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LATEST JURASSIC – EARLIEST CRETACEOUS MASS MOVEMENTS IN THE POLISH PART OF THE PIENINY KLIPPEN BELT AND SILESIAN UNIT (OUTER FLYSCH CARPATHIANS)

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Abstract: Distribution of sedimentary breccias, mass flows; redeposited clasts, which indicate time and mechanisms of origin of tectonic movements within sedimentary basins, are the main objects of the presented paper. These types of tectonic activity in Polish part of the Carpathians is well documented both in the Outer (Flysch) Carpathians and in the Pieniny Klippen Belt. Neo-Cimmerian tectonic events took place both in the Alpine Tethys and Proto-Silesian Basin. A big geotectonic reorganization, known as the Walentowa Phase, took place in AT during the latest Jurassic-earliest Cretaceous (Neo-Cimmerian) movements resulting in extensive gravitational faulting. Several tectonic horsts and grabens, documented by facies diversification, were formed. These rejuvenated some older structures and Middle/Late Jurassic (Meso-Cimmerian) faults which caused uplift of the shallow intrabasinal Czorsztyn pelagic swell. The over-regional significance of this geodynamic episode in the northernmost margin of the Tethyan Ocean is documented also by foundation of the Proto-Silesian Basin. Chaotic type of sedimentation dominated during Late Jurassic times indicating early stages of the Proto-Silesian Basin opening with increased tectonic activity. The detritic material was supplied from two sources: from the Baška-Inwałd uplift separating the Proto-Silesian Basin and the Bachowice Basin located within the North European Platform, and from the island arcs within the Silesian Ridge separating the Proto-Silesian Basin and the Alpine Tethys. The biogenic material originated within shallow-water reefal and carbonate platform zones was transported by turbiditic currents from the uplifted structures on the Proto-Silesian Basin margins into the deeper zones of this basin. Both the calciturbidites and calcifluxoturbidites formed, constituting the main lithosome within the younger lithostratigraphic unit – the Cieszyn Limestone Formation. These deposits represent the oldest turbiditic currents sedimentation known from the Polish Outer Carpathian Basin.

Keywords: Carpathians, Mesozoic, Cenozoic, palaeogeography, plate tectonics

1. Introduction

Synsedimentary mass movement deposits are a key to understanding tectonic activity of the basins during their geotectonic history. Distribution of sedimentary breccias, mass flows; redeposited clasts are the main objects, which indicate time and mechanisms of origin of tectonic movements within sedimentary basins. Pulses of such activity are connected with wide-oceanic remobilization and are well known in several parts of the whole Alpine Europe. A lot of places of this region are full of very well recorded evidence of synsedimentary movements which originated during Jurassic – Early Cretaceous times. Other sedimentary features like neptunian dykes, omission surfaces, condensation beds, redeposited shelly fauna, clastic sediments input to pelagic deposits as submarine wedges, olistostromes/oli-stoliths etc. also support such events. Such effects are strictly connected with activation and mobility of basin bottoms, especially during strong Alpine phases of tectonic revolutions, mainly of Middle – Late Jurassic/earliest Cretaceous (Meso- and Neo-Cimmerian) movements. Our knowledge on these types of tectonic activity in Polish part of the Carpathians is well documented both in the Outer (Flysch) Carpathians and in the Pieniny Klippen Belt (PKB). The main aim of this paper is presenting of Neo-Cimmerian tectonic movements during the latest Jurassic – earliest Cretaceous episode of evolution of neighboured Carpathian basins.

2. Polish Carpathians *versus* Jurassic Alpine Tethys

The Alpine Tethys (AT), which constitutes important palaeogeographic elements of the future PKB and Outer Carpathians (Figs. 1-3), developed as an oceanic basin, a continuation of the Central Atlantic, during Jurassic as a result of Pangea break-up (Fig. 4). The Mesozoic rifting events caused the origin of oceanic type basins along the northern margin of the Tethys. The Inner Carpathian plate was detached from the Eurasian margin by this AT as part of the separation of Eurasia from Gondwana. It was also dissected by the rift system. The deeper water sediments, like radiolarites, were deposit in these rifts, while shallower water carbonate sedimentation prevailed in the uplifted areas. The central Atlantic and AT went into a drifting stage during the Middle Jurassic times. The oldest oceanic crust in the Ligurian–Piedmont Ocean was dated as late as the Middle Jurassic in the southern Apennines and in the Western Alps. Bill et al. (2001) dated the onset of oceanic spreading of the AT by isotopic methods as Bajocian. The spreading phase follows the rifting during Early Jurassic times. The Jurassic rifting and spreading placed Triassic platform carbonate facies on the basin passive margins. Two major Late Jurassic basin, AT and Proto-Silesian Basin, were later included into the Carpathian thrust- and fold-belt. These basins were separated by Silesian Ridge. The NE part of AT was divided by the Czorsztyn Ridge into Pieniny Basin and Magura Basin, part of the Outer Carpathian Basins (Figs. 5, 6). Major plate reorganization then happened during the Tithonian time. The Central Atlantic began to expand into the area between Iberia and the New Foundland shelf. The Ligurian-Penninic Ocean reached its maximum width and the oceanic spreading stopped (Fig. 5). The Tethyan plate reorganization followed the global pattern. This reorganization was expressed by latest Jurassic/earliest Cretaceous tectonic movements, which affected both AT and Proto-Silesian Basin (Golonka et al., 2003).

