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Tectonics of the Chęciny Anticline (Holy Cross Mts., Central Poland) in the light of new cartographic data and calcite vein analysis

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The Variscan orogeny of NE–SW compression has folded the Paleozoic core of the Holy Cross Mountains (Central Poland). The Chęciny Anticline, formed during this tectonic event, is located in the southwestern part of the Kielce Unit. This paper presents structural data from two newly found outcrops of Cambrian rocks that modify the geometric reconstruction of the Chęciny Anticline, especially within its southern limb that is subdivided into two second-order structures: the Rzepka Syncline and the Wrzosy Anticline. The eastern part of the Chęciny Anticline has been reconstructed, pinpointing its fragmentation into a series of blocks (horsts and grabens) separated by faults semi-perpendicular to the anticline axis. New mapping data reveals deep, pre-Triassic erosion of folded Variscan basement, uncovering Cambrian rocks outcropping in the hinge of the Wrzosy Anticline. In the Chęciny Anticline, folding-related shortening has been accompanied by along-strike extension and the formation of syn-tectonic calcite veins, which filled fractures oriented perpendicular to the fold axis. The magnitude of extension has been estimated along a 215 m long main quarry wall of Rzepka Hill, approximately parallel to the Variscan structures and located within the southern limb of the Chęciny Anticline. The total thicknesses of veins filling extension fractures and spaces between clasts in tectonic breccia were summed and indicate 8.4% of strike-parallel extension (~120°) in the Chęciny area. This value was compared to *ca*. 30% of folding-induced shortening, related to NE–SW late Variscan compression. We hence obtain a strain ratio of 30:8.4 = 3.5. This high value of strain ratio indicates that longitudinal extension was a significant component contributing to the late Variscan deformation in the Kielce Unit.

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INTRODUCTION

The Holy Cross Mountains are composed of a Paleozoic core deformed as a result of Variscan folding (e.g., Czarnocki, 1919; Filonowicz, 1973) and a Permo-Mesozoic cover folded during Laramide orogenesis (*op. cit*.). The Paleozoic core comprises two main tectono-stratigraphic units (Fig. 1) – the Łysogóry and the Kielce units (Czarnocki, 1919, 1957; Pożaryski, 1978; Stupnicka, 1992). The southern part of the Kielce Unit is the Chęciny–Klimontów Anticlinorium (Samsonowicz, 1926; Znosko, 1962; Mizerski and Orłowski, 1993), which is divided into tectonic blocks bounded by transverse faults. Within the westernmost block there are the Zbrza Anticline, the Chęciny Anticline, the Gałęzice–Bolechowice Syncline and the Dyminy Anticline (e.g., Czarnocki, 1938; Filonowicz, 1973; Konon 2006).

The Chęciny Anticline (Figs. 1 and 2) is located within the southeastern part of the Paleozoic core of the Holy Cross Mountains (Czarnocki, 1938; Hakenberg, 1971*a*; Filonowicz and Lindner, 1986). It is limited to the south by the Permo-Mesozoic cover (*op. cit*.). Second-order folds, made up of the Rzepka Syncline and the Wrzosy Anticline, outcrop in the southern limb of the Chęciny Anticline. The Wrzosy Anticline is for the first time defined in this paper, based on newly recognized outcrops of Cambrian rocks (Fig. 2). Rzepka is the name of a hill located south of Chęciny town, where an abandoned quarry is located. This quarry, with a 215 m long wall running almost parallel to the regional trend of the late Variscan fold axes, enabled the detailed structural analysis described in this article. Our analysis was directed at estimating the significance and value of local extension induced by the late Variscan folding in this region. We also used new cartographic data regarding Cambrian outcrops to analyse the geometry of the southern part of the Chęciny Anticline where the second-order Rzepka Syncline and Wrzosy Anticline are located. This reconstruction allowed recognition of the block-like architecture of the Chęciny Anticline, with individual, fault-limited blocks being up- and down-thrown with respect to each other. Moreover,

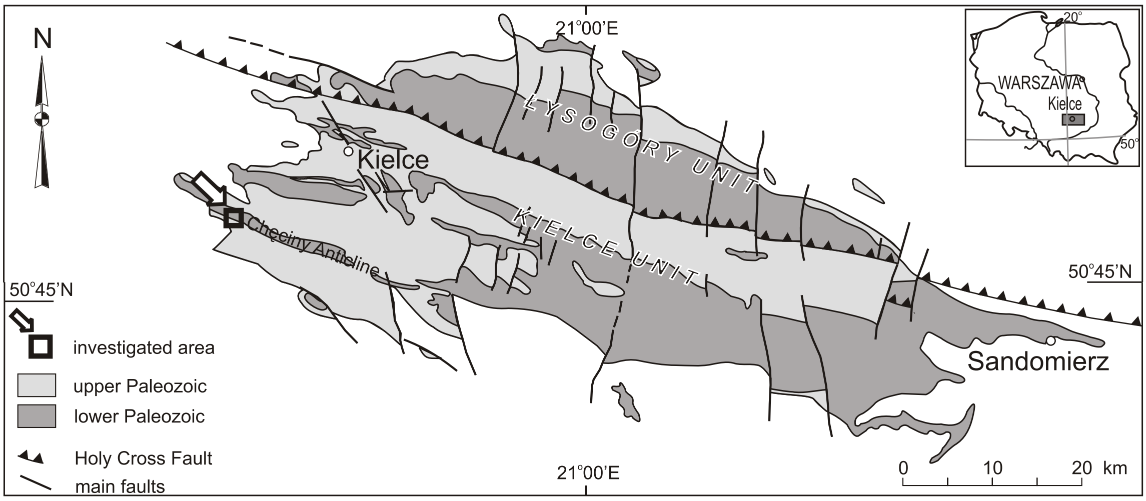

Fig. 1. Location of the study area in the Holy Cross Mts. (based on Kutek and Głazek, 1972)

new map data demonstrate that deep, pre-Triassic erosion reached Cambrian rocks within the core of the Chęciny Anticline.

