Dr Leszek Jankowski

1.Name:

Leszek Jankowski

2. Scientific titles and degrees - including description, place and date, and PhD thesis title.

2003 - PhD Earth Sciences, title: *„Budowa geologiczna przedpola jednostki magurskiej pomiędzy Wisłoką a Dunajcem ze szczególnym uwzględnieniem utworów chaotycznych”* Polish Geological Institute – Carpathian Branch.

1984 - master, Institute of Geological Science Jagiellonian University
title: „*Budowa geologiczna rejonu Czchów – Ruda Kameralna*”.

3. Information about the scientific employment

1985-1990, Polish Geological Institute , Carpathian Branch.

1992-today Polish Geological Institute, Carpathian Branch

4. Scientific achievement according to Dz.U., poz. 595:

a) Title of the scientific achievement

A new look at the geological history of the Carpathians – critical point of view

b) (author, title of the publication, year, journal):

Jankowski L., Nowe spojrzenie na budowę geologiczną Karpat - ujęcie dyskusyjne. Prace Naukowe Instytutu Nafty i Gazu - Państwowego Instytutu Badawczego No 202, Instytut Nafty i Gazu - Państwowy Instytut Badawczy, ISBN: ISSN 2353 – 2718

c) description of the scientific goal of the above papers and presented results including the

discussion of application

The papers chosen for characterizing the scholarship have character of the conceptual presentation, expressing my point of view on the subject of basinal – tectonic history of the Carpathian orogeny. This point of view being an effect of my long-term field works, particularly cartographic. Such point of view is different than presented in Carpathian literature. This (monographic character) paper is present latest numerous data. Models and hypotheses based on field works the entire Carpathian area. It's is regarding many aspects of the geological structure of the Carpathians, their tectonics, as well as development of the relief of the Carpathians. Long-term cartographic works performed on the area of the Polish, Slovak, Ukrainian and Romanian Carpathians, backed up additionally with diverse geological examinations, like e.g. with termochronometric , stratigraphic examinations with balanced cross-sectionsmineralogical gave the ground for outlining the development of scenario of the Carpathian orogeny, different than presented so far in literature. The main purpose of my scientific work were cartographic studies of the area of the Carpathians and circumcarpathian region. Gelogical maps of the different scale are a result of these examinations: general maps (1: 200 000, in their Polish, Slovak, Ukrainian and Romanian section) and. moreover a lot of detailed, geological maps (scale 1: 50 000) were made . I've independently or including co-authors 10 sheets of detailed "Carpathian" maps published. The data collected during of cartographic works, backed up with results of geological analyses (stratigraphic, tectonic, termochronometric, geophysical, geomorphical) let me for creating the new hypotheses concerning the development of Carpathian geology. A chosen monograph is a base for further studies referring a Carpathian orogeny. A few the most of relevant aspects of new concepts of development of the Carpathians are presented. A new scenario of development of Carpathian orogeny was here drawn. Geological structures (different scale) recognised during the field works and mapping supported presented hypotheses. And so the study is an attempt of synthetic of the geological history of the Carpathians . Analysis of the morphology of Carpathian range allows for reconstructing tectonic history of Carpathians. Moreover analysis of morphological forms was of help in recognizing elements of the geological structure. The paper has general character, one should notice that this kind of studies are a rarity unfortunately in the Carpathian literature. New ideas concerning Carpathian geology were formed as a result of cartographic studies of the continuation of works devoted to so called chaotic complexes, begun by me in the middle of 90 years (Jankowski, 1995, 1997, 2007).

Results of my observation and hypotheses referring to the role of chaotic complexes (both sedimentary or tectonic origin) at first they adopted with certain reserve but then more works concerning this subject were already published (cf. Cieszkowski et all, 2012, Starzec et all, 2015). Earliest my papers were

focused on sedimentary origin chaotic complexes, but olistostrome type deposits were discussed earlier (cf. Jasionowicz and Morgiel 1962; Jasionowicz and Szymakowska, 1963; Szymakowska 1966). The cartographic analyses conducted by me, backed up with stratigraphic examinations let discover significant sizes complexes (Jankowski, 1995, 1997, 2007), particularly in the Gorlice region. So called Łużna and Harklowa peninsulas, regarded as Magura Units's elements (Świdziński, 1954; Książkiewicz, 1972; Żytko et all., 1989) turn out to be the Miocene age chaotic complexes. The parts of Magura unit were in Krosno basin by gravity emplaced. Discovering so-called zones of tectonic mélanges which secondary stages of tectonic deformations let substantiate was more significant (cf. Jankowski 2007). Gradually discovered by me (during field works), in every sections of Carpathian range, zones of tectonic mélanges, provided documentation allowed for the change of concepts of Carpathian's tectonic history. Analyses of these complexes allowed for documentation additional stages of tectonic deformations in Carpathian, so called strike-slip stage and collapse of orogeny stage. They allowed also for the change of the cartographic image of the Carpathians in the tectonic aspect (map of the Carpathians , Jankowski, 1997), as well as for the verification some of some stratigraphic units. Fieldwork analysis, for example examinations of paleocurrent directions or facial sequences let me for drawing conclusions which became a ground for formulating new concepts. The examining character and the spatial arrangement of Carpathian so called "flysch" facies esp. so called basinal turbidite facies (as. e.g. Lgota beds facies. Inoceraming facies or Krosno beds) let the concept of transferring the deposition centre during in sedimentary basins of the Carpathians. This concept was formulated earlier by Książkiewicz (cf. Książkiewicz 1977). Sedimentary processes however described then, but the mechanism of migration remained unsolved. Stating appearing of numerous, the same type facies in various tectonic units Carpathians (e.g. Logta beds, Inoceramian beds, Menilite beds, Ćiężkowice beds or Istebna beds)) gave bases for verifying by me old conception of the existences of constants of sedimentary trenches, functioning so far in literature. The critical approach towards this idea was already presented by me (cf. Jankowski, 2004, Jankowski and other 2012). Tracing sedimentary sequence in various regions of the Carpathians, with correlation of events (cf. Jankowski and other, 2012) is pointing for existing in the basinal history of Carpathians of only a few sedimentary cycles. I used a term "depositional system" for describing the co-occurrence of both shallow and deeper facies. Observation of appearing and spatial distribution in the area of the entire Carpathians, already a long time ago gave grounds for making an assumption that the character of depositional systems is changing. It's strongly depend on eustatic see level changing whether of local tectonics (Jankowski, 2004; Jankowski et all, 2012). In this aspect the position of some facies in different tectonic units depends only on the place and the depth of detachment. There are interesting examples in the Ukrainian region of the Carpathians, where e.g. Lgota facies being a "indicator" of Silesian unit, is going in upper parties of the profile into the Inoceramian facies recognized usually in literature as "indicator" of other tectonic unit (eg. Skole, Dukla and Magura units). It's indicating on obviously false assumptions of the close relationship of facies, with specific tectonic units. Examinations conducted by me, concerning spatial distributions of the

