Autoreferat

1. Name:

Rafał Junosza-Szaniawski

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

2005 - PhD Earth Sciences, title: „*Paleomagnetyzm a tektogeneza waryscydów europejskich na przykładzie Ardenów Francji i Belgii*", Institute of Geophysics PAS. The PhD thesis was performed in collaboration with University Lille 1 (France) in the frame of scholarship (type "cotutelle"). The doctoral degree was awarded also by the University of Lille 1 in France (title: *Paléomagnétisme et tectogénése des Variscides du Nord de la France et Sud de la Belgique*", http://www.idref.fr/087758148). Doctorate earned distinction (*très honorable*) awarded by the examining board.

1997 - master, Geological Department University of Warsaw in collaboration with the Institute of Geophysics PAS, title: „*Paleomagnetyzm a diageneza dolomitów dewońskich z regionu kieleckiego Gór Świętokrzyskich*"

3. Information about the scientific employment

1997 -1998, Geophysicist, Institute of Geophysics, Department of Magnetism, Palaeomagnetic research group.

1998 -2005, Assistant professor, Institute of Geophysics, Department of Magnetism, Palaeomagnetic Research Group.

1998-2003, University of Lille 1 (France), Laboratory: Processus et Bilans des Domaines Sédimentaires. Doctoral scholarship from the French Government awarded through a competitive process. The scholarship involves the preparation of a doctoral dissertation in collaboration with the French University and Polish research unit.

2005 - today, Assistant Professor, Institute of Geophysics, Department of Magnetism, Palaeomagnetic Research Group.

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

a) Title of the scientific achievement

Application of paleomagnetic methods for studies of mountain belts evolution

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

[1] Szaniawski R., 2008. *Late Paleozoic geodynamics of the Malopolska Massif in the light of new paleomagnetic data for the southern Holy Cross Mountains.* Acta Geologica Polonica, 58 (1), 1-12.

[2] Szaniawski R., Lewandowski M., 2009. *Palaeomagnetic age constraints indicate post-Variscan orgin of massive breccia in Wietrznia Quarry (Holy Cross Mountains, Central Poland.* Gelological Quarterly, 53 (3), 357-362.

[3] Szaniawski R., Konon A., Grabowski J., Schnabl P., 2011. *Palaeomagnetic age constraints on folding and faulting events in Devonian carbonates of the Kielce Fold Zone (southern Holy Cross Mountains, Central Poland).* Geological Quarterly, 55 (3), 223-234.

[4] Grabowski J., Michalik J., Szaniawski R., Grotek I., 2009. *Synthrusting remagnetization of the Krizna nappe: high resolution palaeo- and rock magnetic study in the Strazovce section, Strazovske vrchy Mts, Central West Carpathians (Slovakia).* Acta Geologica Polonica, 59 (2), 137-155.

[5] Mazzoli S., Szaniawski R., Mittiga F., Ascione A., Capalbo A., 2012. *Tectonic evolution of Pliocene-Pleistocene wedge-top basins of the southern Apennines: new constraints from magnetic fabric analysis.* Canadian Journal of Earth Sciences, 49 (3), 492-509.

[6] Szaniawski R., Ludwiniak M., Rubinkiewicz J., 2012. *Minor counterclockwise rotation of the Tatra Mountains (Central Western Carpathians) as derived from paleomagnetic results achieved in hematite-bearing Lower Triassic sandstones*. Tectonophysics, 560, 51-61.

[7] 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.

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

Introduction

Comprehensive models of mountain belts evolution are based on combinations of a number of complementary data obtained by applying a variety of geological and geophysical research methods (e.g. Nance et al. 2012, Weil et al. 2013). Particularly useful for the study of orogens are paleomagnetic techniques and analyses of the anisotropy of magnetic susceptibility (AMS) providing valuable data on the paleogeography and the history of tectonic deformations. The usefulness and reliability of these methods increases significantly when they are applied in conjunction with other research techniques. Therefore, of particular value are interdisciplinary studies combining various complementary research techniques and focused on resolving specific unexplained issues pertaining to the geotectonic evolution of the studied areas.