GEOLOGICAL SETTING

The Paleozoic core of the Holy Cross Mountains was extensively (and admirably) surveyed by Czarnocki (1919, 1927). However, the timing and geodynamics of folding of the Paleozoic core of the Holy Cross Mountains still remain controversial. According to Kowalczewski (1965, 1971) and Znosko (1999, 2000) the first folding event was late Caledonian in age and produced reverse faults and thrusts. This was when intensive erosion, mainly of Silurian and Ordovician rocks, took place. According to another group of researchers, the late Caledonian event was less significant than the Variscan deformation (Głazek *et al.*, 1981; Orłowski and Mizerski, 1998; Lamarche *et al.*, 1999, 2003 and others).

An important role in the tectonic evolution of the Holy Cross Mountains was played by Alpine orogenesis. This tectonic event was responsible for deformation of the Permo-Mesozoic cover and diapiric-like re-arrangement of the Variscan anticline structures. The effects of this deformation can be observed in e.g., the Chęciny Anticline with ductile rocks in its core (Cambrian thin-bedded sandstone, mudstone and shale; Głazek and Kutek 1970; Jaroszewski, 1972; Stupnicka, 1972; Kowalski, 1975).

Due to the complex geological history of the Chęciny Anticline and its fringing structures in the vicinity of Chęciny, several structural analyses have been conducted in this area (Stupnicka, 1972; Kowalski, 1975; Mastella and Konon, 2002; Dębowska, 2004; Konon, 2004, 2006, 2007 among others). Calcite mineralisation has also been studied in the Chęciny Anticline (Wrzosek and Wróbel, 1961; Migaszewski *et al.*, 1996; Wierzbowski, 1997 and others) and, furthermore, natural resources related to ore mineralisation have been examined (Morozewicz, 1923; Rubinowski, 1954, 1955, 1962, 1971 among others).

The core of the Chęciny Anticline is made of lower Cambrian rocks (Fig. 2C) – claystones as well as mudstones with quartzitic sandstone intercalations, intensely deformed by tectonic processes (Czarnocki, 1928, 1929, 1947; Jaroszewski, 1965; Kowalski, 1975; Stupnicka, 1986; Lamarche *et al.*, 2003 and others). The thickness of lower Cambrian rocks has been estimated at *ca*. 800 m (Hakenberg, 1971*a*, *b*; Filonowicz and Lindner, 1987). The limbs of the Chęciny Anticline are composed of Emsian sandstones, attaining a thickness of a few metres, and Middle and Upper Devonian limestones and dolomites *ca*. 600 m thick (Hakenberg, 1971*a*, *b*; Filonowicz and Lindner, 1987). Thick-bedded, massive and reef limestones predominate, laterally passing into banded dolostone. The youngest Devonian strata, of Frasnian age, are marls and marly shales. Towards the south, the Chęciny Anticline is fringed by Permian and Triassic rocks, lying unconformably over Devonian rocks and belonging to the Permo-Mesozoic cover of the Holy Cross Mountains.

The Chęciny valley, being a textbook example of morphological inversion (a valley at an anticline crest), is mainly filled with Pleistocene glacial deposits (Fig. 2A). Pleistocene deposits occur also to the south of the hills made up of Devonian rocks – Zamkowa Hill and Rzepka Hill (Fig. 2A). The thickness of the Pleistocene attains a few to over a dozen metres.

MAPPING DATA

Two new Cambrian outcrops were found outside Chęciny valley, i.e. outside the Chęciny Anticline core. A new artificial outcrop is located to the east of Rzepka Hill at a petrol station where earthworks uncovered regolith containing abundant quartzitic sandstone fragments, the lithology of which indicates that they are Cambrian. In the outcrop located to the west of Rzepka Hill, regolith with abundant quartzitic sandstone fragments has a contact towards the west with weathered reddish-grey dolomites, whose lithology indicates that they are Eifelian. This contact between Cambrian and Devonian rocks (between blocks no. 3 and 4 in Fig. 2B) is tectonic and is due to a transverse fault. The presence of a fault zone to the west of Rzepka Hill had already been pointed out by Stupnicka (1972),