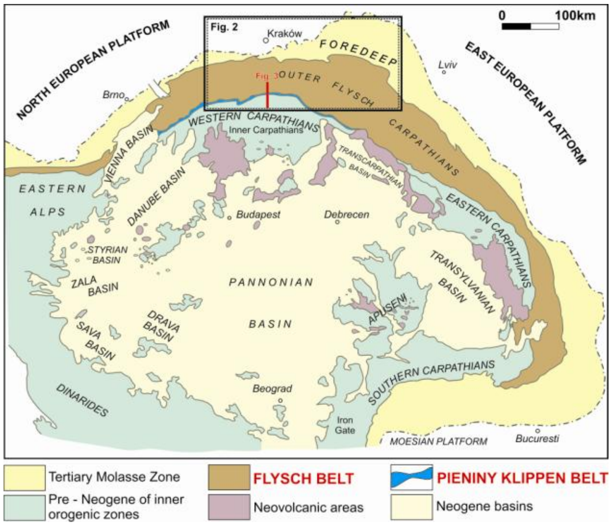

Fig. 1. Tectonic sketch map of the Alpine-Carpathian-Pannonian-Dinaride basin system (modified after Kováč 1998).

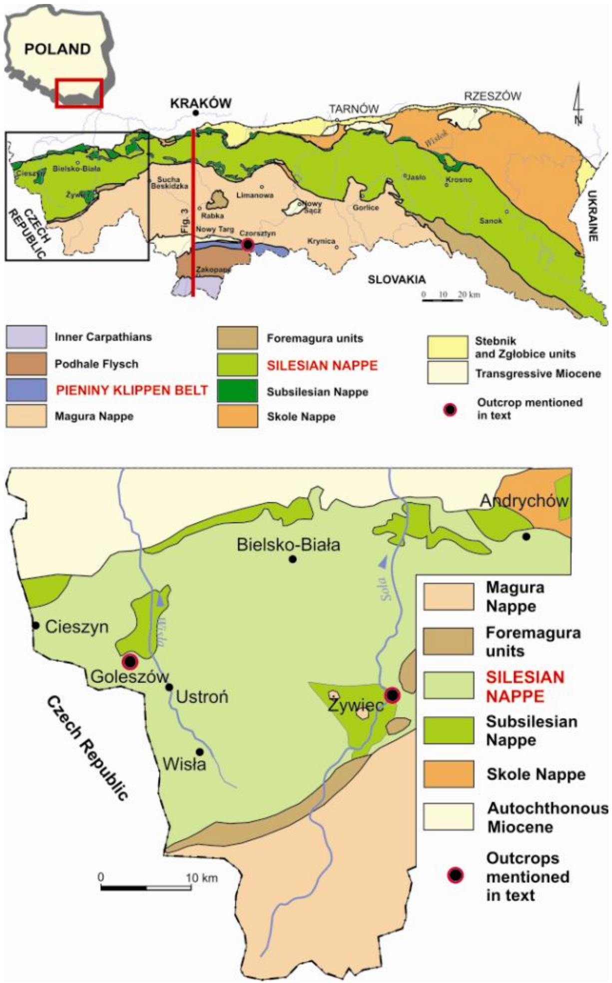

Fig. 2. Geological sketch between Żywiec and Cieszyn towns with location of described outcrops according to geological map of the Outer Flysch Carpathians (after Żytko et al., 1989; simplified).

3. Geological setting and general palaeogeographic sketch

3.1. Pieniny Klippen Belt

The term Pieniny Klippen Belt was first used by Neumayr (1971). The geographic part of this name indicates the mountain range in Poland and Slovakia where numerous klippes build scenic rocks around Dunajec River Gorge, prime geotouristic attraction since 19th century (Krobicki and Golonka, 2008). The “Klippen” are relatively erosion-resistant blocks surrounded by and rising above the less competent rocks, mainly flysch, shales and marls.

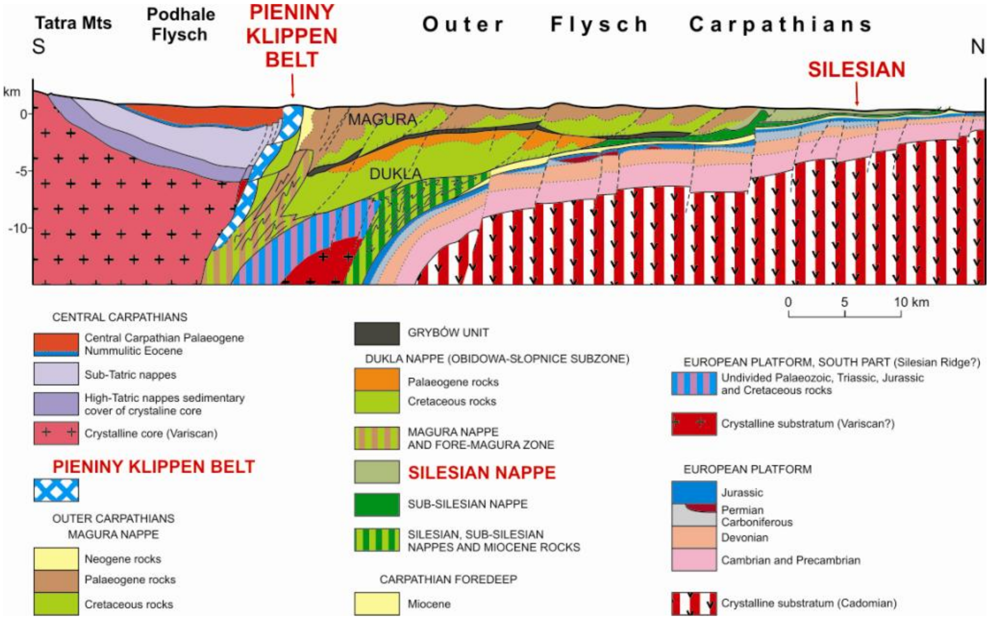

Fig. 3. Generalized cross-section across Polish Carpathians (after Golonka et al., 2006).