Publications [1]-[7] constituting the habilitation achievements presented herein contain information on several studies conducted in the Holy Cross Mountains, the Carpathians and the Apennines. At the core of all these publications lie paleomagnetic methods and studies of AMS. The majority of studies described in these works were of an interdisciplinary nature: they were conducted by research teams composed of scientists specializing in different but complementary fields of knowledge. This allowed the magnetic methods to be supplemented with other research techniques and the research work was based on an in-depth knowledge of the local geological structure. The adopted research objectives were, whenever possible, of a regional nature so as to enable the filling of the most significant gaps in the understanding of the evolution of the studied orogens. Thus, the research work focused on such fundamental issues as, for instance, the paleogeographic position of lithospheric blocks and nappes forming certain mountain belts. Other research work was focused on determining the age of deformations, tracking changes in the orientation of paleostress fields at different stages of the formation of mountains or recognizing the degree of involvement of the studied areas in the specific deformation phases. The obtained results significantly enriched the existing knowledge of the structure and origins of the studied mountain belts and provided an important contribution to the understanding of their evolution. All the research work in question was a basic science as it expanded the general knowledge of the evolution of the crust of the Earth. Some of the obtained results may, however, find their way into applied research, for instance research pertaining to the evolution of petroleum systems located in the vicinity of the studied areas.

Overview of publication [1]

The research described in publication [1] was conducted in the area of the Kielce zone of the Holy Cross Mountains (SHCM) forming the northern part of the larger lithospheric unit known as the Małopolska Block (MB). MB is interpreted as a terrane – it is generally considered to be an independent block of the of the Earth's crust which detached from the edge of the continent of Gondwana, was then subjected to independent drift and then collided and accreted with the East European Craton (e.g. Bełka et al. 2000, Winchester et al. 2002). The age of the eventual amalgamation of MB and the East European Craton has been the subject matter of research and discussions for a number of years: it was originally interpreted as associated with both the Caledonian orogeny or the Variscan orogeny but has recently been predominantly described as Cambrian (cf. Pożaryski 1991, Stupnicka 1992, Lewandowski 1993, Dadlez et al. 1994, Bełka et al. 2000, Nawrocki 2000, Schatz et al. 2006). Similar doubts also surrounded the history of deformations of late Paleozoic sediments in the area of SHCM. Discussions of this topic focused on the following issues: the scale of syndepositional deformations, the course and timeframe of Variscan orogenies and the significance and scale of tectonic reactivation of the turn of the Maastrichtian and the Paleocene (e.g. Kutek and Głazek 1972, Lewandowski 1981, Szulczewski 1989, Lamarche 1999, Konon 2006).

Selected in publication [1] as the primary objective of the research was analysis of the rotation of the SHCM unit in relation to the stable parts of the continent. The rotations were studied both with a view to verifying the age of the accretion of MB and exploring the possibility of a subsequent reactivation of the suture zone under intraplate tectonic conditions. Another objective of the research was to determine the age of folding in the area of SHCM. Analyses were performed on Devonian carbonate rocks due to the broad geographic extent of their exposures. Study samples were collected from the whole area of the outcrop of these rocks in SHCM. Moreover, samples were collected so as to enable the conduct of fold tests focused on major kilometric-scale regional folds rather than any smaller fold structures located in the wings of these large folds. Paleomagnetic analyses enabled the separation of the three components of remanent magnetization of different blocking temperatures. The observed properties of the components of remanent magnetization were consistent with those described in earlier publications (Grabowski and Nawrocki 1996, 2001, Szaniawski 1997, Zwing 2003, Grabowski et al. 2006), and that is why the letters A, B and C proposed by Zwing (2003) were adopted for the purposes of their classification. Fold tests, based on sites mean directions, provided evidence for an early synfolding origin of one of the components and a post-folding origin of another component. The age of the two components was estimated based on a comparison between calculated inclinations and reference data for Baltica.

The obtained results permitted the drawing of a number of important conclusions concerning the tectonic origin of the studied area. The most important conclusion concerns the position of MB in relation to the East European Craton. The acquired data provide evidence that at least since the Visean the units in question did not experience any significant rotations in relation to one another. Because the sampling locations were distributed over the entire area of SHCM, the obtained results are representative for regional interpretations. Other conclusions pertain to the age of the studied kilometric-scale folds – the obtained results prove that their geometry was shaped during the Variscan orogeny. Most probably, the earliest deformation phases occurred as early as during the Visean, whereas the current form of these folds was shaped before the early Permian. Thus, the obtained results specify a more exact timeframe for the Variscan deformations. These results also demonstrate that the regional fold structures which were analyzed in the inner zones of SHCM, i.e. away from the more intensely deformed edges of this unit, were not subjected to a significant reactivation during the deformation phase at the turn of the Maastrichtian and the Paleocene.