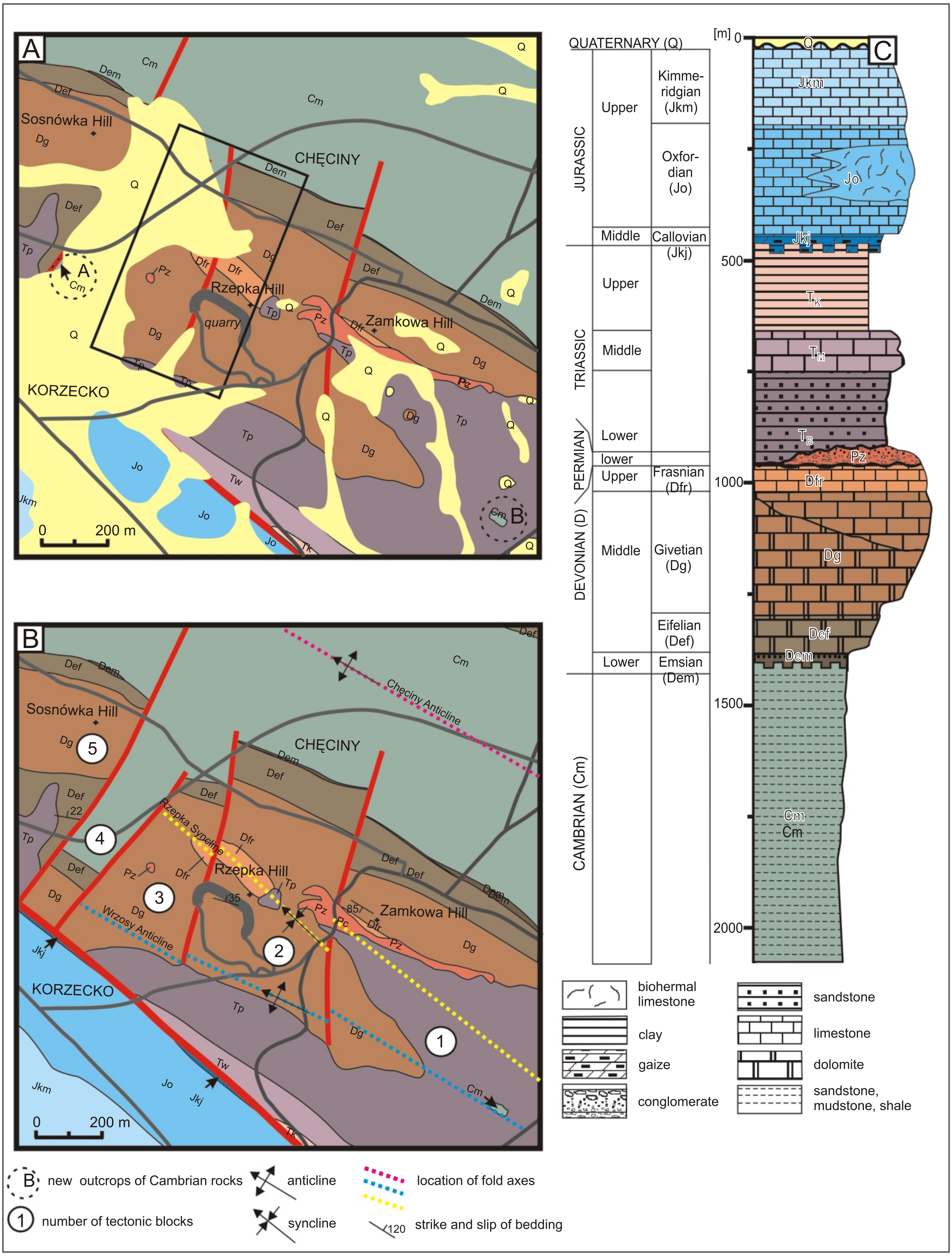

Fig. 2. Simplified geological maps and profile of the study area (based on Hakenberg, 1971*a*, *b*, changed by present authors)

A – superficial geology, black rectangle – location of Figure 7A; **B** – bedrock geology; **C** – lithostratigraphic profile; lithostratigraphic units: TK – Keuper + Rhaetian, TM – Muschelkalk, TB – Buntsandstein, Pz – Zechstein however, our new data suggests that this zone is composed of two faults between which a narrow belt of mainly Quaternary deposits (overlying Cambrin) may be observed (Fig. 2A, B).

South of Rzepka Hill abundant quartzitic sandstone clasts, the lithology of which indicates that they are Cambrian, were found disconformably on Buntsandstein (Triassic) cover (Fig. 3). These clasts are usually well-rounded and their sizes vary between 0.5 and 10 cm. Clasts within the basal part of Buntsandstein conglomerate also include abundant limestone and dolomite fragments, both rounded and angular. Angular fragments are often of vein calcite of different sizes (a few to over a dozen cm). The angularity in this case is due to the large (and easily cleaving) crystals. Rounded clasts of white and pink vein calcite, up to 2 cm in diameter, are also abundant and a few rounded lydite clasts have also been found (Fig. 3B). The matrix in the Buntsandstein conglomerate is made of quartz sand and accompanied by mica. The cement is calcareous and its red colour is due to hematite (Rubinowski, 1962).

STRUCTURAL ANALYSIS

The Rzepka Syncline and Wrzosy Anticline together form a subordinate (second-order) fold within the southern limb of the Chęciny Anticline, the latter stretching between Miedzianka Hill in the NW and the Radkowice village vicinity in the SE. The Rzepka Syncline is a local structure, present only to the south of Zamkowa Hill and at Rzepka and Sosnówka hills. It does not continue towards the NW, where instead several faults, responsible for the complex tectonic structure of Zegzela Hill and Żebrownica are present (Kutek and Głazek, 1972). The Chęciny Anticline is divided into transverse, fault-bounded blocks. These are usually normal faults that give way to elevations and depressions. Five fault-bounded blocks can be distinguished in the part of the Chęciny Anticline investigated. Starting from the SE and continuing towards the NW these blocks are named (Fig. 2B): Zamkowa Hill (1), Rzepka Hill (2 + 3), Korzecko (4) and Sosnówka Hill (5). A map view shows that within Zamkowa and Rzepka hills the anticlinal axis plunges towards the NW (Fig. 2B). The Korzecko block is the most elevated, producing widening of the band of Cambrian outcrops. Most of this block is covered by Quaternary deposits. Moreover, the considerable width of the valley cutting through the southern limb of the Chęciny Anticline, and the great thickness of glacial (Pleistocene) deposits, indicate a lack of Devonian in the valley basement. According to Kowalczewski (1963) transverse faults cutting the Chęciny Anticline are of pre-Zechstein origin.

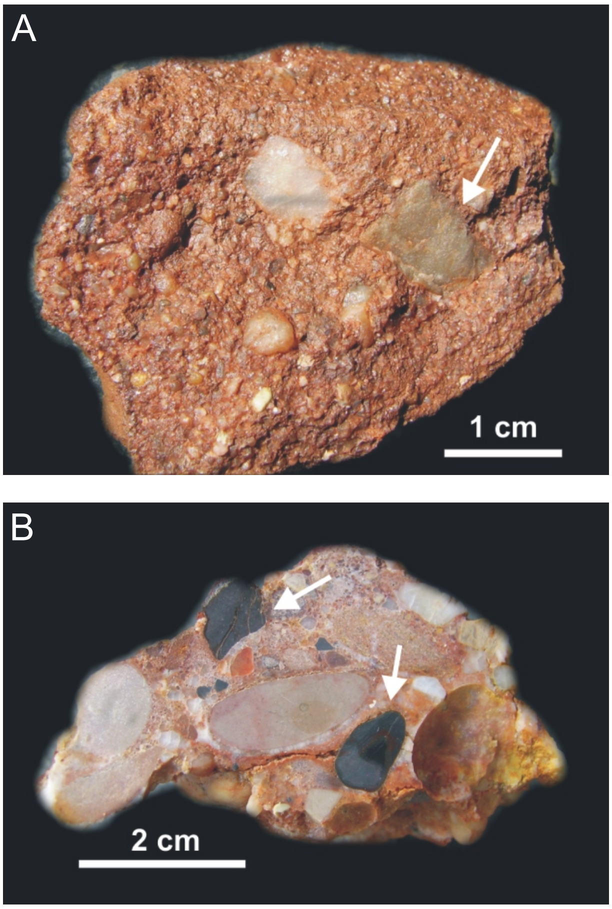

Fig. 3. Photographs of selected fragments of Lower Triassic rocks with clasts of Cambrian quartzitic sandstone (A) and lydite (B)

This suggestion is supported by the fact that the transverse faults are oriented coplanar to extensional fractures, which later on (during block-like vertical movements) were transformed into faults. Depressions, which originated due to vertical movements along fault hanging walls, are often filled with Buntsandstein deposits. Buntsandstein deposits preserved in tectonic grabens delineate pre-Triassic relief and indicate the pre-Triassic age of the transverse faults.