The PKB forms a strongly tectonized feature some 600 km long, 1-20 km wide, stretching from Wienerwald in Austria to northern Romania and marking the boundary between the Outer Flysch Carpathians and Inner (Central) Carpathians (Figs. 1, 2). In the modern literature (e.g. Krobicki and Golonka 2008 and references therein) the present day confines of the PKB are regarded as strictly tectonic and characterized as sub-vertical faults and shear zones (Fig. 3), along which a strong reduction of space of the original sedimentary basins took place (Birkenmajer, 1986; Golonka and Krobicki, 2006; Krobicki and Golonka, 2006; 2008).

The PKB tectonic components of different age, strike-slip, thrust as well as toe-thrusts and olistostromes were mixed together, giving the present-day mélange character of the PKB, where individual tectonic units are hard to distinguish. Together with the Outer Carpathians the PKB form the northernmost part of the Polish Carpathians.

In palinspastic reconstructions, the Czorsztyn Ridge has the SW-NE orientation which is inter-

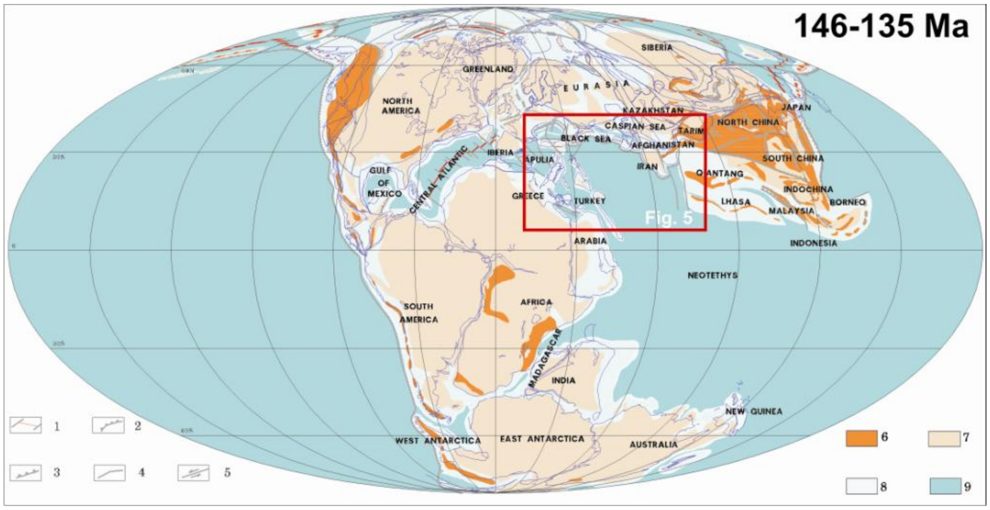

Fig. 4. Global plate tectonic map of latest Jurassic – earliest Cretaceous. Explanations: 1 – oceanic spreading center and transform faults; 2 – subduction zone; 3 – thrust fault; 4 – normal fault; 5 – transform fault; 6 – mountains; 7 – landmass; 8 – shallow sea and slope; 9 – deep ocean basin (from Golonka 2000; modified).

preted by means of palaeomagnetic data, relationship of sedimentary sequences and paleoclimate (see discussion in Golonka and Krobicki, 2001; Lewandowski et al., 2005; Grabowski et al., 2008). The AT basins divided by the Czorsztyn Ridge were dominated by a pelagic type of sedimentation. The deepest parts of AT are well documented by deep water Jurassic – Early Cretaceous radiolarites and *Maiolica*-type cherty limestones (Golonka and Sikora, 1981; Birkenmajer, 1986; Golonka and Krobicki, 2004; Jurewicz, 2005). The shallowest zone is represented by the so-called Czorsztyn Succession which primarily occupied the SE slope of the Czorsztyn Ridge (Birkenmajer, 1986; Golonka and Krobicki, 2004; Krobicki and Golonka, 2006) (Figs. 6-8).

The oldest Jurassic rocks known in the Polish part of the PKB are Pliensbachian to lowermost Bajocian dark marls and spotty limestones, or *Bositra* ("*Posidonia*")-bearing black shales with spherosiderites of widespread Tethyan oxygen-poor *Fleckenmergel* facies (Birkenmajer 1986). Rapid change of sedimentatary conditions took place during the late Early Bajocian, when the Czorsztyn Ridge uplifted, and therefore its SE slope was a good place for sedimentation of well-oxygenated crinoidal limestones. The origin of the mid-oceanic Czorsztyn Ridge was connected with this Bajocian postrift geotectonic reorganization (Golonka et al., 2003; Krobicki, 2006) and is coeval with the spreading phase of AT (see also Lewandowski et al., 2005). According to Krobicki and Wierzbowski (2004, 2009), there is no indication of continuous sedimentation between black shales and crinoidal limestones. The hiatus and rapid change of sediments character indicate rapid vertical tectonic movement related to the ridge origin due to Bajocian movements. Plašienka (2002) postulated the thermal uplift above the distal, subcrustal part of detachment fault. During Jurassic – Early Cretaceous times, the Czorsztyn Ridge was submerged and did not supply clastic material into AT basins more. Sedimentation of younger (latest Bajocian – Tithonian) red nodular *Ammonitico Rosso*-type limestones with abundant *Globuligerina* and *Saccocoma* continued on the Czorsztyn Ridge was an effect of vertical movements which subsided the ridge and produced tectonically differentiated blocks, neptunian dykes and scarp-breccias (see Golonka et al., 2003; Krobicki and Golonka 2006 and references therein). Boom of planktonic *Globuligerina* foraminifers in the ridge facies (Oxfordian) was simultaneous with the maximum development of radiolarians within the basinal zones (Birkenmajer 1977, 1986; Mišík 1999; Wierzbowski et al. 1999). This episode marked the beginning of a great facial differentiation between the deepest and shallowest succes-