Overview of publications [2] and [3]

The good recognition of remagnetization stages in the Devonian rocks collected in SHCM (summarized in publication 1), including the estimated age of three remagnetization episodes, the learning of magnetic properties of remanent magnetization and the performance of regional fold tests, paved the way for further research on the tectonic origin of the studied area. Such research, as described in publications 2 and 3, was aimed at determining the relative age of selected tectonic structures in relation to each remagnetization episode. Chosen for the research were tectonic structures whose time of origin raised particular controversies in the context of events of a regional nature and was broadly discussed in the literature. The specification of a more exact timeframe for processes leading to the formation of these structures allowed the researchers to draw conclusions of great significance for the tectonic evolution of the entire Holy Cross Mountains.

Publication [2] presents an analysis of a breccia from the Wietrznia quarry. Its age and origin had two differing interpretations: the majority of authors described it as having been formed after the Variscan orogenies and associated its origin with karst processes (Szulczewski 1995, Urban 2007). According to alternative views, its origin was much earlier, associated with synsedimentary processes, i.e. the tectonic activity during the rock deposition period (Lamarche et al. 2003). At this point, it is worth noting that due to the considerable size of the breccia in question, the adoption of the latter model would entail the need to assume a very large scale of syndepositional tectonic deformations during the Devonian.

For the purposes of the research described in publication [2], the so-called breccia test method was applied. In the samples collected from different blocks of the breccia, the directions of two components of remanent magnetization were identified and calculated. The magnetic properties of these components corresponded to components B and A known from the in situ rocks and interpreted in an earlier publication (Szaniawski 2008) as early syn-orogenic Visean and post-orogenic early Permian, respectively. The directions of the two components were consistent within the distinct blocks of the breccia but differed entirely between the blocks. This means that the breccia was formed after the recording of the two components, which denies its syndepositional origin.

In turn, publication [3] presents the relative dating of a number of tectonic structures selected from the western edge of the SHCM unit. In this territory, in particular in the area of contact between the Paleozoic core and its Mesozoic margin, the results of earlier tectonic studies indicated particularly intense deformations from the Maastrichtian-Paleocene period (Gągol et al. 1976, Głazek et al. 1981, Lamarche et al. 2002, 2003). Selected for the research described in publication [3] were large kilometric-scale folds, small metric-scale fold structures, a breccia covering the folded sediments from the Laskowa quarry and deformed rock strata adjacent to dextral strike-slip faults of the north-south orientation. The origin and age of these faults have been the subject matter of a heated scientific discussion (Konon 2007, 2009, Świdrowska and Lamarche 2009).

The laboratory tests described in publication [3] included detailed petromagnetic analyses (isothermal remanent magnetization (IRM) and the so-called Lowrie tests) and then thermal demagnetization aimed at separating the components of natural remanent magnetization. According to the results, the tested rocks contained a record of two components of remanent magnetization identified as secondary components A and C dated in publication [1] to the early Permian and the period extending from the late Permian to the early Triassic. The directions of the early Permian component of remanent magnetization indicated dextral rotations of 20 degrees which were interpreted as the effect of late Variscan deformations. These rotations are present only in the western parts of the SHCM unit. The fold test results revealed reactivation of some of the examined fold structures which occurred after the early Permian. In turn, studies performed on the strike-slip faults indicated that the faults were active after the early Permian but most probably before the deformations of the Maastrichtian-Paleocene period. Similar studies performed on the breccia revealed that it was formed after the early Permian remagnetization. A comparison of the obtained results with the existing results of tectonic research permits the identification of a number of deformation phases which occurred within a changing stress field. It provides an important contribution to the understanding of the intricate tectonic evolution of the Holy Cross Mountains.

