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PROFESSOR MARIAN KSIĄŻKIEWICZ – CARPATHIAN GEOLOGIST

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Professor Marian Książkiewicz was noticeable among numerous Carpathian geologists by versatility of his geological achievements, scrupulosity, and ability to create new syntheses. He not only prepared geological maps, but also worked on lithostratigraphy, sedimentology, palaeontology, tectonics, palaeogeography, and geodynamics. In all these topics he obtained outstanding results, recognised both in Poland and abroad.

Prof. Książkiewicz considered geological mapping as a principle geological task that allowed to understand properly not only static geological structures, but also geological processes. He created a specific school of geological mapping and educated a number of excellent field geologists. He carried out geological mapping mainly in the Western Carpathians, and as a result presented several outstanding maps. Prof. Książkiewicz also stressed the importance of geological trips to other areas and countries to broaden geological knowledge. He often travelled outside the Northern Carpathians to study other flysch basins, for instance, in Wienerwald and Caucasus, and usually published interesting deductions and comparative papers (Książkiewicz & Sokołowski, 1934a; Książkiewicz & Skoczylas-Ciszewska,1937; Książkiewicz & Leško, 1959a; Książkiewicz, 1962, 1973).

Marian Książkiewicz started geological research already during his university education and carried out geological mapping in the area of Wadowice (West Carpathians) between Radziszów and Andrychów (Książkiewicz, 1929, 1930, 1931b, 1932a and c). Later on, his researches included the whole sheet Wadowice and adjacent areas, up to the Olza River towards the west (Książkiewicz, 1931b, 1932b, 1959a, 1964), and up to the Babia Góra Range towards the south (Książkiewicz, 1935d).

As an effect of his mapping, several new modern maps were presented, for example the map of the northernmost part of the Western Carpathians between Cieszyn and Bielsko (Burtan *et al.*, 1938), the map of a part of the Magura Nappe in the Beskid Średni Mts. (Książkiewicz, 1935a, 1958b), and of the Babia Góra Range (Bieda & Książkiewicz, 1963). Particularly famous was his map of the Wadowice sheet, scale of 1: 25,000, finished before the World War II, which was illegally printed by Germans during the war (Książkiewicz, 1941). For a long time it was the best geological map of the Carpathians. During his fieldwork, Prof. Książkiewicz not only very precisely localised exposures, but also, first of all, studied lithological successions, their mutual relationships and age based on analysis of micro- and macrofaunal species, sedimentological processes, and tectonics. He deserved the credit for the distinction of several new lithostratigraphic units and reambulation of some older units within the Western Flysch Carpathians. He distinguished, among others, geize sandstones (Książkiewicz, 1936, 1938, 1951a) within the Lower Cretaceous sequences and proved that they are replacing a part of the Grodziszcze and Lgota beds, cherty marls between the mid-Cretaceous variegated shales and Godula sandstones, and correlated them with similar deposits from the East Carpathians (Książkiewicz, 1951a). He also distinguished the Upper Cretaceous Jastrzębia Marls, Gorzeń beds, Szydłowiec Sandstones, and the Eocene Przybradz beds (Książkiewicz, 1951a). With co-workers, he distinguished the mid-Cretaceous radiolaritic layer (Burtan *et al.*, 1933) bearing distinct resemblance to the described later "Bonarelli horizon" of Central Apennines. He proved that the thick-bedded Ciężkowice Sandstones could be replaced by variegated shales and marls (Książkiewicz, 1932c), and the Godula Sandstones by red shales (Książkiewicz, 1936). Later on (Geroch *et al.*, 1967), he presented a model of facies changes in the Western Flysch Carpathians (Fig. 1).

Another achievement of Prof. Książkiewicz was the distinction of the Woźniki Unit (Książkiewicz, 1936a) and its succession, that later provided the basis for the distinction by him of a new Outer Carpathians unit, the Sub-Silesian Unit (Książkiewicz, 1951b, 1953 ed.) It should be stressed that, already in 1936, Prof. Książkiewicz suggested that a part of the variegated marls in the Wadowice area could be of Late Cretaceous age, but unfortunately later he resigned from this opinion. However, after successive in-