Cieżkowice sandstones, Istebna beds, Mszanka sandstones confirmed incorrectness of such idea. Discovering of another areas of appearing of chaotic complexes (sedimentary origin, slumps and slides) about the type of great flows (e.g. in front of Węglówka unit - cf. Jankowski and Probulski 2011, whether in the front of the Carpathian thrust), pointed at their co-occuring great chaotic complexes (sedimentary origin) with zones of tectonic mélanges. Observed correlations between appearing of sedimentary origin chaotic complexes and tectonic mélanges let for developing the general model of the process of orogeny building. Moreover it helps explaining the reasons of appearing of chaotic complexes in described places of the orogenic wedge. Appearing of a few belts of olistostrome type chaotic complexes it was stated during during field works. Usually they are appearing in front of very important thrust zones (in Gorlice area in front of Magura Unit, in front of Węglówka thrust and in front of Carpathian thrust). Examinations are pointing that process of co-occuring olistostrome type chaotic deposit and appearing of so called out-of-sequence thrust closely is conditioned with need to keep the permanent angle of the orogenic wedge (so-called critical angle) during a process odd shortening of Carpathian basin.

Accepting such mechanism of the forming of Carpathian orogeny let for clarifying position and cause of forming a olistostrome belt - Pieniny Klippen Belt. Primary sedimentary genesis (as block in matrix slumping unit) was suggested (cf. Nemčok, 1980; Plašenka & Mikuš; 2010; Jankowski and Margielewski, 2015). Later PKB olistostrome stayed assigned to Inoceramian depositional system (Jankowski 2015). The arrangement of tectono - facial contacts in PKB whether in the Węglówka tectonic zone is indicating the existence oot-of-seqence thrust during the shortening the Carpathians basin (also modeling and balancing cross section seem to confirm it; cf. Castelluccio ah all. 2015). The most important period, both basinal history, as well as of history of orogeny creating was a change of the trend and the tectonic regime; from extension (responsible for the sedimentary basin accommodation space creating, till the Crataceous period) on compression (until stopping the process shortening in Miocene age). The process of inversion is well described. The process of the change of the tectonic regime is the time of Lgota and Variegated marls deposition. Lgota beds and Variegated marls are a typical vedge top deposits (De Celles & Giles, 1996). The appearance of the Inoceramian depositional system facies starts a stage of compression and forming a foredeep basin (traditionally called flysch basin). The foredeep basin is developed in front of so called Inner Carpathians (so called Laramian orogenic front). Analysing the facies distribution I made an assumption of the unification of the basinal space of the Outer and Inner Carpathians. They constitute the uniform basin space. Traditional division on so-called Inner and Outer Carpathians is artificial. The confirming a such assumption is appearing of the Lgota type and Inoceramian beds in Tatra Mts and in Pieniny Klippen Belt. For describing a process of forming orogeny and transferring a depositional center is possible to apply well-known model (De Celles and Giles, 1996). The model applied by me shows the spatial distribution of the facies in Inoceramian system in

Late Cretaceous – Paleocene period. During this period, in the southern part of the sedimentary basin, it is possible to recognize different facies of Inoceramian type – among others slumps and slides called Pieniny Klippen Belt. In central part of this depositional system Inoceramian beds (*sensu stricte*) are dominating. But on the northern slope Istebna beds are dominating and shallow water facies called Rybie sandstone or Frydek marls. Such, completely different (as decribed in literature) model is explaining the co-occurrence different facies (as for example a Inoceramiand beds and Istebna beds; Inoceramian beds and Frydek marls). In the light of above concepts, great chaotic complex of the Pieniny Klippen Belt created as the complex of blocks of calcareous rocks surrounded by Inoceramian type "matrix", was pushed off to (beginning one's history) foredeep basin (traditionally called flysch basin). Pieniny Klippen Belt chaotic complex was called the "wild flysch (cf. Castelluccio et all, 2015) in this paper was already assigned to the Inoceramian system. The outlined arrangement backstop – foredeep basin - forebulge assumes his migration what is well-known for literature (cf. Książkiewicz 1972). With additional assumption made in my model, is a changing of direction of shortening. The field observations confirmed the migration of the of the centre of deposition. It's reflected in transferring so called "axial" facies - Inoceramian (late Cretaceous) facies is changing into Beloveza facies (Paleocene) and into Hieroglyphic facies (Eocene). This so called a basinal facies are co-occuring with "slope type" facies as Łącko Marls or Variegates shales and with "chanel-filling" facies as Ciężkowice sandstones or Magura sandstones. At the same time facieses of the top-wedge sedimentation type are developing, covering the area PKB. In Carpathian's literature the term of "cordilleras" is still functioning. It means usually intrabasinal ridges providing clastic material. The Cordilleras they appear and are disappearing. The is lack of explanation of this mechanism. In my presentation mechanism of the transfer of the arrangement backstop – foredeep basin - forebulge is responsible for transferring areas; in the time and space. The migrating areas of slope and forebulge is performing the role of source areas. Process of the transfer and closing of the basin the process is ending in Miocene. Usually in Carpathian's literature foredeep basin is being identified with Miocene foredeep. The beginning of the forming Miocene foredeep is starting with appearance slope "olistostrome type" Worotyszcze beds. This slope cover is cutted by the channels filled by coarse conglomerates – Słoboda conglomerates. The process closing basin space and creating Carpathian orogeny during period of shortening he is held through the process of thrusting (in sequence), piggy back mode. The trust zones are oblique towards the axis of depositional systems. Such a model of oblique cutting causing the presence of the same facies of the same depositional system in different tectonic units. This model was already suggested (cf. Jugowiec - Nazarkiewicz, Jankowski 2001). He is explaining appearing e.g. Ciężkowice type sandstones in a few tectonic units. Field research, a new of geological maps of the area of the Carpathians, seismic data (cf. Jankowski and Probulski, 2011) but also the first thermochronologic examinations led to the recognize additional secondary stages of tectonic development. It was not taken into account in literature so far. These additional tectonic stages they are taking place after compressional (or transpressional) stage of tectonic history. These additional stages of the deformation have big influence on cartographic image and morphology of the Carpathians. The first additional

