nel sandstones position and relationships with other facies is associated with high risk.

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Lithological Control on Tectonic Deformation of Upper Neogene, Poorly Indurated Strata at Witów, Carpathian Foredeep (Poland)

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Uppermost Miocene and/or Pliocene Witów series (Brud and Worobiec, 2003) crops-out in the Carpathian Foredeep ca. 40 km east of Kraków (Fig. 1). The series, up to 40 m thick, comprises interbedded conglomerate, gravel, sandstone, sand, mud, and clay. In the lower part of the series, clay and mud predominate, whereas the upper part is composed mostly of poorly indurated sandstone and conglomerate. The Witów series has been studied in four exposures located in a single sand-pit in the village Morsko, 3 km west of the town of Nowy Korczyn. Our observations are restricted to the upper, coarse-grained part of the series which was deposited by a braided river. In this part, beds of sandstone and conglomerate pinch out laterally at short distances. Most sandstone beds contain dissipated well-rounded pebbles and cobbles. The conglomerate is mainly sand-supported, whereas clast-supported conglomerate occurs occasionally. The clasts in the conglomerate are well-rounded. They show shallow imbrication which is differently orientated in particular exposures. The clasts are mainly sandstones, siliceous rocks, and carbonates. The large majority of the clasts in conglomerate, as well as the pebbles and cobbles in sandstone were transported from the Outer Carpathians from a distance of at least 30 km. Most of the clasts are less than 10 cm across, although few clasts up to 30 cm in diameter have also been observed.

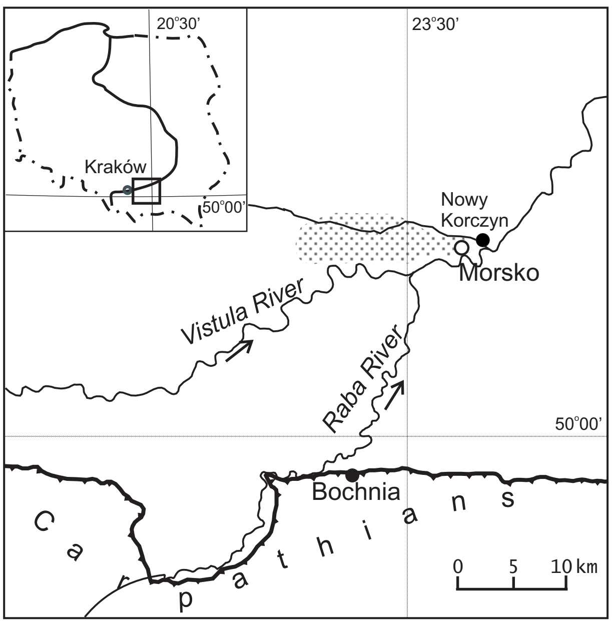

Fig. 1. Location of study area.

Observations

Sandstone

Sandstone beds are cut by numerous metre-scale joints and normal and strike-slip faults. The joints are subvertical. They terminate at the sandstone/conglomerate boundary. The majority of faults are restricted to single sandstone beds. Close to the normal faults, the dissipated discoidal and elongated pebbles and cobbles in sandstone are rotated into position in which AB planes of these clasts (planes containing the maximum and intermediate axes of clasts) are parallel to the faults (Fig. 2). The strike-slip faults do not cut the clasts dissipated in sandstone, but omit them. The offset on the strike-slip faults is only exceptionally visible. The majority of the normal and strike-slip faults termi-

Fig. 2. Normal fault cutting conglomerate; note that clasts adjacent to the fault are rotated into position parallel to the fault surface.

nate at the sandstone/conglomerate boundary where the normal faults splay out showing horse tail structures within conglomerate. Both normal and strike slip faults cutting sandstone show distinctive clean-cut surfaces.

Conglomerate

Only few of the faults cut both sandstone and conglomerate beds. Within conglomerate, these faults form zones up to few centimetres wide. Inside these zones, discoidal and elongated clasts are rotated into position in which AB planes of these clasts are parallel to the zones. Moreover, the mean size of the clasts within the zones is smaller than that outside the zones.