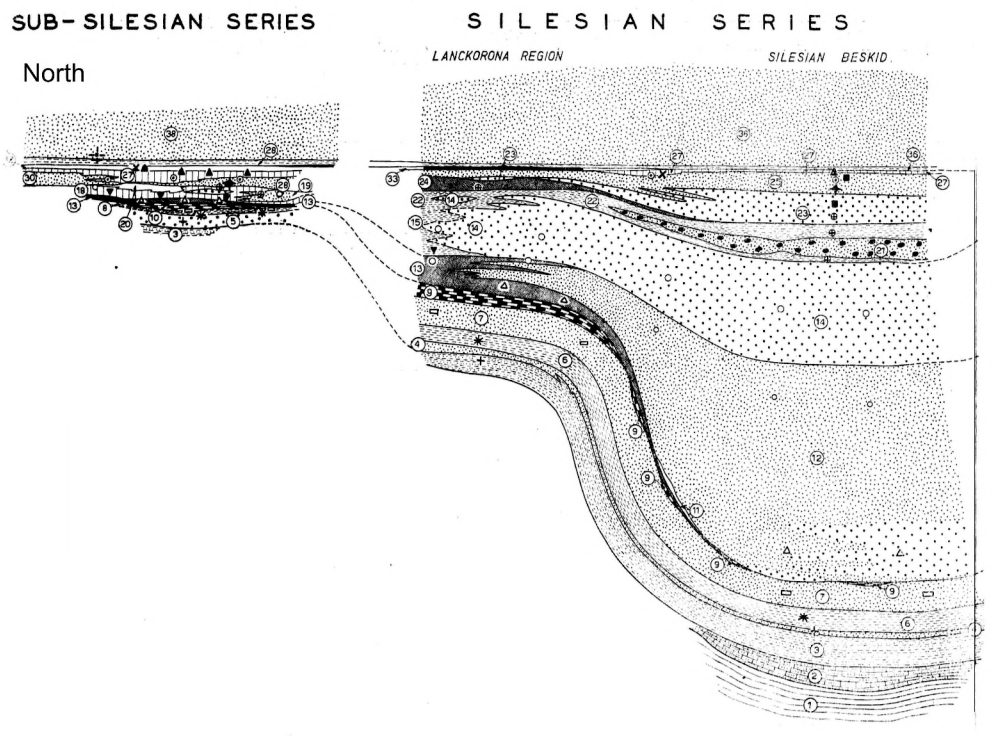

Fig. 1. Model of change of lithofacies from the inner (Silesian Series) to outer (Sub-Silesian Series) part of the Western Carpathian Flysch Basin, presented by Książkiewicz (Geroch *et al.*, 1967)

vestigations, especially micropalaeontological ones, and the discovery of *Globotruncana* sp., he returned to the primary opinion (Książkiewicz, 1950a). He was also the first who described in the Western Carpathians the Eocene greenish marls below the Menilite beds (Książkiewicz, 1932c, 1967), an equivalent of the *Globigerina* Marls from the Central and Eastern Carpathians. Another achievement of Prof. Książkiewicz was the systematisation of the Magura Nappe succession and the distinction of the Eocene Osielec Sandstones, Sub-Magura, and Supra-Magura beds (Książkiewicz, 1935a, 1948b, 1958b, 1967a, Bieda *et al.*, 1968).

The results of his studies conducted before and directly after the Word War II were presented in the above mentioned unique explanatory text to the Wadowice sheet (Książkiewicz, 1951). In this monographic paper, he presented and thouroughly discussed several problems, ranging in scale from individual exposures up to the palaeogeography and geodynamic problems of the Western Flysch Carpathians.

Prof. Książkiewicz devoted much of his interest to the geology of calcareous klippen within the outer part of the Flysch Carpathians, in the Andrychów area (Fig. 2) known

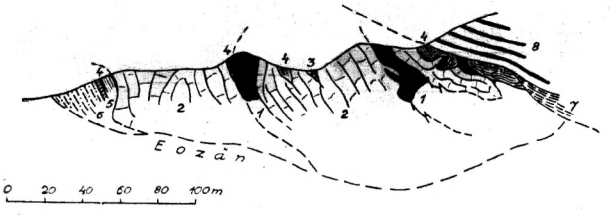

Fig. 2. Schematischer Durchschnitt durch den östlichen Teil der Klippe von Inwałd. 1. »Mylonite«. 2. Inwalder Kalk. 3—6. Obere Kreide: 3. Konglomerate. 4. Mergel. 5. Sandsteine. 6. Mergelschiefer. 7. Wierzowice-Schiefer 8. Ligota-Schichten.

Fig. 2. Schematic section across Inwałd Klippen (Książkiewicz, 1935a) and subsequent sections drawn after drilling of two boreholes (Książkiewicz & Liszkowa, 1972)

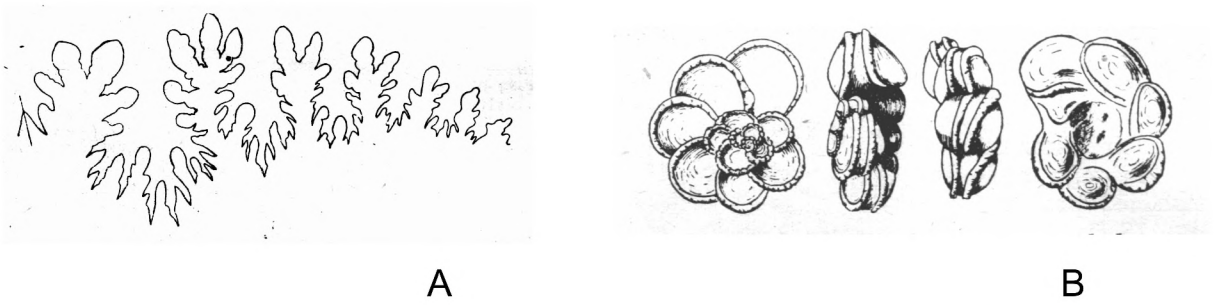

Fig. 3. Drawings of fauna by Książkiewicz from calcareous exotics from Bachowice: **A** – ammonite lobe-line *Calliphylloceras disputabile*, **B** – *Globotruncana lapparenti* (1963b)

from the 19th century. He established their geological setting and especially lithostratigraphy (Książkiewicz, 1935a, b, c; Książkiewicz & Liszkowa,1972), and regarded them as the remnants of a cordillera "*Urantiklinale von Inwałd*" within the West Carpathian basin.

Prof. Książkiewicz also examined in detail a previously unknown section of the shallow-water Jurassic and Cretaceous series from the exotic rocks in the Bachowice village area, situated north of Andrychów (Książkiewicz, 1955, 1956b). These studies allowed to reconstruct the Jurassic and partly Cretaceous sequences, different both from the foreland and from those known in the Carpathians. It was a strong proof that a significant part of the deposits of the Carpathian basin could have completely disappeared from the surface during later tectonic movements. Prof. Książkiewicz related the sedimentation of the Bachowice exotic rocks with volcanic activity in the Western Carpathian basin during the Palaeocene. He also published several papers on other volcanic activities in the Carpathians, but not all of them are still valid (Książkiewicz & Gaweł, 1936; Książkiewicz & Wieser, 1954a, b; Książkiewicz, 1958).