tectonic deformation stage is by me named strike-slip stage. During this stage primary thrust faults as a strike – strike slip faults were reactivated. Along these strike-slip zones wide zones of the mélange are developed as well as different strike-slip associations are formed. Most common structures creating strike-slip association are the flower structures type, structures of the type of the horse's tail type structure and different types of strike slip basins. My long-term field observations and examinations made along tectonic mélange zones are revealing the close relationship of their forming with secondary deformations (so far not described in literature). During the first recognized additional stage of tectonic deformations (named by *strike-slip stage*), a lot of tectonic structures associated with shear zones (mélange zones) are formed. Cartographic study (e.g. Jankowski, 2014; Jankowski and Probulski 2011) zones of mélanges are indicating areas, of complex geometry associated with strike-slip faults. Within these strike-slip fault associations "flower structures" moreover "horse tail" structures and different strike-slip basins (pull-apart basins, Burchfield and Stewart, 1966) being formed. The "flower structure" type geometry within such elements as Bystre slices (in Baligród and Skrzydlna areas) was stated. In the presented monograph I displayed a few models of the forming of tectonic windows, one pf them assuming taking the window zone out within flower structures. Spatial arrangement observed by me in Świątkowa tectonic window area and in Wapienne (Beskid Niski) tectonic window or Sopotnia tectonic window is pointing the geometry of flower structure type. The good examples of the strike-slip basins (pull-apart type) formed during strike-slip stage tectonic deformation are Orawa – Nowy Targ, Nowy Sącz or Iwkowa basins. Mentioned above "intramontagna" basins were filled with the Miocene deposits, and later being affected by the gravitational collapse of the Carpathian orogeny - the process is confirmed by appearing normal faulting zones. The process of forming of geometrically complicated "flower structures" is leading to peculiar "mixing" of both of tectonic units and facies elements.

So characteristic "mixing" of facies and tectonic elements suites (Silesian, Węglówka and Skole units) is observed in Węglówka, Grabownica oil field areas. This seemingly complicated geometry it's possible easily to explain by the flower structure geometry. The flower structure type geometry in this area is stated by the cartographic works and seismic analyses (Jankowski and Probulski, 2011). Analogous "mixing" of tectonic and facial elements, typical for big scale, regional flower structure we can observe in Pieniny Klippen Belt flower structure (Plasenka, Mikus, 2010; Jankowski et all, 2012). Moreover, specific mixing of Tatra Mts and PKB elements (visible in Wag valley) I it is possible to assign to the geometry of the flower structure type. The field research and tectonic analyses showed that structures of this type were appearing in the area of Carpathian foredeep. With geometry of the flower structures type it is possible to characterize Roztocze region or Holy Cross Mountains region. Cartographic studies, field research, observation of tectonic structures, or termochronometric studies (cf. Mazzoli et all all, 2010, Zattin et all, 2011, Andreucci et all 2014,) demonstrated existing in tectonic history of the Carpathians another, important stage of tectonic deformations

- the stage of the gravitational collapse of orogeny (cf. Dewey 1987). This stage is being shown to have a significant importance both for the geological structure of the Carpathians and for morphology as well for migration path of hydrocarbons. The stage of the collapse of orogeny was registered both in Inner, Outer Carpathians and in Carpathin foredeep. Process of the gravitational collapse of orogeny (associated with it so-called tectonic denudation) caused tectonic exhumation of large areas of the Carpathians. The big amount of "erosion" is a result of gravitational processes, rather than as a result of climatic erosion given in studies (cf. Kovac et all, 1994). Demonstrated with termochronometric examinations amount of the removed materials (e.g. in the area of the Wetlińska Połonina estimated erosion was 3 km) it isn't possible to explain him with removing as a result of erosion – there's no this material in *intramontagne* basins and no in foredeep area. Zones of the tectonic mélange recognized in the area of the Babia Góra Mountain, or other mountain ranges of the Carpathians show existing of the process so called footwall elevation as a result of the isostasy. The footwall elevation process is explaining the exhumation and "erosion". In the process of the collapse older shear zones were reactivated as a normal faulting. With the process of the collapse of orogeny the extensive large mountain ranges were moved and big mass wasting is observed. The transferring large mountain ranges is noticeable in many regions of the Carpathians (cf. Jankowski and Margielewski, 2102). The process of the collapse can be also responsible for tectonic windows creating. The moving previously thrusted tectonic units back (as result of the collapse – normal faulting) causes the denudation of the tectonic window. It is worthwhile emphasizing that recognizing the geometrical position of zones of the mélange is crucial for creating models of tectonic windows. In such a context one should consider the genesis of the Mszana Dolna tectonic window. The moving back Magura unit thrust (process of the collapse) causes a denudation of the tectonic window zone. In case of the tectonic window of Żywiec, is probable one or the other model. The process of the collapse can be also responsible for Smilno tectonic windows creating. The important aspect of the processes of secondary tectonic deformations, there is their influence on the morphology of the Carpathians. Secondary stages of the deformation; e.g. strike-slip stage or collapse stage have a important impact on development of the rivers and streams network. An arcuate course of river valleys is characteristic of the Carpathians. For explaining this phenomenon I used the model of the disintegration of mountain ranges along big strike-slip zones (e.g. along the Skawa, Raba, Dunajec river zones). In the study I gave the number of examples of such a gravitational disintegration of massifs in the area of the Carpathians. The research on chaotic complexes has also a practical aspect. Discovered zones of tectonic mélanges can play a substantial role for determining migration paths of hydrocarbons. That zones of tectonic mélanges being characterized by a strong mineralization, so they can be most important path of the migration of hydrocarbons.