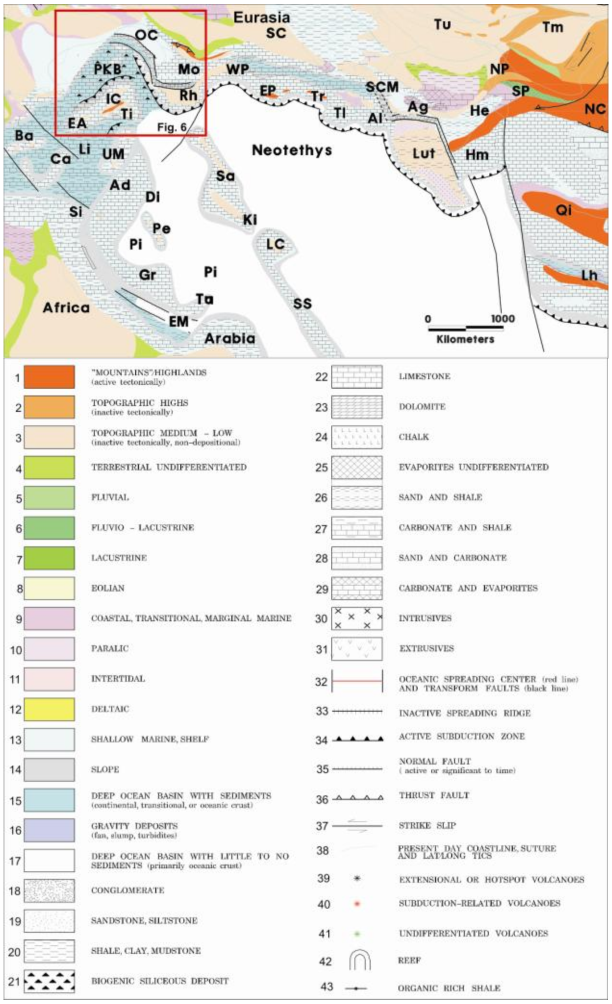

Fig. 5. Plate tectonic, paleoenvironment and lithofacies map of the western Tethys, Central Atlantic and adjacent areas during the latest Jurassic – earliest Cretaceous time (after Golonka 2004; slightly modified). Abbreviations of oceans and plates names: Ad – Adria (Apulia); Ag – Aghdarband (southern Kopet Dagh); Al – Alborz; Ba – Balearic; Ca – Calabria-Campania; Di – Dinarides; EA –Eastern Alps; EM – Eastern Mediterranean; EP – Eastern Pontides; Gr – Greece; He – Heart; Hm – Helmand; IC – Inner Carpathians; Ki – Kirsehir; LC – Lesser Caucasus; Lh – Lhasa; Li – Ligurian (Piemont) Ocean; Mo – Moesia; NC – North China; NP – North Pamir; **OC – Outer Carpathians**; **PKB – Pieniny Klippen Basin**; Pe – Pelagonian plate; Pi – Pindos Ocean; Qi – Qiangtang; Rh – Rhodopes; Sa – Sakarya; SC – Scythian; SCM – South Caspian microcontinent; Sl – Sicily; SP – South Pamir; SS – Sanandaj-Sirjan; Ta – Taurus terrane; Ti – Tisa; Tl – Talysh; Tm – Tarim; Tr – Transcaucasus; Tu – Turan; UM – Umbria-Marche; WP – Western Pontides.

sions. Similar compositions of facies are well known in several European Alpine regions (e.g. Betic Cordillera, Southern Alps, Apennine, Karavanke and Ionian Zone). During latest Jurassic – earliest Cretaceous times (Tithonian – Berriasian) cherty limestones of *Maiolica*-type (=*Biancone*) facies were deposited within deeper environments (Wieczorek 1988). The Late Cretaceous history of AT basin is characterized by deposition of multicoloured green/variegated/red marls marking unification of sedimentary regimes within ridge and slope successions and by formation of synorogenic flysch deposits in the basinal parts. Then, the Czorsztyn Ridge collided with the Inner Carpathian terranes around the Cretaceous/Palaeogene boundary (Birkenmajer, 1986).

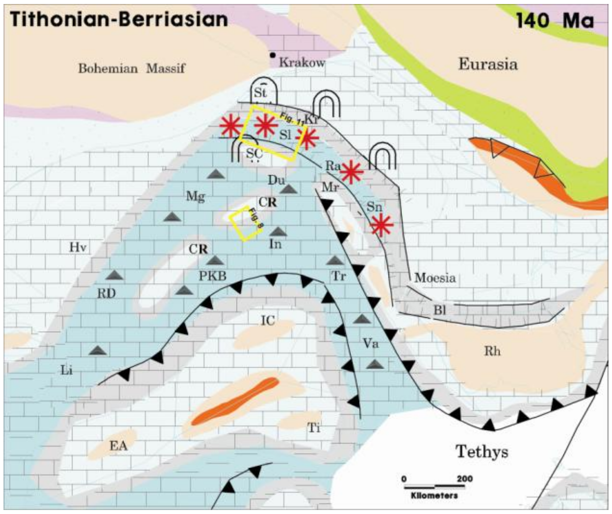

Fig. 6. Paleoenvironment and lithofacies of the circum-Carpathian area during the latest Jurassic – earliest Cretaceous; plates position at 140 Ma (modified from Golonka et al. 2006) with occurrence of rift-related magmatism (red stars). Abbreviations, Bl – Balkan rift; **CR – Czorsztyn Ridge**; Du – Dukla Basin; EA – Eastern Alps; Hv – Helvetic shelf; IC – Inner Carpathians; In – Inačovce-Kričevo zone; Kr – Kruhel Klippe; Li – Ligurian Ocean; Mg – Magura Basin; Mr – Marmarosh Massif; **PKB – Pieniny Klippen Basin**; Ra – Rakhiv Basin; RD – Rheno Danubian Basin; Rh – Rhodopes; SC – Silesian Ridge (Cordillera); **Sl – Silesian Basin**; Sn – Sinaia Basin; St – Štramberk Klippe; Ti – Tisa plate; Tr – Transylvanian Ocean; Va – Vardar Ocean. Explanations of colours and symbols – see Fig. 5a.