The Rzepka Syncline is slightly oblique to the main (Chęciny) Anticline, which is easily understandable in the case of such a small fold, plunging and dying-out towards the NW (Fig. 4). Most of the extensional fractures are geometrically related to the Rzepka Syncline. When our work began, we first divided these fractures into groups based on vein fill mineralogy (pure calcite, Fe-calcite and hematite). However, the results showed that the fracture orientation is independent of mineralisation type (see Okamato *et al.*, 2006). Therefore, our measurements are shown on only two contour diagrams in Figure 5: non-mineralised (Fig. 5A) and mineralised (Fig. 5B). These diagrams reveal 2 groups of extensional fractures: longitudinal (L) and transverse (T) to the fold structures. A geometric analysis of the fracture system indicates that, within both mineralised and non-mineralised fracture types, a fracture set oriented transverse to the fold axis predominates (Fig. 5A, B). Many of these fractures became non-vertical, their angle of dip becoming *ca.* 80° SE. This can be attributed to fold axis plunge. The plunge of the Rzepka Syncline and Wrzosy Anticline axes towards the NW is clear in plan view, because Cambrian rocks crop out at the south-east edge of the Wrzosy Anticline (Figs. 2 and 4). Transverse fractures (T) are layer-perpendicular and calcite-mineralised (Fig. 5B). Their dominant orientation is almost parallel to the compression direction (~13°). The second set of fractures (L) that can be distinguished in stereograms (Fig. 5) – the fractures parallel to the fold axis (longitudinal) – are related to the bending of a large fold hinge and the development of extensional fractures semiparallel to the axial plane above a neutral surface of the hinge region. The mean strike of the (L) fracture set is 135° and fractures dip steeply at 75–90° towards the S (Fig. 5).

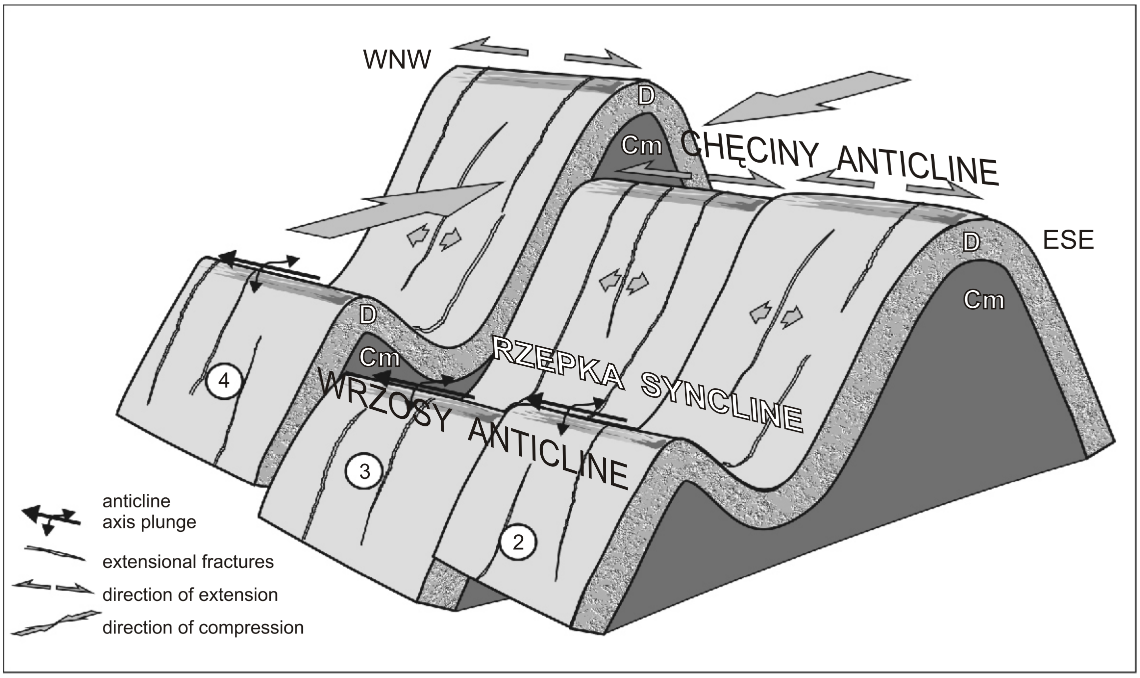

Fig. 4. Schematic 3D block-diagram of the Chęciny and Wrzosy anticlines and Rzepka Syncline divided into blocks