The conceptual models presented in the submitted monograph esp. the model of the development the orogeny with particular reference to of zones of tectonic mélanges, is creating the perspectives for of search of

hydrocarbons in the Carpathians. It is as important, that there were no successes in oil and gas seeking during the last decades, in spite of large numbers of oil seeps in Carpathians . Importance of zones of mélanges for the oil prospecting was underlined already in the first studies (cf. Jankowski, 1995, 1997, Leśniak and Jankowski, 2009, Jarmołowicz - Szulc and Jankowski 2011). As a result of my cartographic works, many zones of mélanges were discovered, in the entire area of the Carpathians. Field works determining the position of chaotic complexes in Carpathians and cartographic documentation associated with it, have a significant importance for interpretations of seismic data. It's useful oil (Probulski, 2008, Probulski& the Maksym, 2015). The tectonic mélanges zones are very well visible in seismic sections (cf. Probulski 2008). The field research, as well as so far made by me (or with my co-autors) geological maps (e.g. Jankowski 2013, Jankowski Ślączka, 2014, Jankowski and Kopciowski, 2014 Jankowski and Paul, in the press) are pointing at the universality of appearing in the area of the entire Carpathians characterized above tectonic structures. Esp. normal faulting (collapse orogeny stage) and strike- slip faulting (strike-slip stage) are visible in the field. The normal faulting and strike-slip faultings definitely are dominating amongst evident structures in Carpathian outcrops. It is a characteristic thing, that in spite of already of long-term discussion about zones of mélanges and generally of chaotic complexes in the Carpathians mélange zones aren't being marked on maps. In the submitted paper I discussed a lot of zones of mélanges discovered successively in many Carpathian regions. I devoted the particular attention to the zone of mélange (discovered by me)of the in Bieszczady mountains, appearing in the area of the Ukrainian Carpathians (Podpołozie area) as far as Baligród area. Moreover I devoted attention to broad mélange zone called Lanckorona- Żegocina zone (cf. Jankowski 2007). The Lanckorona-Żegocina zone was probably a out-of-sequence thrust what is showing character of contacts and the thrusting direction. It was reactivated secondarily as the strike-slip zone genetically connected with neighboring strike-slip basins (Iwkowa basin) and tectonic halfwindow (Pisarzowa). In collapse stage of the deformation this zone was used as normal fault zone. The field observation of the Żywiec tectonic window is indicating the zone of the mélange usually called Subsilesian tectonic unit. The similar zone of the mélange is visible in the so-called Wiśniowa tectonic window, to the south of Dobczyce. The field research conducted by me in the marginal part of the Carpathians showed of appearing here of chaotic complexes. So called Subsilesian unit and Marginal flysch unit are in fact a zone of the tectonic mélange. Zones of the mélange are visible in the marginal part of the Carpathians; the south of Cracow. Well visible oucrops of chaotic complexes are appearing in the Tłuczań, Zygodowice, Witanowice (the chaotic complex cropping out in this area contains a blocks of limestones), Radocza, Przybradza or Chocznia as well as e.g. in Targaniczanka river. Similar zones of mélanges are visible in the Roczyn Czaniec area. Genesis of the marginal chaotic zone, called Andrychów Klippen Zone, is similar to the genesis of the Pieniny Klippen Belt. Similarly in the zone of the mélange we are finding so-called Bugaj granite. A lot of the tectonic mélange zones, I discovered within the Magura unit.

The area of the Magura unit underwent discussed secondary stages of tectonic deformations. The arcuate shapes of the shear zones are suggesting the primary forming of large flower structures. The shear zones are secondary reactivated during the collapse deformation stage. The best revealed zone of the mélange is visible in the Kamienica river valley of the (cf. Jankowski et all 2012). Zones of mélanges were discovered by me in the valley of the Biała river valley in Śnietnica, Brunary, Florynce, Kaclowa or Zachełmie. The chapter in the monograph I devoted to deliberations of the general nature referring both to the tectonic position of orogeny as well as of character of the Carpathian basin. In considering about basinal history I assume a little shortening of the basin space. It is matching with balancing cross sections (cf. Castellucio ah all 2015, Gagała and other 2012, Probulski 2008). Moreover this assuming is justifying in field facts i.e. appearing of the same facieses in different areas (both Inner and Outer Carpathians) e.g. Lgota beds, Inoceramian Beds, Menilite Beds or Krosno beds. In my opinion, so called subduction model of Carpathian orogeny position the model should be should critically searched what geophysical studies are also already implying (cf. Grad et all 2006, Malinowski et all 2013, 2015). Recognizing the position volcanic rocks of the Pieniny Klippen Belt the subduction model should be searched. So called oroklinal bending process can be one of reasons creating so called Carpathian orocline, manifesting itself in bending of space of Carpathian basin, as well as forming arcuate shape of orogeny.