3.2. Silesian Unit (Outer Flysch Carpathians)

The Outer (Flysch) Carpathians are composed of Jurassic to Early Miocene flysch sequences. During the Alpine orogenic processes in Miocene times, the north-verging nappes were detached from their original basement (Ślączka et al., 2006). The Proto-Silesian (Severin-Moldavidic) Basin originated during Late Jurassic times together with syn- and post-rift deposits (Figs. 6, 11). Part of this basin was included into the Silesian Unit, one of the Outer Carpathian nappes. The Silesian Ridge (Fig. 6 – SC) was an uplifted area, originally as a part of the North European platform separating during Jurassic – Early Cretaceous times AT and the Proto-Silesian Basin (Fig. 6). Now it is known only from exotics and olistoliths occurring within the various allochthonous units of the Outer Carpathians. The shallow-water marine sedimentation prevailed on the Silesian Ridge during the Late Jurassic and earliest Cretaceous. The carbonate material was transported from the ridge toward the Proto-Silesian Basin. This basin developed within the North European Platform as a rift and/or back-arc basin. Its basement is represented by the attenuated crust of the North European plate with perhaps incipient oceanic fragments. The sedimentary cover is represented by several sequences of the Late Jurassic – Early Miocene age belonging recently to various tectonic units in Poland and Czech Republic. The Baška-Inwałd Ridge has been located on the opposite side of the Proto-Silesian Basin and its slope contains mainly carbonate deposits and originated as shoulder uplift separating the Bachowice Basin from the Proto-Silesian Basin. The Vendryně Formation (Kimmeridgian – Tithonian/Early Berriasian) represents the oldest deposits of the Silesian Unit (Nappe) (Figs. 2, 9, 10) (lithostratigraphy after Golonka et al., 2008). This formation is built of dark-grey marly shales with rare intercalations of redeposited detrital limestones (Fig. 10) containing fossils of shallow-marine fauna, mainly echinoderms and molluscs. Deposits forming huge sliding slices with numerous deformation structures indicating chaotic type of sedimentation occur within the profile. The rocks of the Vendryně Formation are exposed both in the classic type locality in Vendryně on the Czech side of the Silesian Unit and on the Polish territory (for example – in the abandoned quarry in Goleszów) (Figs. 2, 10). They are covered by the Cieszyn (Těšín) Limestone Formation (Late Tithonian – Middle Valanginian) which are represented by (organo)detrital and pelitic limestones intercalated by grey/black shales. Limestones are usually thin-bedded with typical features of turbiditic deposits: sharp erosive base of beds, gradational fractionation, ripplemark-convolute cross-lamination in the top parts of beds, sometimes with numerous trace fossils on the soles of beds, flutcasts, delicate ripplemarks in fine-grained type of limestones, resedimented shales and carbonate clasts (often with fractionation) etc., and additionally with rare cherts (comp. Waśkowska-Oliwa et al., 2008). The younger, Middle Valanginian–Barremian Hradište Formation is represented mainly by grey/black shales with intercalations of very thin- to medium-bedded calcareous sandstones (lower part–Cisownica Shale Member; formerly Upper Cieszyn Beds) and thick-bedded sandstones and conglomerates (upper part of formation – Piechówka Sandstone Member; formerly Grodziszcze Sandstones). Also some rocks, formerly known as Wierzowskie Beds are now included into the Hradište Formation. The Hradište Formation is covered by the Veřovice Formation (Aptian) represented by dark and black shales and mudstones rich in organic matter. Younger is the Lhoty Formation (Albian) representing synorogenic flysch-type deposits.

