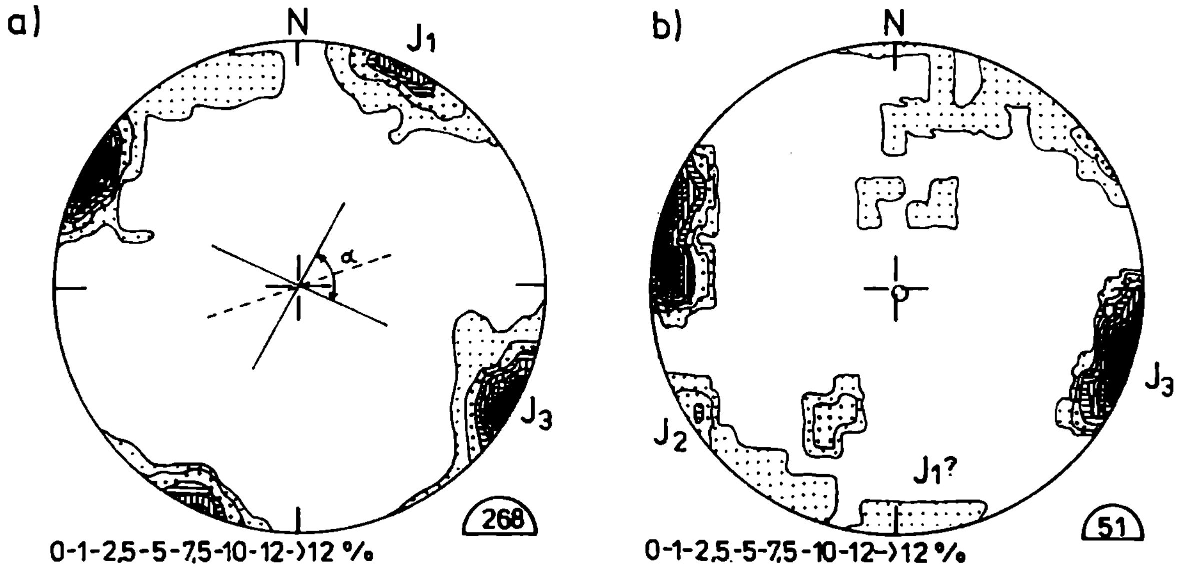

Fig. 5. Diagrams of joints within Upper Jurassic limestones: *a* – Kapelanka, *b* – Rząska – Mydlniki Wapiennik

Fig. 5. Diagramy ciosu w wapieniach górnej jury: *a* – Kapelanka, *b* – Rząska – Mydlniki Wapiennik

these structures were being formed during one tectogenetic cycle (cf. Roberts, 1965; Hancock, 1968; Jaroszewski, 1972, Salski, 1977). Origin of structures belonging to the both groups was interfingering in time. Slickenside structures and sliccolites utilized joint surfaces. This enabled a conclusion (Dżułyński, 1953, p. 391) that the formation of joint preceded that of faults. On the other hand, slickenside structures and sliccolites, being related to appropriate joint directions, do also occur on surfaces of lower inclination which cannot be associated with joint systems. It can be suggested that the formation of joint, slickenside structures and sliccolites was to a certain extent independent. This can prove a suggestion that slickenside structures represent complementary conjugated shears.

A polyphase character of structural evolution of the Carpathian foreland in the Cracow Region is documented by the presence of several systems of slickenside structures (Krokowski, 1977). Vertical attitude of stylolitic rods points to the formation in gravitation normal stress field pattern, developed under stress produced by overlying rocks. The observed stylolites-sliccolites-slickensides sequence can evidence their tectonic origin (Krokowski, 1977). Joint fractures and small faults (Fig. 5) had also their bearing on the formation of overlaps.