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5. Other scientific achievements

In the list of studies given below, describing my achievements and scientific interests (published already after getting a doctor's degree), 11 papers were published in magazines being in a Journal Citation Reports base. Moreover 8 already published cartographic monographs (8 maps and 8 explanations were presented. I've prepared for publishing next 2 cartographic monographs. Moreover maps (in the different scale) and 20 papers published in Polish and foreign magazines (outside the JCR list)were presented. I attached informations about 6 organized by me (or with IOP or INIG or with foreign geologists) of polish and international conferences. Cartographic studies based on field observation are my purpose and the subject of the research of many years. It results from the specificity of the Polish Geological Institute (Geological Survey), but also from my individual interests. In the past years I performed a lot of cartographic studies - the total area of cartographic maps is over 3000 km^2. The field research let me to the critical approach towards many schematic views concerning the geological structure and the development of the Carpathians. The field works were a ground for many examinations in the elementary geology, but also for applying new methods research: e.g. termochronometric, geochemical or petrologic methods. The discovery a chaotic complexes esp. tectonic mélanges were one of effects of cartographic works. I attached below thematic scopes of many studies (performed independently or in cooperation with geologists of different specializations), with brief elaboration were described of works referring to them.

5.1. **Termochronometric examining the Carpathians – the process of burying and exhumation.**

[1] Mazzoli S., Jankowski L., Szaniawski R., Zattin M., 2010 - Low-T thermochronometric evidence for post-thrusting (< 11 Ma) exhumation in the Western Outer Carpathians, Poland. *Comptes Rendus Geoscience,* 342: 162-169.

Presented publications are an effect of the long-term cooperation with the specialist staff from Universities of Padua, the Bologne and Palermo, using termochronometric methods and with tectonic structural analysis. Collaborative researches in the Outer Carpathians allowed for distinguishing and dated of individual stages exhumation of rocks associated with processes of thrusting, of erosion and with the

late gravitational disintegration of orogeny. They are innovative studies, in which the concept of the process of the orogenic collapse in the Carpathians was proven and his substantial role during exhumation of some fragments of orogeny. Process of the collapse stated in many orogens (cf. Dewey 1987) was recognized also in the Carpathians. Process of sampling and for these examinations included already appointments of profiles zones of appearing of tectonic mélanges. The investigations were in Polish section of Carpathians conducted. The normal faulting structures were recognized. This structures pointing on completely different reasons of the orogeny forming than the approach dominating in literature (dominance of the compression).

[2] Zattin M., Andreucci B., Jankowski L., Mazzoli S., 3, Szaniawski R., , 2011, Neogene exhumation in the Outer Western Carpathians. Terra Nova, 23, 283–291, 2011.

In this paper, for determining the process of exhumation the results of the termochronometric methods were used. Apatite fission – track analysis was used to investigate the evolution of the Outer Carpathian. An essential stage of the tectonic development of the Carpathians was substantiated - stage of the orogenic collapse, the thrusting process was overlapped by extension. The result show a general decrease a burial degree towards a foredeep region. Younger ages of exhumations are defined to the eastern region whereas exhumation in the central-western region is older. Exhumation in the chain is inferred to have occurred since Early Miocene, it's coeval with thrusting but extensional tectonic is likely to have played an important role during Late Miocene exumation.

[3] Andreucci B., Castelluccio A., Jankowski L., Mazzoli S., Szaniawski R., Zattin M, 2013 - Burial and exhumation history of the Polish Outer Carpathians: Discriminating the role of thrusting and post-thrusting extension. *Tectonophysics* 608: 866-883.

Several tectonic processes have been proposed to be important to the recent evolution of the Polish Outer Carpathians, i.e., Paleogene–Neogene thrusting, post-thrusting extension, Quaternary reactivation of compression. This work, similarly as well as above based on the methodology of examinations termochronometric was made in multidiscipline scientific team. This work tests the effect of these processes on exhumation of the wedge,in order to verify their timing and relative role in shaping the Polish Outer Carpathians. AFT, AHe and ZHe analyses were performed on samples collected along the study region. This allowed the reconstruction of their post-depositional minimum heating, depth of burial and timing of cooling and exhumation. After deposition samples from the innermost units were heated up to temperatures of ca. 60–120 °C (ca. 4–9 km), whereas samples from the outer units were heated to temperatures lower than 60 °C (ca. 4 km). Cooling and exhumation occurred progressively later from west to east (between ca. 25 and 10 Ma in the western sector, between ca. 15 and 5 Ma in the eastern sector). These results have been put in relationship with single structural features to understand the relative role of thrusts and normal faults. In the eastern sector of the study region samples at the footwall of significant

normal faults show a higher degree of reset and younger ages than samples located at the hangingwall. This implies that, in this sector, extensional tectonics played an important role in exhumation. The work is providing with the example of the methodology of examinations giving outstanding results - can be applied also for morphological examinations

[4] Andreucci B., Castelluccio A., Corrado S., Jankowski L., Mazzoli S., Szaniawski R., Zattin M., 2014. Interplay between the thermal evolution of an orogenic wedge and its retro-wedge basin: An example from the Ukrainian Carpathians. Geological Society of America Bulletin 127 (3-4). September 2014.

This paper concerning a thermal history of circumcarpathian region, esp. Ukrainian Carpathians region. Is based on the termochronometric metods. The Carpathian-Pannonian region is made up of the wide extensional Pannonian Basin surrounded by the Carpathian mountain belt. The Pannonian Basin formed in the; Miocene by extension while thrusting was still active at the Carpathian front. The Ukrainian region is an ideal area to reconstruct the relationship between the Pannonian Basin and the Carpathians, due to the relatively simple structural setting and to the progressive but neat transition between the two domains. This study uses low-temperature thermochronometry and vitrinite reflectance analysis to, investigate the effect of the opening of the Pannonian Basin on the thermal and burial exhumation histories of the Ukrainian Carpathians. The results show heating and burial. maximal in the central units of the wedge (up to ~170 °C and 6 km, respectively), tapering out toward both the innermost and the outermost thrust sheets. Cooling and exhumation occurred by means of a first rapid stage between ca. 12 and 5 Ma (exhumation rates of up to ~1 mm/yr), followed by a slower stage from ca. 5 Ma to the present (exhumation rates within 0.5 mm/yr). Timing and spatial pattern of exhumation are compatible with post-thrusting erosion enhanced by isostatic uplift. The extent of exhumation progressively decreases toward the Pannonian Basin, characterized by a thinned crust. No further significant influence of the Pannonian Basin opening on the thermal and burial history of the Ukrainian Carpathians may be inferred based on our results, whereas the comparison of the tectonothermal evolution of the two domains suggests that they are both controlled by the same lithospheric processes. We suggest that active horizontal compression in the Romanian Carpathians and the presence of a thickened litho-sphere beneath the UC contributed to preserve such a thinned lithosphere in the PB region.