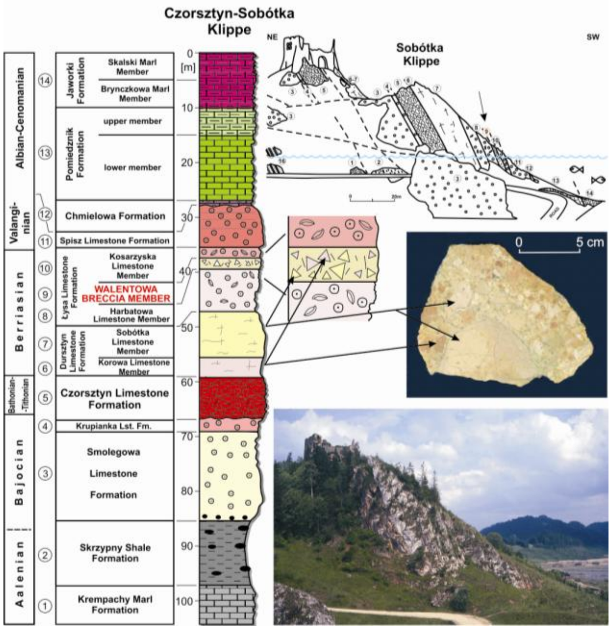

Fig. 7. Stratigraphical section of the Czorsztyn-Sobótka Klippe (PKB) with indication of position of the Walentowa Breccia Member of the Łysa Limestone Formation of the Czorsztyn Succession (lithostratigraphy after Birkenmajer, 1977, slightly modiefied) (photo – state in 1992). Explanations of lithology: 1 – dark-grey/black marls/marly limestones; 2 – black spherosideritic shales; 3 – white cridoidal limestones (with phosphatic concretions in base – black dots); 4 – red/pink crinoidal limestones; 5 – red nodular limestones; 6 – pink micritic *Calpionella*-bearing limestones; 7 – creamy micritic *Calpionella*-bearing limestones; 8 – creamy brachiopodic-crinoidal limestones; 9 – limestone sedimentary breccia; 10 – pink-creamy brachiopodic-crinoidal limestones; 11 – cherry crinoidal limestones; 12 – violet-red marls; 13 – green marls, sometimes with cherts; 14 – green and variegated *Globotruncana*-bearing marls.

4. Synsedimentary breccia and debris flow deposits

4.1. Pieniny Klippen Belt

In the PKB the best example of synsedimentary breccia occurs within widely distributed, exclusively carbonate sedimentation of the Berriasian Łysa Limestone Formation which is tripartite and consists of the Harbatowa Limestone Member, Walentowa Breccia Member and Kosarzyska Limestone Member (Birkenmajer, 1977). The first and third members are represented by crinoid-brachiopod sparitic and micritic limestones. However, the most typical product of synsedimentary tectonic activity is the middle member (*Calpionellopsis* Zone of the Berriasian – Wierzbowski and Remane 1992) composed of pelagic limestones containing pinkish and creamy fragments of underlying beds (so-called *Calpionella* limestones – both Korowa and Sobótka Limestone members of the Dursztyn Limestone Formation), interpreted as synsedimentary scarp breccia (Birkenmajer, 1958; 1975; 1986). Sedimentation of this breccia coincides very well with the moment, when the shallowing effect was strongest, as a change of brachiopod assemblages indicates (Krobicki 1994, 1996; Golonka and Krobicki, 2001). After the Neo-Cimmerian uplift of the Czorsztyn Ridge, the sedimentation depth of the Czorsztyn Succession zone can be estimated between 400-500 m (Cecca 1992), on the basis of palaeoecological considerations of the Lower Berriasian Rogoźnik coquina (partly facies equivalent of the Sobótka Limestone Member). Consequently, the shallowing-upward effect of this vertical movement reached about 100-200 meters. In the Inner Carpathians, both sedimentological and age equivalent of the Walentowa Breccia Member occur – the so-called Nozdrovice Breccia, which is, contrary to our opinion, considered by Slovakian geologists (Reháková and Michalík, 1992; Michalík et al., 1995; 1996; see also Staniszewska and Ciborowski, 2000) as an eustatic-controlled resedimentation event that produced synsedimentary breccias along submarine scarps (Michalík and Reháková, 1995). On the other hand, Plašienka (1999, 2002, 2003) interpreted these resedimentation events as an important rifting phase – the Walentowa Phase – which affected tectonic evolution of the Western Carpathians during the earliest Cretaceous.

4.2. Silesian Unit

The western part of the Polish Carpathians region, between towns of Cieszyn and Żywiec, is the best

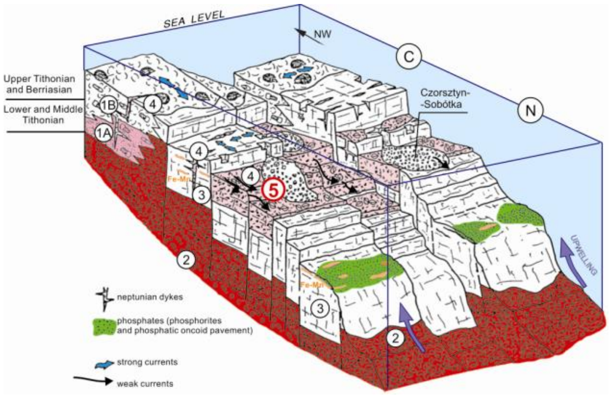

Fig. 8. Model of sedimentation on the intraoceanic Czorsztyn pelagic swell in Berriasian times with effects of pronounced Neo-Cimmerian tectonic movements (after Krobicki 1996; modified). Abbreviations: 1 – Rogoźnik Coquina Member (A – sparitic coquina; B – micritic coquina); 2 – Czorsztyn Limestone Formation (Ammonitico Rosso facies); 3 – Sobótka Limestone Member (Dursztyn Limestone Formation); 4 – Harbatowa Limestone Member (Łysa Limestone Formation); **5 – Walentowa Breccia Member** (Łysa Limestone Formation); successions: C – Czorsztyn; N – Niedzica.

for study of the uppermost Jurassic and lowermost Cretaceous debris flow deposits of the Silesian Unit (Fig. 2). According to the newest lithostratigraphical scheme of the western part of the Outer Carpathians (Golonka et al. 2008) they belong to Vendryně Formation, Cieszyn Limestone Formation and Hradište Formation (Cisownica Shale Member) (Figs. 9, 10) (see above) and cropping out in the Goleszów abandoned quarry (Fig. 10 lower part of photo) and in the Żywiec profile along the bank of the Soła River (Fig. 10 upper part). The thickness of debris flow deposits ranges from 2.5 to 30 meters. The share of the clastic framework does not exceed 30%. These sediments can be correlated with the facies A1.3 of Pickering et al. (1986) and facies GyM of Ghibaudo (1992). They include numerous fragments and pebbles of detrital and pelitic limestones of the Cieszyn Limestone Formation, organodetrital limestones, marly shales, Carboniferous and metamorphic rocks – granitic gneisses, gneisses and crystalline schists. Pebbles are randomly arranged in a mass of structureless, hard, marly silt. Generally, both the clays and embedded lumps of limestone have bends and folds closing towards the north suggesting that the sliding mass moved from the south.