Joint fractures are very steep and vertical and form two orthogonal systems: $J_1 - J_3$ and $J_2 - J_4$ (Krokowski, op. cit.). Well-developed joints of the $J_1 - J_3$ system display large, several dozen metres long, smooth surfaces. These joints are not strictly rectilinear, when seen in vertical crossection and build characteristic

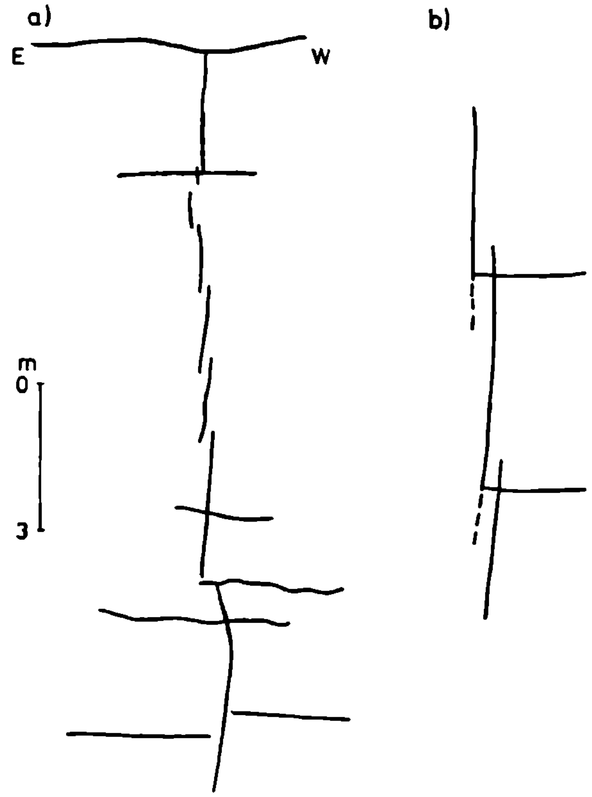

Fig. 6. *a* – an example of en echelon arranged joint surfaces, Kapelanka, SW wall of the abandoned quarry. *b* – mode of formation of overhangs developed at the intersection of horizontal discontinuities and en echelon joint fractures

Fig. 6. *a* – przykład kulisowego ułożenia spękań ciosowych, Kapelanka, SW ściana nieczynnego łomu. *b* – sposób tworzenia się okapów powstałych na przecięciu się poziomych nieciągłości z kulisowymi spękaniami ciosowymi

en echelon forms, the orientation of which is locally uniform. En echelon series of fractures form mainly narrow discontinuity zones and are oriented almost vertically. Individual fractures are arranged at an acute angle to the axes of fracture series (Figs. 6, 7, Pl. I).

It can be suggested that overlaps were being formed at an intersection of bedding planes, bedding joints or other sloping discontinuities with steeply dipping joint surfaces (Fig. 6, Pl. I). Due to exploitation or erosion processes the part situated beneath an overlap or that lying above a step, falls off which gives an illusion of horizontal mass displacement. Such an interpretation is partly concordant with that of Dżułyński (1953), although the role of en echelon arrangement of joints is more distinctly underlined.

A fixed orientation of overlaps sensu Gradziński (1955) points to an uniform arrangement of echelon fractures and, hence, to their importance in mechanical analysis of fractures.

Tectonic overlaps are closely associated with gently dipping tectonic ribs, frequently occurring within Jurassic limestones, especially in the southern part of the Cracow Upland (Krokowski, 1977). These ribs, together with en echelon arranged joint fractures of steeply dipping axes, evidence the formation in the gravitational normal stress field system (σ_1 – vertical). Overlaps and gently dipping tectonic ribs occur on various surfaces, especially those which are perpendicular or oblique to fold structures in the Carpathians. The surfaces and walls containing overlaps and ribs are associated with main directions of joint. These features cannot support the hypothesis, explaining overlaps as being related to horizontal displacements of rocks. Joint fractures in Jurassic limestones of the Kapelanka quarry form two, high-angle sets, intersecting at 80–85°. The bisectrix of the acute angle is oriented ENE–WSW. It is probable that joints of this system developed under strike-slip stress pattern (σ_2 – vertical) and formed