Prof. Książkiewicz supplemented his lithostratigraphic studies by determination of macro- and microfauna. The most important papers related to this topic refer to the macro- and microfauna (Fig. 3) from Bachowice (Książkiewicz, 1956b), Early Cretaceous fauna from Lanckorona

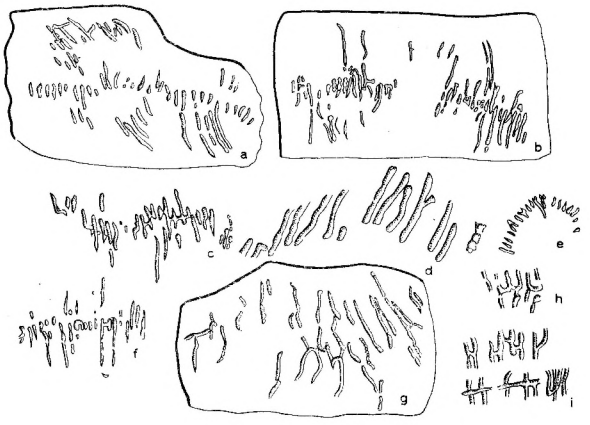

Fig. 4. One of new ichnosp. (*Desmograpton fuchsi*) described by Książkiewicz (1977)

(Książkiewicz, 1938), Early Cretaceous ammonites from the Grodziszcze beds at Woźniki (Książkiewicz, 1963b), *Globotruncana* from the upper variegated limestones of Bachowice (Książkiewicz, 1956a) and from variegated marls in the West Carpathians (Książkiewicz, 1950a).

Very important and often pioneer studies carried out by Prof. Książkiewicz were devoted to trace fossils (Fig. 4)

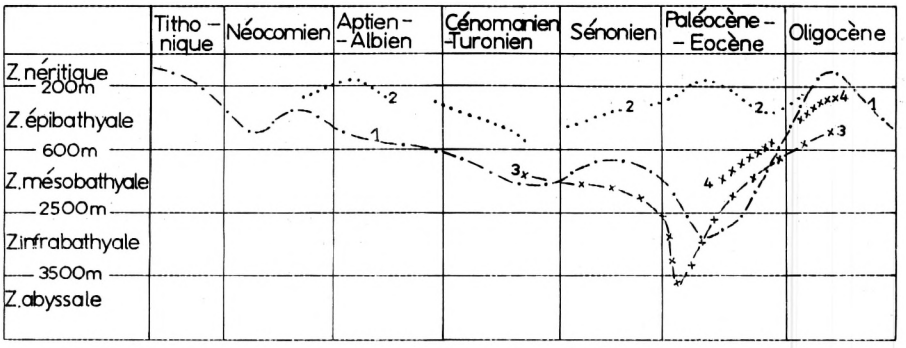

Fig. 1. — Changements de profondeur dans le bassin carpathique.
1 : Profondeur dans la fosse principale, zones distales ; 2 : Profondeur dans la fosse principale, zones proximales (à proximité des rivages) ; 3 : Profondeur dans la fosse de Magura, zones distales ; 4 : Profondeur dans la fosse de Magura, zones proximales.

Fig. 5. Changes of depth in the Carpathian Flysch Basin (Książkiewicz, 1976)