Goleszów (Figs. 2, 10)

In this abandoned quarry, the oldest Outer Carpathian pre-flysch type deposits crop out, which are well visible in the eastern wall of the quarry. These rocks, discovered by Peszat (1968, 1971), belong to the Vendryně Formation, and are represented by dark grey and black marly shales and massive marls with thin, single beds of pelitic, sandy and detritic limestones. All these type of rocks composed huge slumping structures (Słomka 1986a) with well visible deformation structures originated during submarine mass movements (olistostromes, debris flows, gravelstones etc), which dynamically developed on a steep slope presumable during seismic activity in the Proto-Silesian Basin (Słomka, 1986b). Three levels of synsedimentary deformation occur in this quarry. The lowest is 2-4 m in thickness and consists of strongly folded dark marls. The second one has variable thickness (from several to dozen meters) and is characterized by occurrence of dark marls with blocks of detritic limestones and isolated fragments of massive marls, marly shales and thin-bedded flyschoidal rocks. The biggest blocks reach up to 6 m in di*mension. The topmost level (3-5 meters in thick*ness) is represented by dark grey and black shales with irregular blocks of detritic limestones (Fig. 10). Foraminiferal assemblages from the matrix indicate uppermost Jurassic age, but foraminifers and calcareous dinocysts in thin sections suggest Early Tithonian age (Olszewska 2005). However, the oldest part of these units has been earlier determined even as Late Kimmeridgian (Malik, 1994). All sedimentological features indicate a very rapid sedimentation of different kinds of submarine mass movements during large-scale catastrophic (*sensu* Malik 1994) resedimentation events, as it was earlier suggested by several authors (comp. Nowak, 1964; 1973; Peszat, 1968; 1971; Słomka, 1986b).

Żywiec – Soła River valley (Figs. 2, 10)

Geological position of investigated outcrops along

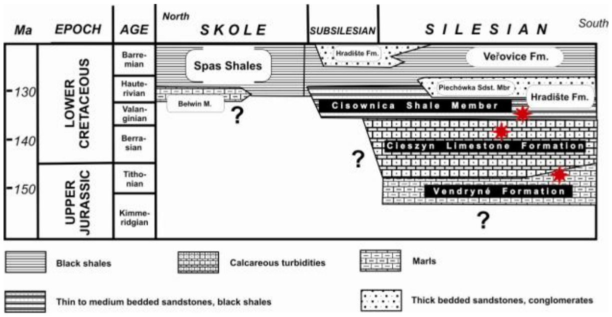

Fig. 9. Stratigraphical position of the Jurassic/Cretaceous boundary units of the Polish Outer Flysch Carpathians (after Słomka 1986, modified; lithostratigraphy – see Golonka et al. 2008) with position of debris flows (red stars).

the Soła River in Żywiec is very complicated by tectonic folding structures and was studied by several authors (Malik, 1994; Słomka, 2001; Golonka et al., 2006 with literature cited therein). More southern part of the long outcrop is built by mass movement deposits (up to 30 m thick) represented by dark grey/black marly shale matrix with abundant exotic rocks, both magmatic/metamorphic and sedimentary ones (Carboniferous coals including); typical exotic-bearing gravelstone of the Cisownica Shale Member of the Hradište Formation (Valanginian in age). Some characteristic exotics are of uppermost Jurassic/lowermost Cretaceous deposits originated a little bit earlier in the Proto-Silesian Basin or surrounding regions. Sedimentological analysis suggests rapid sedimentation of these mass movement deposits with full transitional spectra from olistostromes to debris flows (Tokarski, 1947; Słomka, 1986b; Golonka et al., 2006) (megaturbidites – *sensu* Malik, 1994).

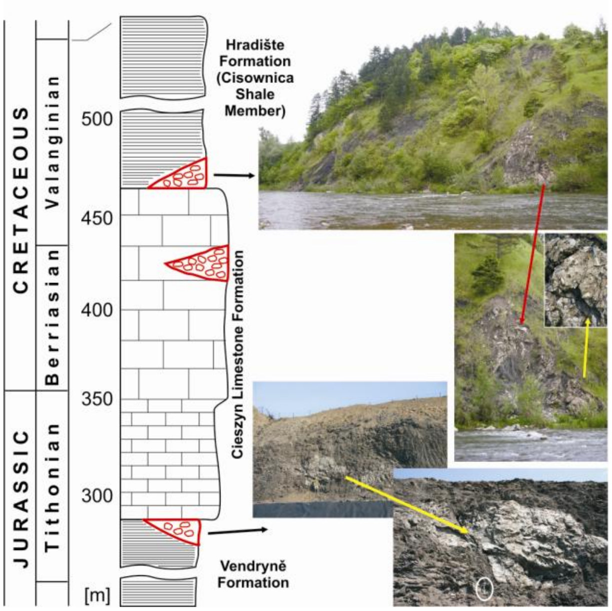

Fig. 10. General section of the Jurassic/Cretaceous boundary units of the Outer Carpathians in vicinity of Żywiec (after Słomka 1986a; changed and modified) with position of debris flows and location of outcrops described in the text – Goleszów (lower photo), Soła River (upper photo); lithostratigraphy after Golonka et al. 2008.