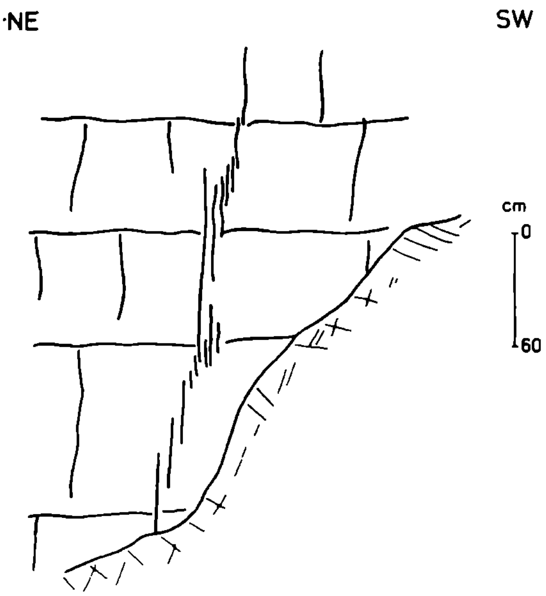

Fig. 7. Sketch of a narrow zone of en echelon fractures displaying steeply inclined axes. Jurassic limestones, Kobylanka Valley

Fig. 7. Schematyczny rysunek wąskiej strefy kulisowo ułożonych spękań o stromo położonej osi szeregu, wapienie jurajskie, okolice Doliny Kobylańskiej

two vertical sets of shears. This is proved by morphological properties of joint surfaces, vertical tectonic ribs, conjugation and the attitude similar to that of joints of the WNW–ESE and NNE–SSW system, which occur within Permo-Mesozoic deposits of the Cracow Upland (Krokowski, 1977). The origin of these joints can be confined to Mesozoic (Early Alpine) tectonic movements, the greatest intensity of which is usually being connected with the Laramide phase. During structural evolution of the area there occurred a change in stress field pattern, from the strike-slip (σ_2 – vertical) to the gravitational-normal or even tensional one (Dżułyński, 1953; Bogacz, 1967). This change was probably associated with both Laramide movements and, to a larger extent, with Miocene tectonics when Mesozoic deposits of the platform-type Alpine structural stage were thrown under overtrusting Flysch Carpathians. Normal dip-slip properties are more distinctly pronounced in structures of this region.

DISCUSSION

Overlaps and genetically related sloping and horizontal tectonic ribs resemble structures described by Jaroszewski (1968) as tectonic ledges. Tectonic ledges originated from displacements of rock patches along intrabedding planes. Surfaces oblique to bedding planes were not involved in these movements and, thus, could evidence the displacement.

In case of overlaps and horizontal tectonic ribs bedding planes behave passively while tectonic transport protrudes along discontinuities such as joints or faults. It appears that the origin of these two groups of structures was different. The presence of horizontal tectonic ribs does not exclude a possibility of intrabedding displacements, forming structures of the tectonic ledges type. These features resulted, however, from different forces. Such a conclusion leads to different mechanical interpretations, as far as regional scale of investigations is concerned.

It can be suggested that interpretation of features like tectonic ledges should be performed very carefully. The decisive criteria for establishing the origin of these features are slickenside structures occurring on movement planes.

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EXPLANATIONS OF PLATES – OBJAŚNIENIA PLANSZ

Plate – Plansza I

Fig. 1. Tectonic overlaps within Jurassic limestones on joint surfaces of the NNE–SSW set (J_3), inactive quarry at Kapelanka, Kraków. A vertical ("strike-slip") tectonic rib seen on the left-hand side.

Fig. 1. Okapy skalne w wapieniach jurajskich na powierzchniach ciosu zespołu o biegu NNE–SSW (J_3), nieczynny łom na Kapelance w Krakowie. Z lewej strony fotografii występuje pionowe („przesuwcze") żebro tektoniczne.

Fig. 2. Traces of vertical and steeply inclined joints of the NNE–SSW (J_3) set and their en echelon arrangement. Upper Jurassic limestones, Kapelanka quarry. On joint surfaces there are overlaps, visible in the right-hand side of the photo. Gradziński (1955, 1972) and Jaroszewski (1968) attempt to interpret the same structures as tectonic ledges. Bedding planes do not reveal any traces of slips or slickenside structures. This is proved by the presence of numerous joints cutting bedding planes. Illusion of horizontal displacement is caused by en echelon arrangement of joints.