Explanations as in Figure 2

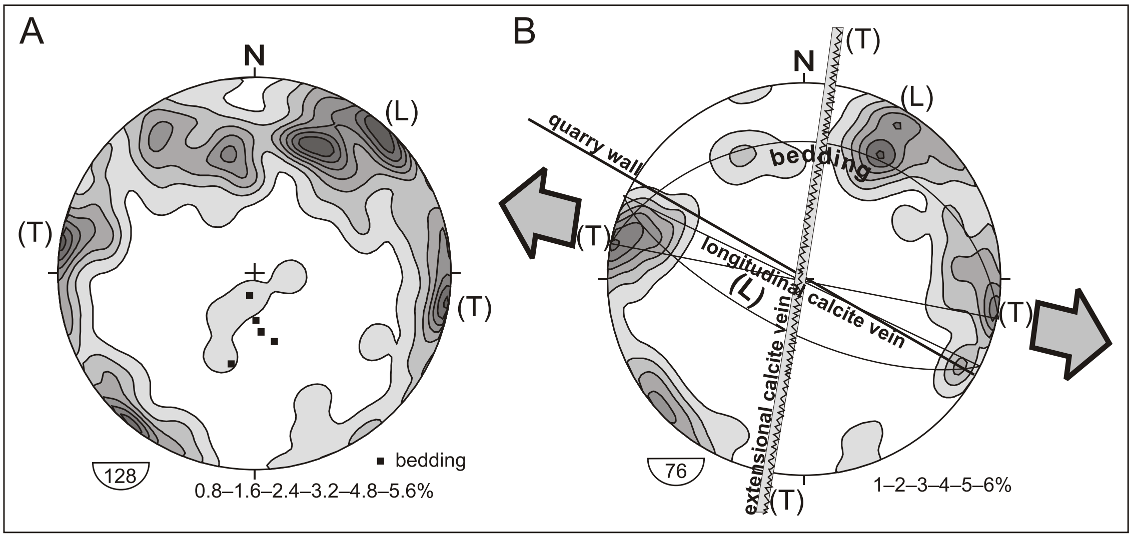

Fig. 5. Stereographs of fractures within Givetian dolomites, quarry wall in Rzepka Hill

A – fractures without mineralisation; **B** – with calcite and Fe-calcite mineral veins; (L) – longitudinal fractures, (T) – transverse fractures; lower hemisphere, pole to plane

CHARACTERISTICS OF CALCITE VEINS AND TECTONIC BRECCIAS FROM THE RZEPKA QUARRY

Macrocrystalline calcite veins transverse (T) to the fold structures are usually a few mm to a few cm thick and the number of mineral layers within individual veins is usually between one and three. More growth zones can be distinguished in the thickest vein in the quarry located at the western end of the quarry wall (Fig. 6A, B). Most of the veins are symmetrical, with an easily visible median line. Fibres grew from the vein wall towards the centre, making these syntaxial fibre veins (Ramsay and Huber, 1983). Veins opened faster than the crystal growth rate or by periodic sealing and fracturing (via a mechanism of crack-seal growth; see Passchier and Trouw, 1998). A lack of curvature of the growing fibres indicates no vein-parallel displacement during crystal growth. Individual calcite crystals are a few mm to 2–3 cm long. Most of the veins contain traces of hematite mostly in between consecutive growth layers, which colours the veins red or pink.

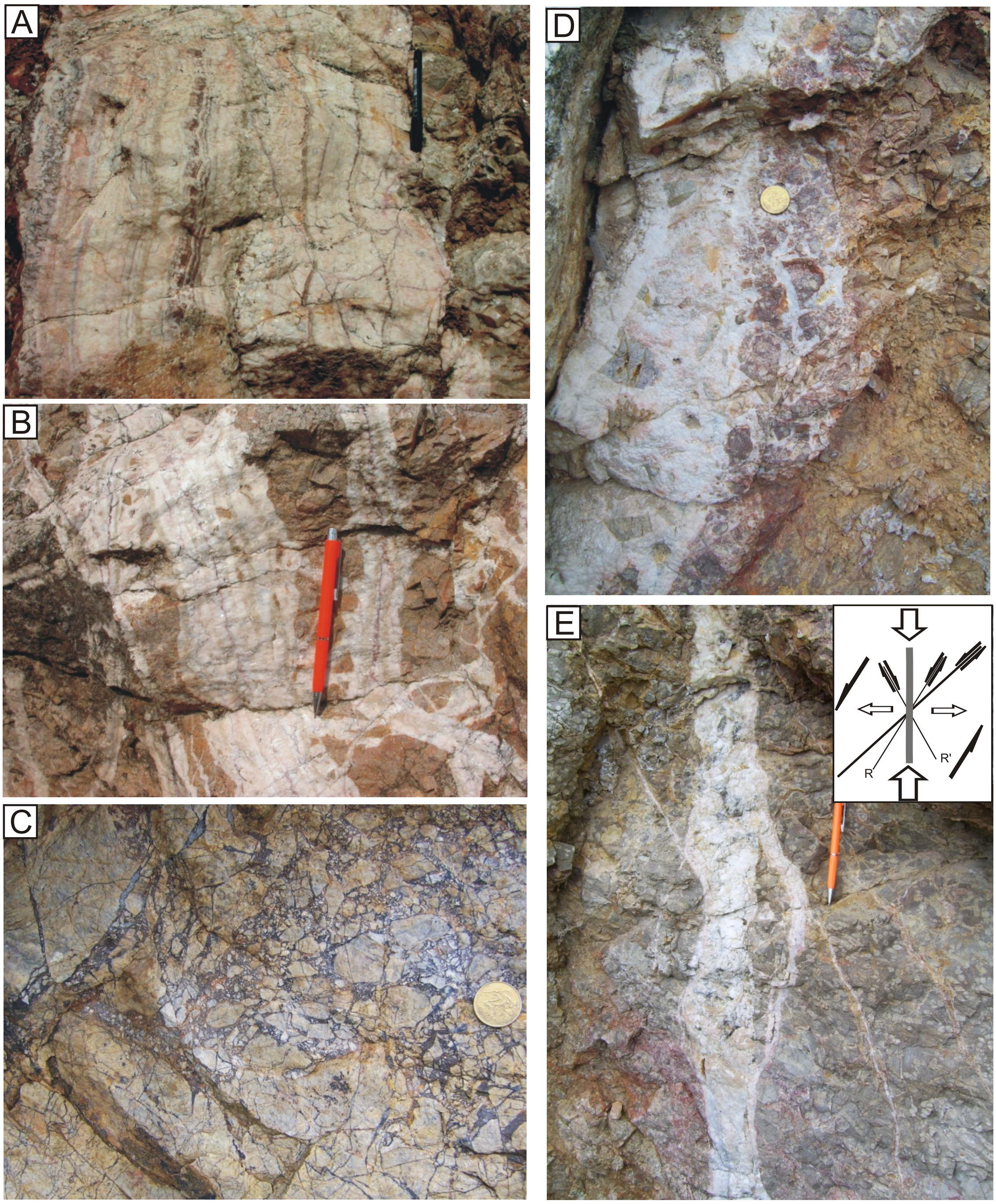

Fig. 6. Photographs of calcite veins and dolostone breccia in the Rzepka quarry wall