Numerous clasts in conglomerate are cut by joints. The joints are restricted to single clasts; they do not enter the matrix of conglomerate. Altogether, the attitude of 200 joints has been measured. The architecture of the joints is well-organized (Fig. 3). Most of the joints are subvertical. The angles between the joints and AB planes of clasts are usually high. Eighty percent of the angles surpass 70° (Fig. 4). The distribution of jointed clasts in the conglomerate is not uniform. The number of jointed clasts is larger close to the metre-scale normal faults than away from the faults. The jointed clasts are especially numerous close to horse tail terminations of the metre-scale faults. Moreover, the fractured clasts occur more frequently in clast-supported conglomerate than in the sand-supported conglomerate.

Fifteen strike-slip, normal and reverse faults cutting clasts in conglomerate have been observed. The offsets on these faults are up to 1 cm. All these faults are restricted to single clasts; they do not enter the matrix.

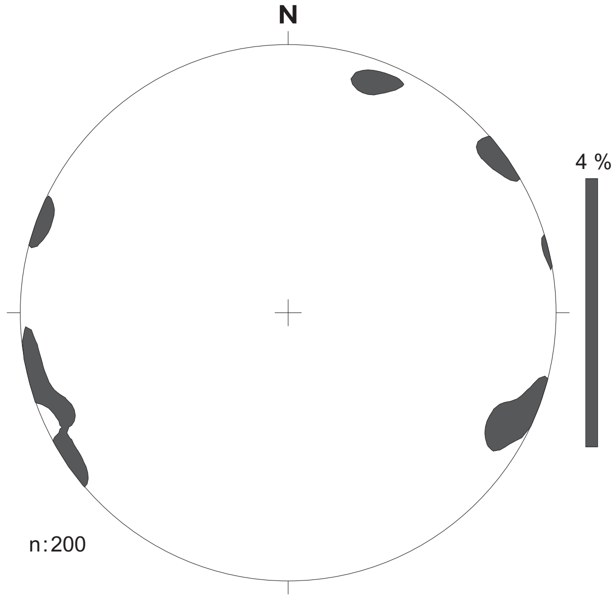

Fig. 3. Orientation of clast-scale joints.

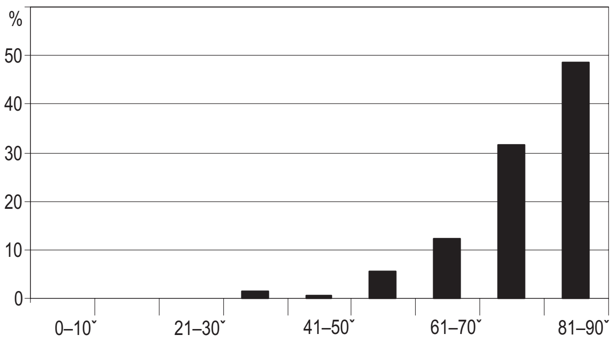

Fig. 4. Histogram of angles between joints and AB planes of clasts; data set: 197.

Discussion and conclusions

(1) The style of deformation within the Witów series is closely related to lithology of the deformed strata. The scale of deformation is different in sandstone and in the conglomerate. The sandstone is cut exclusively by metre-scale joints and faults, whereas in the conglomerate these structures are mainly of the clast-scale. The metre-scale faults in the sandstone are much more numerous than those in the conglomerate. Moreover, the metre-scale faults in sandstone show distinct clean-cut surfaces, whereas in conglomerate they form zones up to few centimetres wide.

(2) The increase in the number of jointed clasts close to the normal metre-scale faults shows that the jointing was related to normal faulting. On the other hand, omitting of clasts by the strike-slip metre-scale faults implies the lack of connection between the jointing and the strike-slip faulting.