It is worth noting at this point that a similar research methodology was used in the master's thesis of J. Roszkowska, M.Sc., entitled „Palaeomagnetic and structural analysis of the Gałęzice-Bolechowice syncline in the Kowala region" written under the joint supervision of Dr. Andrzej Konon and myself. The thesis, defended at the Department of Geology of the University of Warsaw, received a „very good" grade. The results presentation delivered at the 12th „Castle Meeting" on New Trends in Geomagnetism won awards and prizes (the Certificate of Excellence and the IAGA Young Researcher Travel Award) from by the event organizers (http://www.irm.umn.edu/quarterly/irmq20-3.pdf, see detailed information on page 2).

Overview of publication [4]

The fourth publication presented herein describes research work conducted in Slovakia's Strážov Mountains belonging to the Central Western Carpathians unit. The subject matter of the studies was the late Jurassic and early Cretaceous limestones of the Križna nappe. The research focused on the issue of secondary rock remagnetization: as was the case with many other carbonate rocks forming mountain belts (see, for instance, Szaniawski et al. 2003, Elmore et al. 2012), the studied limestones were chemically remagnetized which resulted in the recording of secondary remanent magnetization. Remagnetizations of this type may be identified based on advanced petromagnetic tests, and the revealed directions of secondary remanent magnetization are useful for the purposes of tectonic and paleogeographic interpretations. Because remagnetization mechanisms are genetically related to the various geological processes that affected the rocks, a broader understanding of the interrelated phenomena allows researchers to present consistent and multifaceted interpretations.

In the research presented in publication [4], my task was to provide petromagnetic measurements: hysteresis loops and remanent coercivity (Hcr) analyses. The studies were conducted using a MicroMag vibrating magnetometer owned by the Institute of Geophysics of the Polish Academy of Sciences. The obtained results were presented in the form of Day diagrams (Day et al. 1997) and were compared with the theoretical curves (Dunlop 2002), permitting the identification of magnetic properties characteristic of chemical remagnetizations. This particular remagnetization was found to be characterized by varying intensity in rocks selected from different exposures. In the studies described in publication [4], I also participated in the tectonic interpretation of the directions of secondary remanent magnetization. In accordance with the presented model, the magnetization was recorded at the intermediate stage of rock deformation during the multi-stage tectonic evolution of the area.

Overview of publication [5]

Publication [5] describes research work conducted in the southern Apennines. The research focused on relatively young (Pliocene and Quaternary) sediments filling small sedimentary basins. Such basins, known as wedge-top basins, were formed on top of moving orogenic wedge. AMS analysis was applied as the primary tool for the research described in this publication. For decades, the results of AMS studies have been used in tectonic interpretations, because they allow researchers to read orientation of paleostress in rocks subjected to horizontal compression (e.g. Pares et al. 1999). It was discovered relatively recently that AMS methods may also be applied successfully in studies of weakly deformed clay sediments as they enable the determination of the direction of extension in sedimentary basins (e.g. Cifelli et al. 2005, 2007). A similar research objective was set in publication [4] referred to above. The AMS method was applied in order to determine the direction of extension associated with the formation of the studied basins and to find out whether and which of the basins were subjected to subsequent compression, and if so, then in which direction.

Samples of clay rocks for the AMS tests were collected from four different sedimentary basins. Laboratory work began with petromagnetic analyses involving the so-called thermoanalysis, hysteresis loop tests and analysis of changes in magnetic susceptibility as a function of temperature. The results proved that magnetite is the dominant ferromagnetic mineral present in the majority of the studied rocks. However, the content of ferromagnetic minerals is relatively small and the observed magnetic susceptibility of an order of 200×10^{-6} SI results primarily from clay minerals with paramagnetic properties. Subsequent measurements revealed that the AMS origin is associated predominantly with sedimentation processes coupled with a smaller but clearly recognizable involvement of tectonic processes. Thanks to the obtained results, it was possible to distinguish two phases of development of the studied basins: the extension phase (in the NNW-SSE direction) and the subsequent compression phase (in the NE-SW direction).

The results of AMS studies were interpreted together with the results of tectonic analyses, the available results of seismics and stratigraphic data specifying the age of sediments in the distinct sedimentary basins. Interdisciplinary research permitted the identification of changes in the regional stress field at the final stages of evolution of the orogenic wedge and at the same time linked the studied stresses with the geometry of the tectonic structures formed as a result of their operation. The presented interpretation of changes in the tectonic regime assumes an impact of regional tectonic activity of basement on the overlying orogenic wedge. Initially, this led to an extension phase within the wedge and the formation of the studied sedimentary basins, and then to a compression accompanied by deformations of a thick-skinned nature. Thus, the research presented in the publication contributed to a better understanding of the late stages of evolution of the southern Apennines orogen.