Such type of redeposited material in olistostromes/debris flows indicates the building of the Silesian Ridge during the initial stage of the active cordillera development, at least since Tithonian – Berriasian times. The tectonic activity caused uplift of the Silesian Ridge, its slope and continental rise of the Proto-Silesian Basin. The deposits of the Cieszyn Limestone Formation were eroded again and redeposited as debris flows. Much greater participation of the coarse-grained facies of the upper part of the Cieszyn Limestone Formation and the appearance of mass-movement debris-flow deposits containing fragments of older rocks and exotics (both metamorphic and Palaeozoic sedimentary rocks) suggest a higher rate of uplift during the latest Jurassic – earliest Cretaceous (Neo-Cimmerian) activity and "cannibalism" of the Proto-Silesian Basin (comp. Matyszkiewicz and Słomka 1994; Waśkowska-Oliwa et al., 2008). Tectonic movements of the Silesian Ridge (and probable also the opposite – Baška-Inwałd Ridge) were presumably connected with development of initial rifting in the Proto-Silesian Basin, as documented by the presence of teschenitic magmatism (Grabowski et al.,

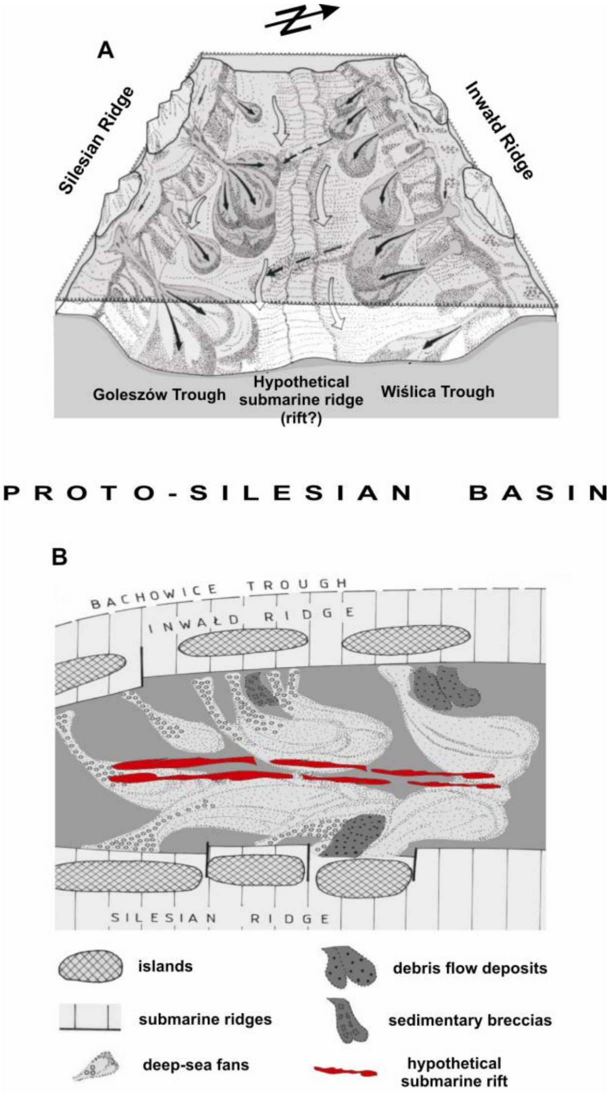

Fig. 11. Palaeogeographical blockdiagram of sedimentation of the oldest flysch deposits in the Proto-Silesian Basin (Jurassic/Cretaceous transition – Tithonian/Berriasian) (A) and its hypothetical palaeogeographical sketch (B) (after Słomka 1986a; slightly modified).

2003; Waśkowska-Oliwa et al., 2008 with references therein) (Fig. 11). Such submarine magmatic processes took place mainly during Early Cretaceous times, but first episodes of magmatic activity could began even during Early Tithonian (148.6 ±1.8 Ma) (op. cit.) during the first step of opening of the Proto-Silesian Basin (Ślączka and Słomka 2001; Golonka et al., 2006).

In the more northern part of this outcrop, typical deposits of the Vendryně Formation occur, with numerous synsedimentarily deformed hard clasts of marls, which were interpreted as resedimentation effect, quite similar to the same-age deposits from the Goleszów quarry (Malik, 1994).

5. Conclusions

Latest Jurassic – earliest Cretaceous tectonic events took place both in the Pieniny Klippen Basin (AT) and Proto-Silesian Basin documenting over-regional significance of this geodynamic episode in the northernmost margin of the Tethyan Ocean. An important geotectonic reorganization, known as the Walentowa Phase, took place in these two regions during the Neo-Cimmerian times, resulting in extensive gravitational faulting. Several tectonic horsts and grabens were formed, rejuvenating some older faults which raised shallow intrabasinal Czorsztyn pelagic swell again and are documented by facies diversification. Additionally, these movements divided the basin into different zones with their own water circulation patterns, probably of an upwelling type. Volcanic activity (both intra-plate alkaline volcanism in the Ukrainian part of the Pieniny Klippen Belt – Krobicki et al. 2005, 2008, and the Proto-Silesian rift-related magmatism) (Fig. 11) and change of oceanographical regimes (upwelling currents) also most probably reflect this geotectonic phenomenon.

Chaotic type of sedimentation dominated during Late Jurassic times indicating early stages of the Proto-Silesian Basin opening with increased tectonic activity. The detrital material was supplied from two sources: from the Baška-Inwałd uplift separating Proto-Silesian Basin and the Bachowice Basin located within the North European Platform, and from the island arcs within the Silesian Ridge separating Proto-Silesian Basin and AT. The biogenic material originated within shallow-water reefal and carbonate platform zones and was transported by turbiditic currents from the uplifted structures on the Proto-Silesian Basin margins into deeper zones of this basin. Both the calciturbidites and calcifluxoturbidites formed, constituting the main lithosome within the younger lithostratigraphic unit – the Cieszyn Limestone Formation. These deposits represent the oldest turbiditic sedimentation known from the Polish Outer Carpathian Basin.

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