(3) The good organization of the architecture of the clast-scale joints shows that jointing took place in situ. Most of the studied clasts are derived from the Outer Carpathian flysch strata which are usually cut by numerous joints filled by calcite veins. Therefore, the Neogene and Quaternary fluvial deposits within the Outer Carpathians (short sedimentary transport) con-

tain numerous clasts cut by inherited joints filled by these veins. The organization of inherited joints is very poor (Tokarski and Świerczewska, 2003). However, within the Witów series we have observed only very few veined clasts. It appears that the long sedimentary transport resulted in decomposition of veined clasts and consequent absence of inherited joints. We conclude that the longer the sedimentary transport is, the better organization of clast-scale joints can be visible.

(4) Most of the studied clast-scale joints are orientated subperpendicular to perpendicular to the AB planes of the clasts, notwithstanding orientation of the planes. This suggests that joints form subperpendicular to the existing lithological boundaries, notwithstanding the orientation of the latter.

(5) Within the Witów series, the direction of offset is only exceptionally visible on the metre-scale strike-slip faults that cut sandstone beds, and this handicaps the analysis of the faults. On the other hand, the offset is evident on the faulted clasts.

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Devonian Exotics in the Pieniny Klippen Belt Flysch and their Significance for the Plate Paleozoic Plate Tectonic Reconstruction of the West Carpathia

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Introduction

In Poland, Slovakia and the Czech Republic, Carpathian Fold Belt consists of an older unit known as the Inner Central or Central Carpathians and a younger one, known as the Outer West Carpathians the latter being overthrust onto the southern part of the European platform (Golonka and Lewandowski, eds. 2003). The boundary between the overriding Inner Carpathian (Alcapa plate) and the European plate is the Pieniny Klippen Belt. The fit between these plates constitutes one the problems of the Carpathian plate tectonic reconstruction. The most logical assumption would be to produce a reconstruction of the Pieniny Klippen Belt Basin, built of the Mesozoic sedimentary successions basins with the European margin on one side and the Inner Carpathian plate on the other (Golonka and Lewandowski, eds., 2003). The known basement of the Inner Carpathians comprises however variously metamorphosed Precambrian, Lower Paleozoic to Lower Carboniferous rocks (Gawêda et al., 2003) while the Devonian-Lower Carboniferous rocks of the European platform under Outer Carpathian south of Krakow are unmetamorphosed and undeformed (Slaczka, 2001).

The devonian exotics

The new discovery of the unmetamorphosed Devonian limestones in the exotic pebbles in the Pieniny Klippen Belt and Outer Carpathian Flysch (Silesian unit) certainly will help to solve this problem. The Pieniny exotic is represented by micritic boundstone from mainly blue algae with partially recristalized matrix. Most important among the fossils are: *Parathurammina*, *Bisphaera*, *Caligella*, *Earlandia*), calcispheres, ostracods, and multi-chamber forams (e. g. *Tournayellina*, *Palaeospiroplectammina*). They indicate the late Famennian – early Visean, but the lack of diagnostic forms younger than late Famennian and occurrence of the numerous primitive forms point to the late Famennian age.

The Outer Carpathian Flysch exotic was found in the Gródek on Dunajec river. It is a strongly dolomitised mudstone with numerous microfossils such as: algae (*Issinella*, *Kamaena*, *Girvanella*), calcispheres (*Archaesphaera*, *Radiosphaera*), single-chamber forams (*Vicinesphaera*, *Parathurammina*, *Bisphaera*, *Irregularina*), crinoids, echinoids spines, ostracods, brachiopods and vermetid gastropods. This assemblages of fossils indicate lagoonal facies characteristic for the late Devonian strata.

Plate tectonic implications

The Pieniny exotic pebbles were supplied from the so-called Andrusov Ridge, which belonged to the northwestern margin of the Inner Carpathian terrane southeast from the Pieniny Klippen Belt Basin (Birkenmajer et al., 1990, Golonka et al., 2003). This margin was destroyed during the orogenic process or may be is now hidden under the Central Carpathian Paleogene. The Devonian rooks were deposited in the shallow basin in the foreland of the Inner Carpathian Variscides. The Precambrian or lower Paleozoic (Caledonian) continental crust constituted the floor of this basin. This configuration display similarities with the Brunovistulicum (Finger et al., 2000, Kalvoda, 2001, Kalvoda et al., 2003) suggesting that the area belonged to the Avalonian