It is worth noting at this point that the above publication is an example of the methodology and organization of research that I consider to be the most appropriate and that I would like to continue. The research work described herein is the result of close cooperation between scientists specializing in various complementary disciplines. The research idea and the designation of appropriate research objectives were the outcome of discussions concerning unexplained aspects of the evolution of mountain ranges and the possibility of applying magnetic methods for their examination. The field work was carried out by the following team: Professor S. Mazzoli, a specialist in the tectonics and regional evolution of the Apennines, Dr. A. Ascione and Dr. A. Capalbo, specialists in the local geology and age of rocks based on biostratigraphy, F. Mittiga, a geology student at the University of Naples, and I, a paleomagnetist. My participation in the field research was funded as a one-week grant awarded by the Ministry of Foreign Affairs of the Republic of Italy following a competition procedure based on an evaluation of the preliminary research plan. All magnetic tests for the research were performed in a Warsaw laboratory of the Institute of Geophysics of the Polish Academy of Sciences. For two months, student Francesco Mittiga participated in the related laboratory tests performing his research internship under my supervision, funded under the Erasmus Programme. Work on the final analysis of all data and the formation of an interpretation model was performed in close cooperation, taking advantage of the interdisciplinary knowledge of all the authors of the publication.

Overview of publication [6]

The research presented in publication [6] was conducted in the Tatra Mountains which, in accordance with the current tectonic classification, form part of the Central Western Carpathian (CWC) unit. The CWC unit itself is considered to be part of the so-called Alcapa, which is interpreted as a micro-continent that prior to merging with the European Plate was subjected to independent movements as a self-contained block of the Earth's crust. The research objective was to obtain new information on the paleogeographic position of the Tatra Mountains (and thus also of the CWC unit and the Alcapa) in relation to the stable parts of Europe.

Selected for the research were early Triassic red sandstones of the autochthonous Tatra unit. The choice was not accidental and was based on a number of reasons. Firstly, what red bed sandstones are known for is that quite often they preserve a decipherable record of primary remanent magnetization. As a result, rocks of this type are commonly used in paleomagnetic studies involving paleogeography and magnetostratigraphy (e.g. Stamatakos et al. 1995, Nawrocki 1997). Furthermore, the studied sandstones are placed directly on the rocks of the Tatra crystalline basement and are exposed along the entire length of the autochthonous unit. Thus, the collection of a number of samples along the belt of the outcrop of these rocks allowed the researchers to achieve results representative of the entire block of the Tatra Mountains. The study was limited, however, to the autochthonous unit, because the overlying nappes may have been subjected to independent local rotations during the overthrust process. Moreover, the studied lowest part of the sedimentary rock profile of the autochthonous unit was subjected to only minor deformations during the late Cretaceous thrusting process. The field observations and measurements performed by our team revealed that the studied strata were inclined only during one Neogene tectonic phase. The relatively simple and well-recognized tectonic position of the studied rocks made it much easier to interpret the paleomagnetic results, enabling the researchers to draw reliable paleogeographic conclusions of a regional scale.

Rock samples collected from 7 sites were analyzed in a laboratory of the Institute of Geophysics of the Polish Academy of Sciences. The lab work began with petromagnetic studies involving thermoanalysis, IRM curves, Lowrie tests and analysis of changes in magnetic susceptibility as a function of temperature. The results demonstrated that magnetic minerals of high coercivity fields, such as hematite and goethite, prevail in the studied sandstones. Subsequent work included AMS analysis and IRM anisotropy tests. The results of these measurements indicated the predominantly sedimentary origin of the mineral alignment, which was discussed in the context of the so-called inclination error. Afterwards, the samples were subjected to a thermal demagnetization process which enabled the separation of the magnetization, characterized by high blocking temperatures and dual polarity, recorded by the hematite carrier. The obtained magnetization directions were subjected to the so-called inversion test which yielded a positive result. The calculated average direction of remanent magnetization was then compared with the reference data, revealing only a minor counterclockwise rotation of the Tatra block relative to the stable parts of the European continent. The obtained value of the rotation was discussed in the context of the results of other paleomagnetic studies taking into account the intricate multi-stage history of deformations of the study area.