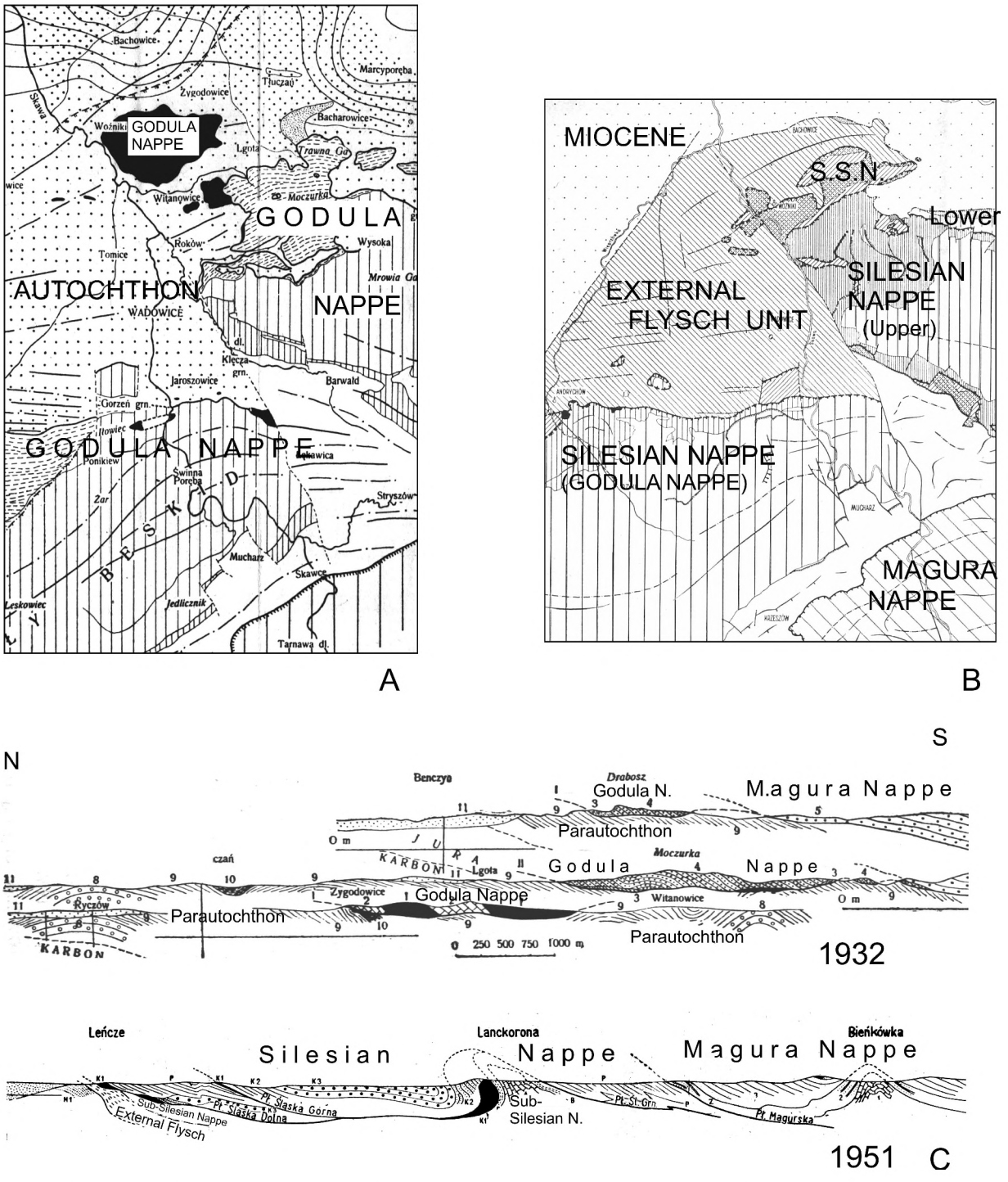

Fig. 6. Development of the idea of tectonics of the Wadowice region. **A** – map from year 1932 (Książkiewicz, 1932); **B** – map from year 1951 (Książkiewicz 1951a), **C** – cross-sections through the Wadowice area (Western Flysch Carpathians): upper after Książkiewicz (1932c), lower – after Książkiewicz (1952)

within the flysch basin (Książkiewicz, 1958b, 1960a, 1961b, 1968a, 1970, 1977c). His collection is one of the largest in the world. He described 57 ichnogenera and 147 ichnospecies (see Uchman, 1998). He also was a promotor of researches on life condition in flysch basins (Książkiewicz, 1959a, 1961a). He documented an important role of redeposition of fauna, the influence of marine currents for the distribution of microfauna, and the dependence of microfaunal assemblages on the type of sediments. He also gave some explanations of unfavourable life conditions in the flysch basins. On the basis of faunal assemblages, trace fossils and sedimentary structures, Prof. Książkiewicz made

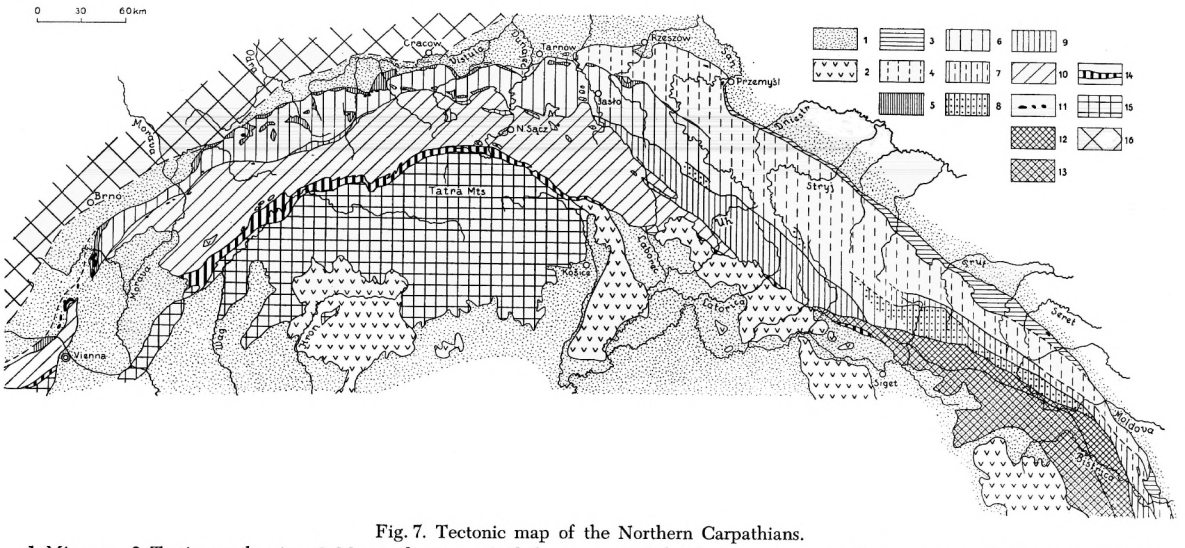

Fig. 7. Tectonic map of the Northern Carpathians.
1 Miocene; 2 Tertiary volcanics; 3 Marginal nappe; 4 Skole nappe; 5 Sub-Silesian nappe; 6 Silesian nappe; 7 Kostrzyca-Tuzlau nappe; 8 Czarnohora nappe; 9 Fore-Magura group; 10 Magura nappe; 11 Klippes within the Flysch zone; 12 Internal Flysch of the Eastern Carpathians; 13 Marmaros zone; 14 Klippes belt of Pieniny; 15 Internal zone of Western Carpathians (Pre-Paleogene units and their cover); 16 Foreland

Fig. 7. Tectonic map of the Carpathians (Książkiewicz, 1956)

an analysis of the changes of bathymetry within the Carpathian flysch basins (Książkiewicz, 1975, 1976). According to him, the Carpathian flysch was deposited mostly in epi- and meso-bathyal zone, but some horizons could have been deposited at infra-bathyal and abyssal depths in proximal areas. Moreover, a part of flysch could have been deposited in shallow-water, neritic conditions (Fig. 5).