[5] Castellucio A, Andreucci B., Zattin M., Ketcham R., Jankowski L., Mazzoli S., Szaniawski R., 2015, Coupling sequential restoration of balanced cross sections and low-temperature thermochronometry. The case study of the Western Carpathians. Geological Society of America.doi:10.1130/L436.1.

In this paper, a new approach is applied to test a proposed scenario for the tectonic evolution of the Western Carpathian fold-and-thrust belt– foreland system. A N-S balanced

section was constructed across the fold-and-thrust belt, from the Polish foreland to the Slovakia hinterland domain. Its sequential restoration allows us to delineate the tectonic evolution and to predict the cooling history along the section. In addition, the response of low-temperature thermochronometers (apatite fission-track and apatite [U-Th]/He) to the changes in the fold-and-thrust belt geometry produced by fault activity and topography evolution are tested. The effective integration of structural and thermochronomet-ric methods provides, for the first time, a high-resolution thermo-kinematic model of the Western Carpathians from the Early Cretaceous onset of shortening to the present day. The interplay between thick- and thin-skinned thrusting exerts a discernible effect on the distribution of cooling ages along the profile. Our analysis unravels cooling of the Outer Carpathians since ca. 22 Ma. The combination of thrust-related hanging-wall uplift and erosion is interpreted as the dominant exhumation mechanism for the outer portion of the orogen. Younger cooling ages (13–4 Ma) obtained for the Inner Carpathian domain are mainly associated with a later, localized uplift, partly controlled by extensional faulting. These results, which help unravel the response of low-temperature thermochronometers to the sequence of tectonic events and topographic changes, allow us to constrain the tectonic scenario that best honors all available data. What is essential at the work, Pieniny Klippen Belt as the structure about the "wild flysch" type formed as a result of rather a slumping process was. At more late works Pieniny Klippen Belt to Inoceramian sedimentary system was assigned (Jankowski and Margielewski 2015; Jankowski 2015)

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5.2.The stages of tectonic deformation – visible in geological structures of the Carpathians.

[1]Jankowski L., Probulski J., 2011 – Rozwój tektoniczno-basenowy Karpat zewnętrznych na przykładzie budowy geologicznej złóż Grabownica, Strachocina i Łodyna oraz ich otoczenia. Kwartalnik AGH, Geologia 37, 4: 555-583.

[2]Rauch M., Jankowski L., Probulski J., 2012, Origin of curved traces of the thrust and fault-related folds in the Polish Outer Carpathians in the light of analogue modelling. Mineralia Slovaca 44(2012):102.

[3]Rauch M., Jankowski L., Probulski J., 2013, Evolution of the map-scale contractional structures in the eastern part of the Polish Outer Carpathians in light of the field trip investigation and the analogue modelling. 11th Meeting of the CETeG. Vargesztes. 23-27 April 2013. Hungary.

In above given studies a few regions of the Carpathians were characterized. It is possible to recognize the structures closely connected with additional stages of tectonic deformations of the Carpathian orogeny.

The part of described tectonic structures is associated with the stage of the compression (Rauch et all, 2012, 2013) but the majority from them are associated with secondary stages of the deformation (Jankowski and Probulski, 2011). On the example of the tectonically complicated Węglówka region, a particular role of secondary stages of tectonic deformations was described. The secondary stages of tectonic deformation took place after the primary period of the compression (Jankowski and Probulski, 2011). The conclusions are based on field observation and analysis of seismic sections. The primary, compressional stage of building the orogeny was held by *piggy back mode* thrusting. However additional stages of tectonic deformations led to the considerable reconstruction of the architecture of the orogeny. Authors are pointing at the substantial role of these secondary stages deformations; so-called strike - slip stage and collapse stage, where primary shear zones were reactivated. In the important for the oil prospecting area a complex geometry of the flower structure type was demonstrated. The article is the first study explaining the process of multistage deformation of the part of the Outer Carpathians. In this study also a special significance of the stage of the orogenic collapse was already emphasized. The complicated spatial agreement and "mixing" of both, tectonic and facial elements (it's documented by numerous drillings, e.g. Grabownica cf. Koszarski, 1961), results exactly from enclosing this zone into the complicated flower structure.The study has a significant importance for orienting the oil prospecting in the Carpathians. The "deep rooted", principal shear zones – the structures of flower structures type are developed along them. These shear zones can be the migration path of petroleum. Such shear, mélange zones can be the opened or closed geochemical system (Jarmołowicz-Szulc, Jankowski 2011). The migration of hydrocarbons from deep horizons can explain appearing of petroleum deposits here, in spite of the lack of source rocks. Moreover, autors showed the resemblance of the Węglówka zone, limiting Central Carpathian Depression from the north to the analogous tectonic zone limiting Central Depression from the south, developed in similar geometry, with appearing along it of oil-gas deposits.In the study a role of structures inherited, prealpian tectonic structures was emphasized, also a role of the process of the extensions important for the forming "innercarpathian" structure (eg. CKD) was emphasized.