A – fragment of the thickest calcite vein in the W-part of quarry; **B** – minor and less regular vein; **C** – chaotic breccia with mineral cements; **D** – breccia associated with calcite vein; **E** – extensional vein associated with Riedel shears, related to axis plunge

The largest calcite vein in the Rzepka quarry, found at the western end of the quarry wall, is *ca*. 85 cm thick and dips at 70° towards the N, which is an unusual vein orientation in this quarry (Fig. 6A, B). This is a composite type of vein with 50–60 growing fibre layers. Most of the composite veins contain traces of hematite mostly in between consecutive growth layers, which colours the veins red or pink.

The calcite (vein) mineralisation of the Rzepka Hill quarry is probably related to low-temperature, non-metalliferous formation, within which rose-type ("różanka") macrocrystalline calcite veins were formed (Rubinowski, 1962). These veins occur typically in the SW part of the Kielce region, within the Middle Devonian limestones and dolomites. They are considered pre-Zechstein and usually fill (T) fractures semi-perpendicular to regional fold axes (Fig. 5). An additional argument in favour of their pre-Zechstein age is the fact that some fragments of "rose"-like calcite veins are found within the basal part of the Buntsandstein deposits (see above).

Tectonic breccias are abundant in the Rzepka quarry (Fig. 6C, D). These fault rocks occur in the immediate vicinity of calcite veins and represent mosaic or chaotic breccia types (Mort and Woodcock, 2008). The breccias in question probably originated due to hydraulic fracturing (Branquet *et al*., 1999) and/or extension responsible for rock fracturing and associated rock implosion (Sibson, 1986; Loucks, 1999). Origination of these breccias would be synchronous with multiple activated processes of extensional fracture opening. The intense red colour of minerals filling spaces between breccia clasts is due to Fe compounds, saturating Devonian calcareous rocks.

Locally extensional veins are associated with R type brittle Riedel shears (Fig. 6E; compare with Wilcox *et al*., 1973). The former might be related to fold axis plunge towards the west associated with the division of the Chęciny Anticline into blocks. Such geometrical reorganization, giving way to block tilting, might have been contemporary with extensional fracture formation and might have led to local shear stress responsible for the origin of Riedel-type fractures.

EXTENSION ESTIMATE BASED ON CALCITE MINERALISATION

CALCITE VEINS

A large abandoned quarry within Devonian dolomites exists in the study area, providing a unique opportunity to carry out a detailed structural analysis (Fig. 7A). Abundant, nearly vertical, mineralised extensional fractures are exposed in a *ca*. 215 m long main quarry wall that is oriented almost parallel to the regional structural strike. Calcite veins filling these fractures are highly systematic. The thickest veins are oriented perpendicular to regional fold axes and are excellent for geometrical analysis of relationships between folds and fracture sets. In our work we assume that the summed thicknesses of these calcite veins, compared to the Devonian dolomite thickness along a section almost parallel to the regional structural pattern, indicate the amount of extension.

The southern wall of the Rzepka Hill quarry, the subject of our structural study, is located on the southern limb of the Rzepka Syncline (Fig. 7B). The main wall of the quarry is about 10 m high and is oriented at *ca*. 120^{o} and is almost 215 m long. Givetian dolomites are exposed in this wall (Filonowicz and Lindner, 1986, 1987), showing a monoclinal, gentle dip towards the north (Fig. 5A). The bedding is clearly visible in the lower level of the quarry. Its upper, better exposed exploitation level, where the tectonic measurements were taken, is made of massive dolomites. A young transverse fault, found at the western end of the wall, cuts the largest calcite vein in the Rzepka quarry, which indicates the post-mineralisation age of this fault. Calcite mineralisation observed in this quarry may be connected with the rose-type, because it is perpendicular to regional strike of fold axes (Rubinowski, 1962).

To estimate elongation along the extension plane (that is elongation parallel to a fold axis), the thicknesses of all calcite veins were summed up along a section perpendicular to vein attitudes. The Rzepka quarry wall is suitably oriented for this, because measurements taken along the wall required only slight correction. A horizontal line (almost perpendicular to calcite vein planes) has been drawn along the wall of the quarry. Along this line, vein thicknesses and attitudes were measured, and data collected regarding the relative age of mineralisation and fracture

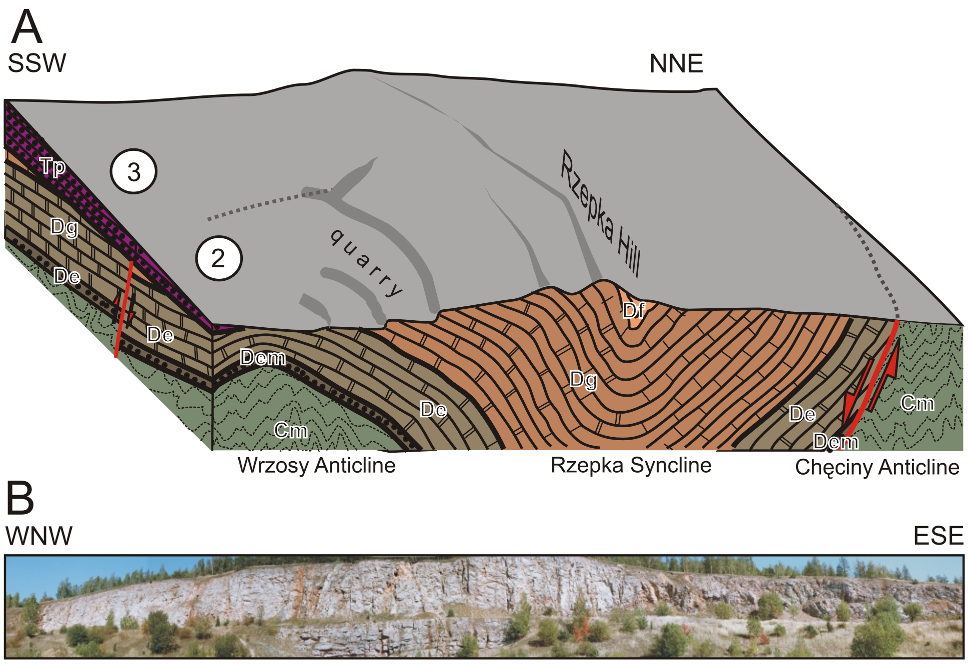

Fig. 7. Structural blockdiagram of the Rzepka Hill area (A) and photo of the quarry wall (B); view from the south

Explanations as in Figure 2

propagation. Mineralised fractures were analysed to compare with all fracture data collected in the quarry (Fig. 5).