Prof. Książkiewicz was the initiator and co-author of monographs dedicated to litho- and biostratigraphy of the Polish Flysch Carpathians (Bieda *et al.*, 1963; Geroch *et al.*, 1967), in which – on the basis of detailed data and the development of lithofacies – their sequences and ages were defined. These monographs are valid up to now, although new nannoplankton data defined the age of some lithofacies more accurately.

The next important contribution of Prof. Książkiewicz to the knowledge of the Carpathians is the elucidation of the tectonics of the Polish Western Carpathians. On the basis of careful analysis of lithostratigraphy and tectonic structures, he proposed a new tectonic subdivision of the area. His earlier studies demonstrated a long and laborious way to find a proper relation between lithostratigraphic units, their age and tectonic affiliation. An example of this can be the development of Prof. Książkiewicz's ideas on the tectonics of the Wadowice sheet (Fig. 6). Basing on primary conceptions of Jan Nowak (1927), he regarded the outer flysch as autochthonous or parautochthonous (Fig. 6), and only more internal units (Cieszyn, Godula and Magura units) as nappes (Książkiewicz, 1929, 1930, 1932c). Later on, he distinguished the next overthrust Woźnice Unit, in front of the Godula Unit. Subsequently, after the discovery of tectonic windows within the Godula Nappe (1936), that showed similar Upper Cretaceous deposits as in the Woźnice Nappe, he introduced and defined a new Sub-Silesian Unit

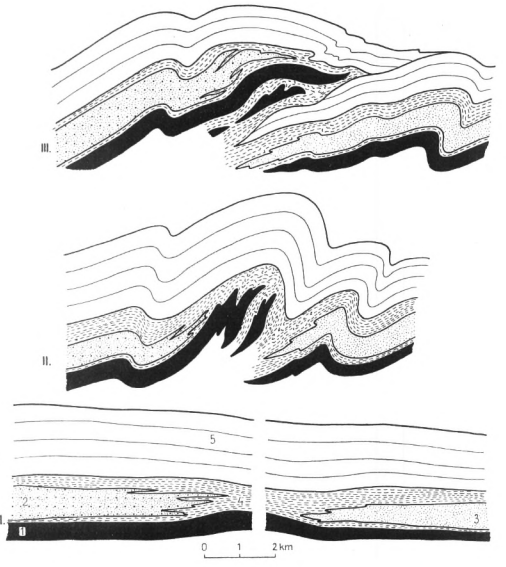

Fig. 8. Origin of overthrusting in the axial zone of the outer flysch basin (Książkiewicz, 1956)

(Książkiewicz, 1951a, 1953). Prof. Książkiewicz, after joining several subunits, distinguished and defined the Silesian Nappe (Książkiewicz, 1951a, 1953) and proved that this nappe continues into the Eastern Carpathians (Fig. 7) between the Skole and more internal, Dukla and Magura, nappes. Therefore, Prof. Książkiewicz can be regarded as the founder of a modern tectonic model of the Western Flysch Carpathians (Książkiewicz, 1952c, 1953). He also attempted to explain the origin of Flysch Carpathians. Important factors, besides underthrusting of the foreland be-

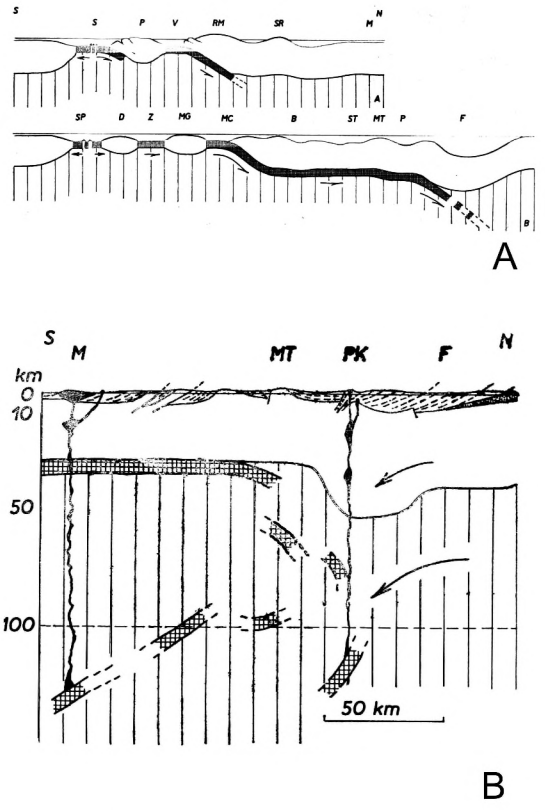

Fig. 9. **A** – Spreading and subduction in the Carpatho-Balkan area during Jurassic–Early Cretaceous times (A. Balkan area, B. Carpathian area, F. Carpathian Flysch Basin); **B** – Underthrusting and origin of magmas in the Carpathians (Książkiewicz, 1977)

low the Carpathians, were lithological differences across the flysch basin (Fig. 8). He developed his tectonic model in later papers (Książkiewicz, 1956a, 1960–1963), and especially in the monograph on the tectonics of the entire Polish Carpathians (Książkiewicz, 1972). In the English version of this monograph (Książkiewicz, 1977b) and in a special paper (Książkiewicz, 1977a), he presented new plate tectonic ideas on the geodynamics of the Carpathians; postulating, for instance, that subduction during the Jurassic and Early Cretaceous was directed towards the north and only later on towards the south (Fig. 9). However, he generally stated "that is very difficult in a simple way to apply the concept of plate tectonics to the origin of the Carpathians". This opinion was confirmed in part by recent results of the deep seismic profile CEL05 (Grad *et al.*, 2006).