The attention was payed to the unification of the facies in the entire Carpathians basinal area. Authors are announcing that big chaotic complex (known earlier in Gorlice cf. Jankowski 1995, 2007) are found also in front of Węglówka thrust. Two next attached here studies, are conceptual presentations of special cases of the cartographic image of some regions of the Carpathians. In the process of the so-called analogue modeling they were trying to reconstruct character of the deformation during the compression stage and to use models to compare with the structures in the field. The "analogue" modeling is revealing a process of creating some olistostromic bodies in front of important thrusts (Rauch 2015).So then, my concepts of creating big chaotic bodies within the Carpathians found here confirming in performed experiments.

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5.3. The additional stages of tectonic deformation. The Carpathian morphology development.

[1]Jankowski L., Margielewski W., 2014 - Strukturalne uwarunkowania rozwoju rzeźby Karpat zewnętrznych – nowe spojrzenie. *Przegląd Geologiczny* 62,1: 29-35.

[2]Jankowski L., Margielewski W., Urban J.: *Strukturalne i litofacjalne uwarunkowania rozwoju rzeźby polskich Karpat zewnętrznych.* III Warsztaty Geomorfologii Strukturalnej. Beskid Niski – Beskid Sądecki – Babia Góra. Kraków–Piwniczna. Wrzesień 2012, pp. 95.

[3]Jankowski L., Szaniawski R., Mazzoli S. (eds): *European Geosciences Union. Polish Carpathians Fieldtrip*. Fieldtrip Guidebook. April 2013.

These papers presents a results of field observation in many areas of the Carpathians. They presented a innovative geomorphologic image of the Outer Carpathians than so far shown in literature. Presented models, hypotheses and field examples pointed at the inappropriateness of assigning the main role in the forming of the morphology for only of lithological differences.

Based on the above mentioned, tectonic model piggy back mode building of orogeny the relief of the Carpathians was explained. Into the innovative way a model of the process of some parts of orogeny elevation was described (like e.g. Babia Góra area). The isostatic elevation model was applied, so called footwall elevation model. Moreover other massifs of the Carpathians were described (e.g. Jaworzyna Krynicka, Cergowa mts) and for these regions this model can also be applied. The footwall elevation process (isostatic compensation) is explaining high values of the erosion in the Carpathians (up to a dozen or kilometers, e.g. Świerczewska 2005), and is explaining lack of eroded deposits (in foreedepp or intramontagna valleys). The removing of a few kilometres thicknesses erosional material took place as co called tectonic denudation, that is a result of the orogeny collapse. Primary thrusted tectonic elements were moved back (in the process of the gravitational collapse) creating the effect of erosional mass wasting. The process of the collapse was demonstrated at mentioned papers (cf. Mazzoli ah all, 2010,. Andreucci ah all 2013; Castelluccio ah all, 2015; Jankowski and Probulski, 2011) however in this study was introduced on specific areas and the determined geological situation. The role of the orogenic collapse and footwall elevation process was exactly discussed on field conferences [2,3].

References:

Andreucci B., Castelluccio A., Jankowski L., Mazzoli S., Szaniawski R., Zattin M, 2013 - *Burial and exhumation history of the Polish Outer Carpathians: Discriminating the role of thrusting and post-thrusting extension*. *Tectonophysics* 608: 866-883.

Castellucio A, Andreucci B., Zattin M., Ketcham R., Jankowski L., Mazzoli S., Szaniawski R., 2015, *Coupling sequential restoration of balanced cross sections and low-temperature thermochronometry. The case study of the Western Carpathians*. Geological Society of America.

Jankowski L., Probulski J., 2011 – *Rozwój tektoniczno-basenowy Karpat zewnętrznych na przykładzie budowy geologicznej złóż Grabownica, Strachocina i Łodyna oraz ich otoczenia*. *Kwartalnik AGH, Geologia* 37, 4: 555-583.

Mazzoli S., Jankowski L., Szaniawski R., Zattin M.: *Low-T thermochronometric evidence for post-thrusting (< 11 Ma) exhumation in the Western Outer Carpathians, Poland*. Comptes Rendus Geoscience, 2010

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5.4. Application of paleomagnetic methods for studies mountain belt evolution.

[1] Szaniawski R., Mazzoli S., Jankowski L., Zattin M., 2013*. No large-magnitude tectonic rotations of the Subsilesian Unit of the Outer Western Carpathians: Evidence from primary magnetization recorded in hematite-bearing Węglówka Marls (Senonian to Eocene).* Journal of Geodynamics, 71, 14-24.

The examinations were performed under direction of. R. Szaniawski - the specialist in the scope of paleomagnetic research. A process of rotations of blocks in Carpathians is still discussed. So far a number of the concept of individual blocks rotations was described (e.g. Unrug 1979) but a number of data and based on paleomagnetic analyses was published. Achieved results are a reason of many discussions and a lot of dubious results were being achieved (Márton and other 2009). The basic problem is a lack of evidence for structural rotations – the problem of tectonic shear-zones separating rotated blocks. Moreover there is a problem of accommodation space between rotated blocks. With the subject of the research, described in this paper, were so called variegated Węglówka marls, sedimentary cover of intrabasinal ridge. The results of investigations reveal no large-magnitude tectonic rotations of the Subsilesian Unit. Paleomagnetic methods are an essential tool of recognizing the process of bending so called oroclinal orogens. It let for reconstructing the primary localization basinal spaces. It is gaining the special significance for the Alpine (European, Mediterranien, North Africa) oroklinal beds.

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Marton E., Rauch – Włodarska M., Krejci O., Tokarski A.K., Bubik M.,2009, *An integrated paleomagnetic and AMS study of the tertiary flysch from the Outer Eastern Carpathians*. Geophysical Journal International 177:925-940.

Unrug R., 1979, *Palinspastic reconstruction of the Carpathian arc before the Neogene tectogenesis*. Rocz. PTG, T. 49, z. 1-2: 3-14.

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5.5. The subduction concept – a new approach

[1]Malinowski M., Guterch A., Narkiewicz M., Probulski J., Maksym A., Majdański M., Środa P., Czuba W., Gaczyński E., Grad M., Janik T., Jankowski L., Adamczyk A., 2013. *Deep seismic reflection profile in Central Europe reveals complex pattern of Paleozoic and Alpine accretion at the East European Craton margin*. Geophysical Research Letters, vol. 40, 1–6.