Fig. 2. Ślady pionowych i stromych spękań zespołu NNE–SSW (J_3) oraz ich kulisowe ułożenie, wapienie górnojurajskie, łom na Kapelance. Są to spękania, na powierzchniach których na fig. 1 prezentowane są okapy skalne (prawa strona fotografii). Struktury te na tej samej powierzchni Gradziński (1955, 1972) i Jaroszewski (1968) tłumaczą jako gzymsy tektoniczne. Wzdłuż powierzchni uławicenia nie ma śladu przemieszczeń i zlustrowań. Świadczą o tym liczne spękania przecinające powierzchnie uławicenia bez jakichkolwiek śladów poziomego przemieszczania się skał. Złudzenie istnienia takich przemieszczeń sprawia kulisowe ułożenie spękań.


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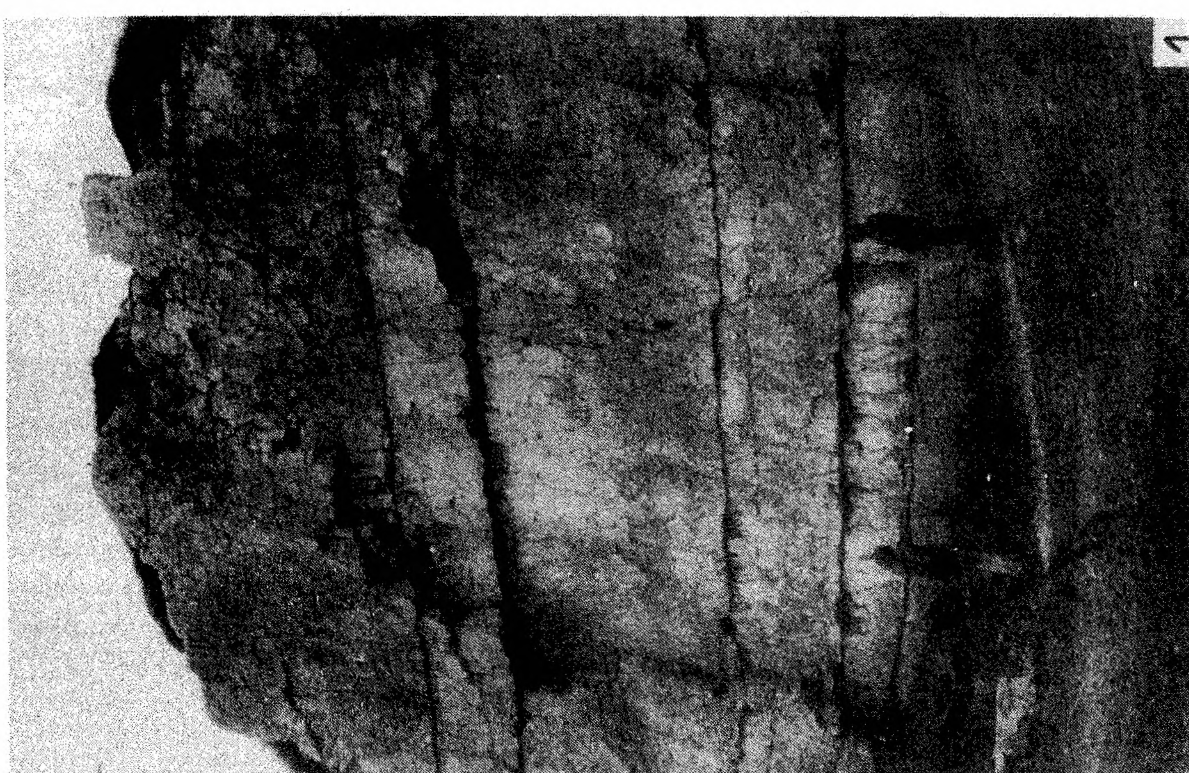
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