Prof. Książkiewicz was also interested in tectonic mesostructures and was a pioneer of systematic studies of joints in the Carpathian flysch (Książkiewicz, 1968b). He suggested that the development of all joints was generally connected with orogenic movements, but in several instances he showed that in the cases where folding took place twice, the second set of joints is cutting the rocks already deformed. He also suggested the influence of neotectonic movements in cases of abnormally preferential strike of joints.

Very detailed knowledge of the Carpathian geology obtained by Prof. Książkiewicz during his field works, excellent orientation in international geological papers, and the ability to create synthetic models enabled him to prepare several monographs, published both in Polish (Książkiewicz, 1951b, 1953, 1972; Książkiewicz & Samsonowicz, 1952) and English (Książkiewicz, 1956a, 1977b).

Very important and fruitful were the works of Prof. Książkiewicz on sedimentology and palaeogeography. Already after returning from abroad in 1945, he creatively combined the studies of sedimentological processes and the structures of flysch deposits (turbidites). He was one of the first who noticed frequent occurrences of cross-bedding in the flysch (turbiditic) rocks (Książkiewicz, 1948b), though in that period it was believed that the cross-bedding rarely occurs in geosynclinal basins (Pettijohn, 1943). He described, for the first time from the flysch rocks of the Carpathians, the occurrence of sequences (Fig. 10) exhibiting features from parallel lamination, through cross lamination, to once again parallel lamination (1948b), and from graded to

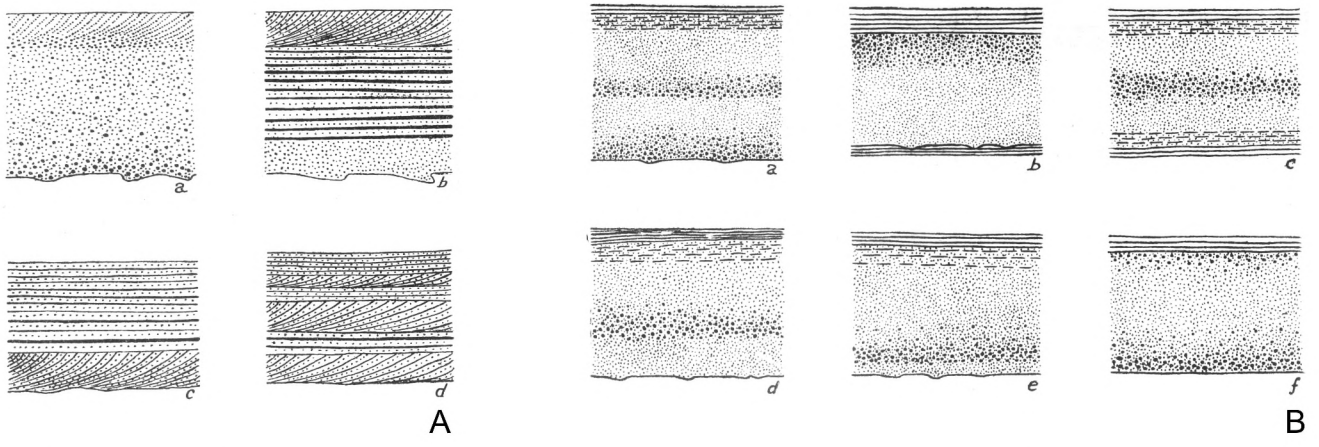

Fig. 10. **A** – Types of graded bedding in the deposits of the flysch Carpathians; **B** – Relation of cross bedding to graded and laminated bedding (Książkiewicz, 1954b)

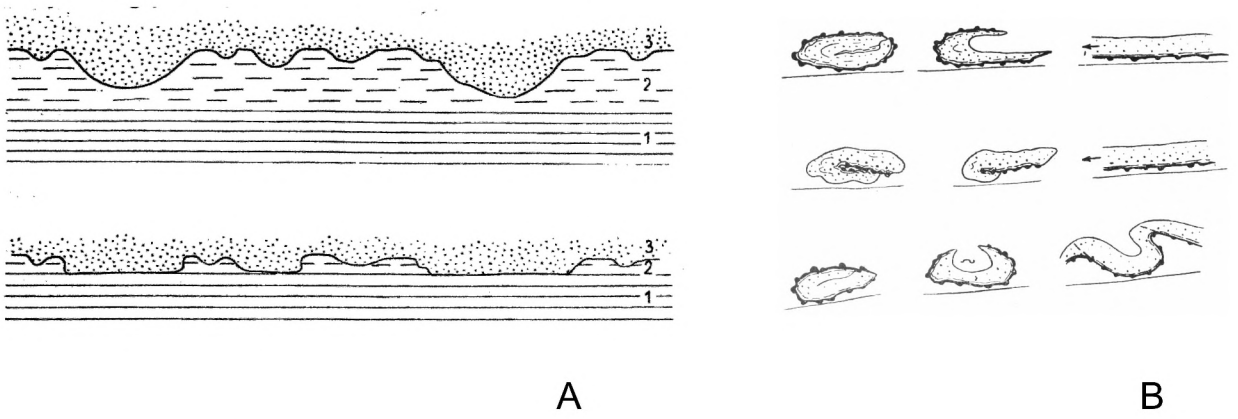

Fig. 11. **A** – Flattening of flute casts owing to the subsidence of the sand beds (Książkiewicz, 1961); **B** – Examples of structures developed during sliding and rolling up of sandstone layers (Książkiewicz, 1958)

laminated bedding (Książkiewicz, 1954b). He suggested (Książkiewicz, 1950) that some contorted laminations within the sandy layers could have resulted from creeping, and that the direction of creeping of deposited material was not always showing the general inclination of the sea bottom, but could be a result of local uplift of the latter. In the quoted paper, he for first time considered flysch as a deep-water sediment and stated that the occurrence of shallow-water fauna within flysch strata was caused by submarine slumps. The following papers were devoted to the explanation of the origin of flattened sedimentary structures (Książkiewicz, 1950) and slump deposits (Książkiewicz, 1958c) (Fig.11).