[2]Narkiewicz M., Maksym A., Malinowski M., Grad M., Guterch A., Petecki Z., Probulski J., Janik T., Majdański M., Środa P., Czuba W., Gaczyński E., Jankowski L.,

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The chosen papers are made by an interdisciplinary team managed mainly by the Prof. A. Guterch (Geophysics Institute, Polish Academy of Sciences). They are portraying the wider geological context of the Carpathian region relating to the entire macroregion of south-east Poland. The majority geological of studies is showing the Carpathians orogeny (in the context of the plate tectonics) as subduction related orogeny. In Carpathian's literature we are finding numerous works suggesting existing (in history basinal-tectonic history) of even a few subduction zones (cf. Birkenmajer 1976; Sikora 1976). Additionally existing of wide oceanic character zones was being suggested. It is worthwhile noticing, that with the subduction concept Książkiewicz (1977) didn't already agree. These geophysical works are so important, and are pointing to the need to reopen discussion on the location entire Carpathian orogeny and the subduction problem should be discussed again. The geophysical examinations were oriented for recognizing most important geological structure of this fragment of Europe, so called T-T line or TESZ at present. It is exceptionally old, deep rooted tectonic zone, many times reactivated, with the rich history of the deformation; from Precambrian to Alpine. Performed seismic examinations allow for the possibility of deep interpretations and showing deep structures. The results of those seismic analysis they are pointing out to the need for the revision of those "subduction" concepts. The seismologic examinations (in which I was able to participate) aren't pointing out to the existence of subduction zones - what was also described at the work (Probulski and Maxim 2015). The results of this seismic investiations agree my publications - my point of views is expressed in the row paper presented here.

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Apart from the Carpathians, my interests were dispatched also to the other areas. The chosen papers concern examinations of the foredeep region esp. marginal part of foredeep called Roztocze region. The Roztocze region is marginal part of Carpathian foredeep, it is getting into forebulge position (De Celles & Giles 1996) during the final stage of Carpathian orogeny migration. Both [1,2] papers describing the mechanism of transferring the and space arrangement of the Carpathian foredeep basin. In the paper attention was payed (what also studies are documenting, cf. Grad et all other, 2006, Malinowski and other, 2013)on tectonic character of TESZ zone. It's a big, sinistral strike-slip tectonic zone. With this tectonic zone genetically connected are some strike-slip structures as a flower structure. According to author's opinion, the flower structure type is responsible for elevation of Holy Cross Mountains massif so far in literature we aren't finding explaining to the strong elevation the HCM. The field research and tectonic measurements gave the ground for recognizing in the Roztocze area the stage of the collapse (noticed in the Carpathians area). It is possible to recognize documenting the process of the collapse structures both in outcrops as well analyzing boreholes. For reconstructing the geological building important is recognizing the age shallow-water facies in Rotocze region.Very much young (Pannonian) deposits were recognized in Józefów area. They are documenting the end of the process of thrusting in Carpathian and Carpathian foredeep area. Other studies [3,4,8] are discussing the unique richness of the geology of the Roztocze region – petrified remnants of wood. The widest spectrum of examinations let explain the processes of petrifying of remnants of wood. The process of the petrification is associated with the end of the sedimentation in foredeep basin. Examinations allowed to portray the redeposition process redepozycji, and transferring a remnants into Quaternary deposits. The examinations and observation were stretched to the area of the Ukrainian part of the Roztocze. Uniqueness of geotouristic advantages of Roztocze region was a subject of the extensive study [3,4,6,7,8]. A field conference was devoted to a new hypotheses concerning tectonic development and to the morphological aspect of Roztocze region. The conference materials and guidebook contain the new informations referring to the morphological development of the Roztocze area. One from exceptionally interesting morphological structures of the Roztocze area are numerous peat bogs. They became the subject of the research documenting the development process of the morphology of the Roztocze region in late glacial period [7] .

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The compared here cartographic studies are an effect of my long-term work in the area of the Polish Carpathians and neighbour states. The majority of sheets was published after a long time - some of sheets waited for publishing up to 20 years. Including published before sheets (cf. Gucik et all 1991 a, b) the area covered by my maps is over 3000 km2. A lot of cartographic observation was devoted to examine so called chaotic complexes. Presented studies have character of monographs, discussing in explanations and portraying individual fragments of the Carpathians on the map (single sheets are area over 300 km2). In many maps sheets made by me the cartographic image is quite different than presented so far. To the problem of chaotic complexes field conference was devoted [1]. The structures documenting additional stages of tectonic deformations were already shown on my maps. Moreover different kinds of chaotic complexes esp. zones of mélanges were also shown on maps

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An oil prospecting aspect was also an essential aim of my examinations. Field research and cartographic, recognizing zones of tectonic mélanges, showed new opportunities of orienting

the exploration work. A new look at the problem of the search was included in the monographic study [1]. The cartographic research of mélange zones confirmed their significance as migration paths of hydrocarbons. The investigations of zones of mélanges showed their mineral diversity. Besides the quartz mineralization the significant is a presence of the bituminous substance pointing at the migration of hydrocarbons. Additionally, at attached papers the geochemical character of dark, bitominous Menilite shales was discussed.

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A lot field observation were used in studies devoted to describing some Carpathian facies. In the study [1] devoted to the particular *biancon*e type facies called in Carpahians Siliceous marls (in the west part of the Polish Carpathians called Żegocina marls) their positions were portrayed. Already in this study with it a model of oblique shearing depositional systems was described - what their appearing in various components of the tectonic Carpathians is explaining. Moreover they already pointed shallow-water character of the number of facies usually called a deepwater "Carpathian flysch". They pointed at shallow-water character of Menilite beds. This point of view overtook views published recently (cf. Dziadzio 2015). In the attached field guide a lot of new views were described and they explained to e.g. primary coloring so called Varigated beds

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Leszek Jankowski