Besides measuring the calcite veins filling the extensional fractures – dilatation within tectonic breccias, where spaces between clasts were similarly filled by calcite – was also measured. Measurements were taken along the same horizontal line.

TECTONIC BRECCIAS

The measurements of calcite mineralisation content within tectonic breccias were based on photographs. Two types of breccia were distinguished: (1) breccias with where the cement colour is lighter than clast colour and (2) those where cement colour is darker than clast colour (Fig. 8). The former type is made of angular, up to 20 cm large fragments of Devonian dolomite with a matrix made of white to pink-white calcite (Fig. 8Aa). The matrix fills spaces between clasts as well as small cracks within clasts. The second type of breccia is also made of Devonian dolomite clasts, but these are smaller and partly rounded (Fig. 8Ba). The largest clasts, up to 2–3 cm in diameter, are angular. The mineral matrix is grey and dark grey, darker than the clasts. Angular clasts are cut by thin calcite veins of the same color and age as the matrix.

An attempt has been made to estimate calcite mineralisation content within both types of breccias. To do so, the colour contrast between matrix and clasts was used. Such calculation methods, based on photographs and using a simple numeric procedure, are becoming more common (e.g., Heilbronner, 2000; Clark and James, 2003; Heilbronner and Keulen, 2006). In this work, the simplest numerical method was used, based on the analysis of monochromatic photographs and grey shade distribution.

The first step was to transform each photograph into a grey-scale picture (Fig. 8Ab, Bb). This was done in the popular graphic software package *CorelPhotoPaint*. The best transformation effects were attained when separating a picture into RGB channels. In both cases of tectonic breccia types the best contrast was seen in the green channel (G). Subsequently, in order to better differentiate between clasts and matrix, brightness, contrast and intensity levels were adjusted and the images were saved in tiff format (without compression). By this means, the photographs were prepared for further analysis in *ArcGIS*.

Then, histograms were calculated, showing the distribution of grey shades in the photographs, where 0 signified black and 255 was white. In both cases the distributions were skewed and indicated less mineralisation than clast content. However, the first type of tectonic breccia contains more mineralisation (compared to clasts) than the second type of tectonic breccia. The next step was the best possible delimitation between rock fragments and matrix (Fig. 8Ac, Bc), to be able to transform the photographs into one-bit maps. Such a transformation allowed calculation of the relative proportions of clasts and matrix. Two main classes were proposed, one containing clasts and the other matrix, the limit between them being set at the dominant value. Contrasting – black and white – colours were assigned to these two classes. Then additional classes were set up below and above the mode. A subsequent step analysed these classes to assign each one to a correct, previously assumed main class. Each time, a black-and-white output was compared to a benchmark grey-scale breccia photograph, by overlying images (Fig. 8Ad, Bd).

To increase the contrast between mineralisation and clasts in benchmark photographs, pixel values were raised to the second or third power. This densifying method was used to best represent both breccia types in black-and-white (one-bit) images. Precise calculation of mineralisation content in % in both breccia types was possible thanks to the described image processing procedure. Thus, the first type of breccia contains as much as 44% of mineralisation and second type contains 31%. Overall, breccias make up *ca*. 2.5% of the entire measured quarry wall length, and mineralisation contained within them makes up almost 1% of this length.

Taking into account calcite vein thicknesses and calcite mineralisation within tectonic breccias, mineralisation was found to constitute *ca*. 8.4% (*ca*. 18 m) of the total wall length (215 m).

DISCUSSION AND CONCLUSSIONS

The Wrzosy Anticline has been distinguished within the southern limb of the Chęciny Syncline, previously known as the Rzepka Syncline (Czarnocki, 1938; Hakenberg, 1971*a*; Filonowicz and Lindner, 1986). These two structural elements are local, second-order folds that do not continue far towards the NW. Instead, in the NW of the investigated area, they are probably substituted by tectonically complicated structures on Żebrowica and Zegzela hills, where overturned layers of Paleozoic rocks could be observed (Kutek and Głazek, 1972). The Chęciny Anticline as well as both second-order folds on its southern limb are upright, open folds with semivertical axial planes (Figs. 4 and 7). According to Konon (2006), the Rzepka Syncline is an example of a footwall syncline, the origin of which could precede fault propagation. According to our new data, the distinction of the Wrzosy Anticline southwards of the Rzepka Syncline, both being symmetrical in nature, seems to preclude such an interpretation in the area studied.

Brittle fracturing of Devonian rocks took place in the late phase of the Variscan orogeny. This process was generally connected with longitudinal extension perpendicular to the axes of macroscopic folds and was responsible for the development of extensional veining. Structural analysis, based on measurements of calcite mineralisation in veins and tectonic breccias, permitted estimation of longitudinal (fold axis-parallel) extension to be 8.4% and to compare this with folding-controlled shortening, determined from the cross-section of Hakenberg (1971*a*), to reach 30%. This way, we obtain a strain ratio of 30:8.4 = 3.5. This high value of strain ratio indicates that longitudinal extension was a significant component, contributing to late Variscan deformation in the Kielce Unit.