Prof. Książkiewicz also paid attention to the importance of microfacies analysis of calcareous turbidites (Książkiewicz, 1971c) and exotic limestones (Książkiewicz, 1971d), in order to determine shallow-water facies around cordilleras. He concluded that exotic limestones could be regarded as Bahamite-type sediments, and that clastic material for the Late Jurassic Cieszyn Limestones was derived from the sediments of shoals and banks bordering the basin. In his opinion, the conditions of deposition could be compared with calcareous turbidite sedimentation in a deep basin adjoining to the Bahama Banks.

Very important and masterly was his basin analysis of flysch of the Carpathians. Already in his early papers he stressed on importance of the study of occurrence and distribution of exotic rocks for palaeogeographic analysis and for the reconstruction and position of source areas regarded by him as pre-Carpathian mountain chains. In a paper published in 1931, he presented a map of distribution of exotic rocks in the Western Carpathians and connected them with intrabasinal islands. In Prof. Książkiewicz's opinion, the detailed study of exotic rocks and klippen, with interpretation of lithofacies changes, was a key to understanding the palaeogeography of the Western Carpathians. On the basis of these early investigations, he presented in 1951 the first model (Fig. 12) of development of the Western Carpathians flysch basin (Książkiewicz, 1951b). He already accentuated the similarity of sediments within the whole basin during the Early Cretaceous and diversification of sediments after mid-Cretaceous. It was caused by sudden uplifts of source areas, both marginal and intrabasinal ones (Silesian, Andrychów and Bachowice ridges) (Figs 13, 14 A). As an effect, several subbasins (Magura, Silesian, Sub-Silesian, Skole) were developed in different lithofacies. Subsequent investigations carried out by Prof. Książkiewicz, including detailed measurements of transport of clastic material, al-

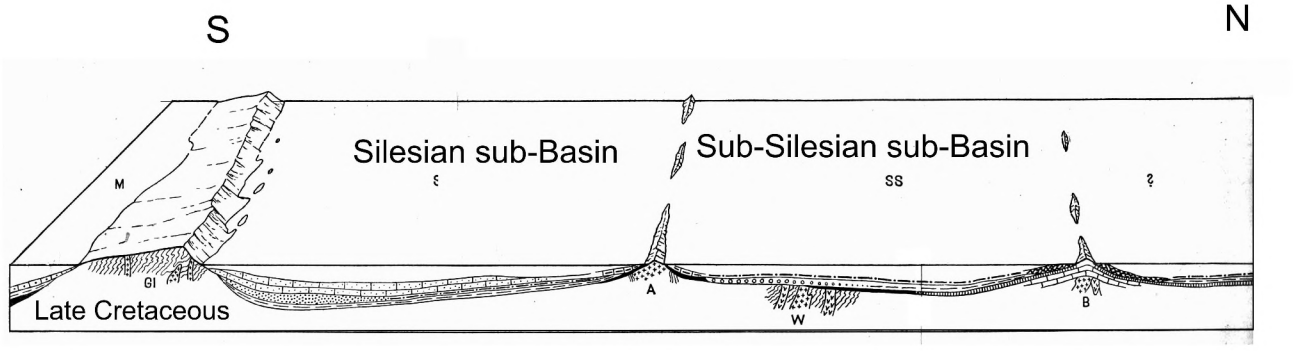

Fig. 12. 3D model of the Western Carpathian Flysch Basin (Książkiewicz, 1951a); M – Magura sub-Basin, islands: Gl – "Silesian", A – Andrychów, B – Bachowice

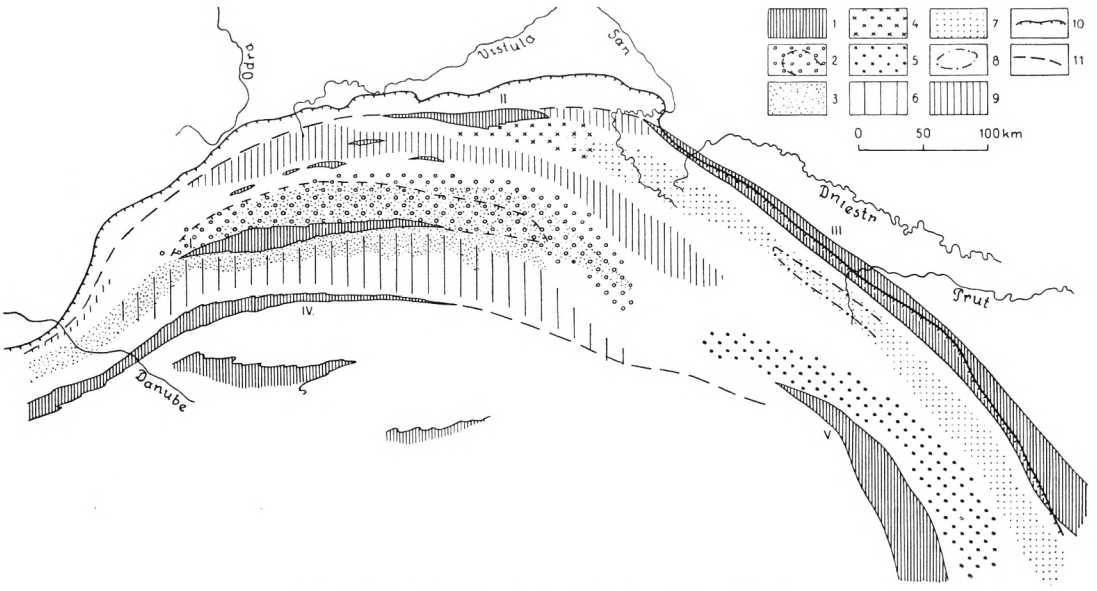

Fig. 5. Principal source areas of the Carpathian Flysch.
1 Cordilleras and mobile borders of the geosyncline: I Silesian cordillera, II Debica-Rzeszów cordillera, III Green rocks zone, IV Pieniny cordillera, V Marmaroš zone; 2 Istebna facies with marked Godula sandstone extent; 3 Ciężkowice facies; 4 Babica exotics bearing clays; 5 Tarcau facies; 6 Magura facies; 7 Kliwa facies; 8 Wygoda facies; 9 Marly and shaly axial facies; 10 Present border of the Carpathians; 11 Presumed borders of the Flysch geosyncline (before the compression).

Fig. 13. Principal source areas of the Carpathian Flysch (Książkiewicz, 1956)

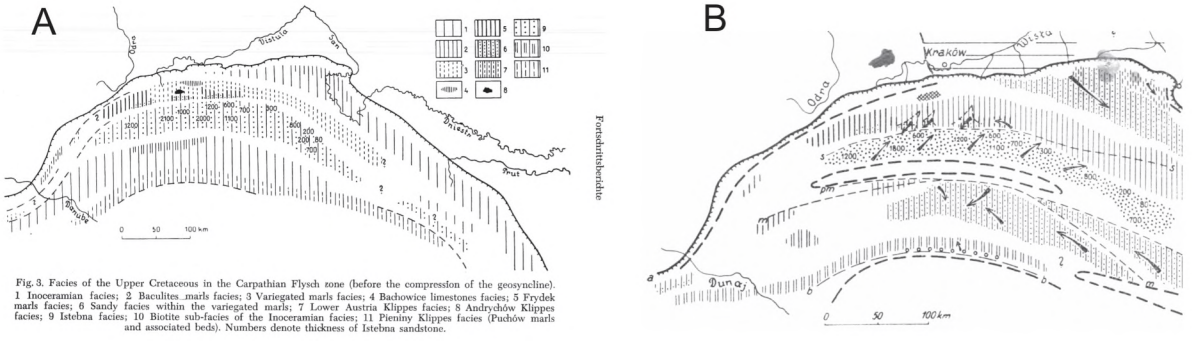

Fig. 3. Facies of the Upper Cretaceous in the Carpathian Flysch zone (before the compression of the geosyncline). 1 Inoceramian facies; 2 Baculites .marls facies; 3 Variegated marls facies; 4 Bachowice limestones facies; 5 Frydek marls facies; 6 Sandy facies within the variegated marls; 7 Lower Austria Klippes facies; 8 Andrychów Klippes facies; 9 Istebna facies; 10 Biotite sub-facies of the Inoceramian facies; 11 Pieniny Klippes facies (Puchów marls and associated beds). Numbers denote thickness of Istebna sandstone.

Fig. 14. Successive palinspastic sketches of the Carpathian Flysch Basin, elaborated by Książkiewicz: **A** – facies of the Late Cretaceous (Książkiewicz, 1956); facies of the Late Senonian: **B** – Książkiewicz (1960), **C** – Książkiewicz, Ed. (1962)

lowed him to create (Fig. 14 B and C) a synthetic palaeogeographic model for the Flysch Carpathians (Książkiewicz, 1954a, 1956a, 1960b, c, 1963a, 1965) as a prominent tectonically active basin. He emphasized the importance of internal ridges (cordilleras) as one of the main source areas for clastic material. It was not a popular idea at that time. It ought to be stressed out that Prof. Książkiewicz was the first who adopted and widespread the measurements of current directions (flute marks, cross-bedding) for the reconstruction of palaeogeography of orogenic basins and showed that the turbidity currents were flowing both along the axis of the basin and obliquely to it, down marginal slopes. In some of these maps it is already possible to recognise submarine fans, although he did not use this term (Fig. 14C). The best example of this kind of map was, initiated by him, unequalled *Palaeogeographic Atlas of the Flysch Carpathians* (Książkiewicz, Ed., 1962). It contains 13 facies maps with palinspastic sketches, practically for every stage of the Cretaceous and Palaeogene.

His analysis of turbiditic sedimentation in deep water basins brought him an international recognition and consequently a number of sedimentologists from abroad visited him to learn his methods of basin analysis. Among them was the outstanding sedimentologist Ph. F. Kuenen. As a result of this visit, a joint treatise (also with Stan Dżułynski) on turbidites in flysch of the Polish Carpathian Mountains (Dżułyński *et al.*, 1959) was prepared, where among others, the origin of structureless sandstones within turbidite sequences was presented and the term "fluxoturbidites" was proposed for them. Even recently, his palaeogeographic reconstructions are cited (see Okada & Kenyon-Smith, 2005) as an excellent example of basin analysis of that period.

During the 1950s and 1960s, Prof. Książkiewicz grouped his students interested in sedimentary structures associated with turbidites and basin analysis, what led to the formation of the worldwide recognized "Kraków Flysch School (see the paper of Kelling *et al.*, this volume).

The above presentation of the achievements of Prof. Książkiewicz shows clearly the outstanding role, which he played in the progress of Carpathian geology and turbidite sedimentology. It ought to be underlined that he always regarded as his duty to present new ideas for discussion during numerous lectures and field conferences.

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