During the late Variscan deformational stage, after the calcite veins were formed, the Chęciny Anticline became fragmented into fault-bounded blocks (Znosko, 1962; Mizerski and Orłowski, 1993; Konon, 2006). The pre-Triassic (pre-Permian? – see Kowalczewski, 1963) age of these transverse faults can be demonstrated on the southern slope of the Rzepka Hill where the fault visible in the west part of the quarry wall is covered by Buntsandstein deposits (Figs. 2B and 7A). Different vertical displacements along these faults produced graben and

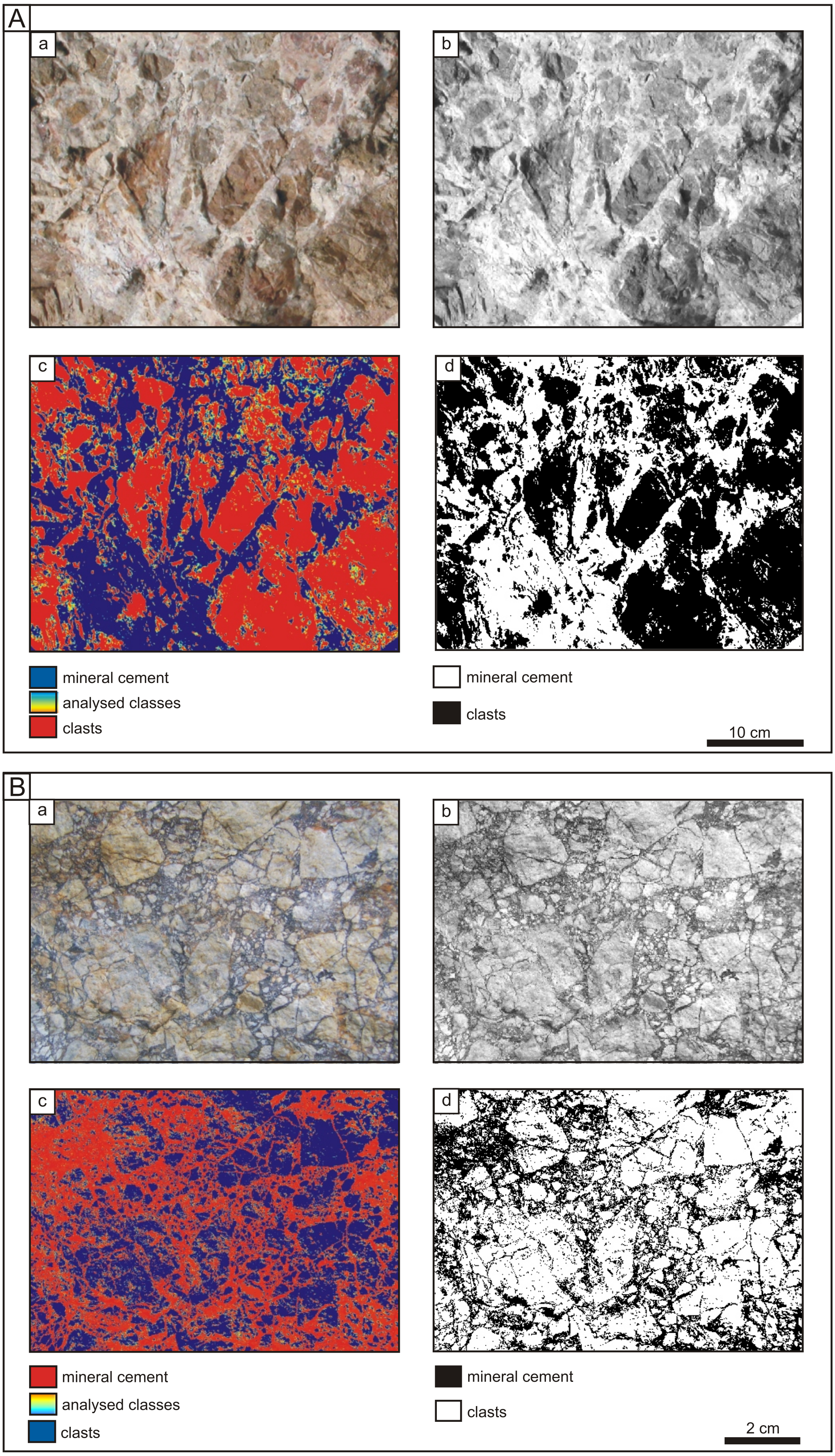

Fig. 8. Selected photographic documentation of breccia analysis based on monochromatic photographs

A – breccia with dark clasts and light mineral cement; **B** – breccia with light clasts and dark mineral cement horst structures and a regional NW plunge of fold axes. Tectonic motion could be activated along transverse discontinuities of different origins, e.g. extensional fractures with calcite mineralisation. Elevated blocks, especially that the Korzecko (no. 4 in Figs. 2B and 4) and the SE part of the Zamkowa block, have been strongly eroded (Kowalczewski, 1971; Stupnicka, 1992). According to Konon (2004) as much as 1 km of Paleozoic rocks were removed in the course of post-Visean erosion. Due to the high elevation of the Korzecko block, only Cambrian rocks are found within it and this is the reason why the Rzepka Syncline and Wrzosy Anticline cannot be traced there (Figs. 2B and 4). Cambrian quarzitic sandstone and lydite clasts within the Buntsandstein deposits indicate the range of erosion within up-thrown tectonic blocks (Fig. 3). Pre-Triassic uncovering of Cambrian rocks could also have been responsible for diapiric-like tectonics (Głazek and Kutek, 1970; Jaroszewski, 1972; Stupnicka, 1972; Kowalski, 1975) and the erosion-controlled geometry of buckle fold interference (Simon, 2005). Due to diapiric-like movements of easily deformable Cambrian thin-bedded sandstone, mudstone and shale, a local detachment at the boundary of competent/incompetent rocks has formed (Konon, 2006). This means that some detachments connected with diapiric-like tectonics could have started relatively early during the late Variscan orogenic stage (Lamarche *et al*., 2003), instead of during the early Alpine (Laramian) tectonic event (Czarnocki, 1947; Głazek *et al*., 1981). This conclusion is also supported by a Triassic stratal cover overlying elevated blocks as well as to tectonic boundaries between them (Figs. 2 and 4).

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