Overview of publication [7]

The last publication discussed herein presents paleomagnetic results obtained from the area of the Outer Carpathians. This unit is an foreland fold and thrust belt forming the frontal outer part of the Carpathians. It is composed mostly of sedimentary rocks thrust over the margin of the European Craton in the form of nappes. Previous paleomagnetic results from the Outer Carpathians brought partly contradictory results, indicating either relatively minor[i] diversified rotations of the distinct parts of thrust belt or pointing to large-scale rotations of the entire thrust belt (cf. e.g. Korab et al. 1981, Grabowski et al. 2006, Márton et al. 2009). This problem is of fundamental importance for the understanding of the final phases of the regional evolution of the Carpathians. With this in mind, the objective of this publication was to supplement the existing paleomagnetic data describing the extent of rotation of the Outer Carpathians.

The research was conducted in south-eastern Poland in the area of the Subsilesian unit. Selected for the tests were sediments typical of this unit – the so-called Węglówka marls characterized by a high content of hematite. Rock samples were collected from 7 sites located along the outcrop belt of the studied marls. The collection of samples was accompanied by tectonic field works aimed at identifying and avoiding areas of intense local deformations. The results of AMS measurements revealed a high compaction of sediments with relatively small (for a thrust belts) internal deformations of tectonic origin. By applying thermal demagnetization techniques, primary remanent magnetization recorded in the hematite carrier was successfully isolated. The direction of this remanent magnetization exhibits only small dextral rotations of the studied unit relative to the stable parts of the continent. Thus, the obtained results support those tectonic interpretations that imply relatively minor and diverse rotations within the Outer Carpathian nappes.

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5. Other scientific achievements

Tectogenesis of outer parts of Variscan thrust-belt in Arednnes (France and Belgium) – determination of the scale, range and genesis of rotations within the thrust belt

The four publications referred to below present the results of, and constitute an extension of, the research carried out for the purposes of my PhD dissertation. The research work described hereunder was based on an integration of paleomagnetic methods, the results of AMS analyses and the results of structural field studies. What these studies revealed was that, contrary to what had been believed earlier, the rotations within the Ardennes chain are not present within the whole thrust belt but are of a local nature and exist in only relatively narrow zones characterized by unusual fold axis orientations. The presented interpretation of the origin of these zones is based on a model of so-called oblique and lateral ramps within the detachment plane. The geometry of the surface of the detachment formed at the thrusting stage was determined by the variable thickness of sediments accumulated earlier on the passive margin of the continent. In turn, the significant lateral variability of the thickness of these sediments was associated with the activity of synsedimentary faults.

Averbuch O., Lacquement F., Szaniawski R., Mansy J-L., Lewandowski M., 2002. *Segmentation of the Variscan thrust front (N France, S Belgium): insights into the geometry of the Devonian Rheno-Hercynian Basin*. Aardk. Mededel. Geologica Belgica, 12, 89-92.

Szaniawski R., Lewandowski M., Mansy J.-L., Averbuch O., Lacquement F., 2003. *Syn-folding magnetization in the French-Belgium Variscides as a marker of the fold belt tectonic evolution*. Bulletin de la Societe Geologique de France, 174, 5, 511-523.

Lacquement F., Averbuch O., Mansy J.-L., Szaniawski R., Lewandowski M., 2005. *Transpressional deformations at lateral boundaries of propagating thrust-sheets: the example of the Meuse Valley Recess within the Ardennes Variscan fold-and-thrust belt (N France–S Belgium*). Journal of Structural Geology, 27, 1788-1802.

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Determination of relative age of Ferques fault (France)

The paper describe relative age determination of tectonic structures based on paleomagnetic methods. I have participated in studies related to Ferque fold including: field works, laboratory studies and result interpretations. The age of fault was estimate as younger then middle Triassic.

Lewandowski M., Mansy J.L., Averbuch O., Lamarche J., Szaniawski R., 1999. *Paleomagnetic dating of brittle tectonic structures: case studies on Ferques Fault (Boulonnais, France) and two faults from the Holy Cross MTS (Poland)*. Comptes Rendus Geoscience. 329, 495-502.

Dating of the processes of burial and exhumation of rocks forming the Outer Carpathians and an interpretation of the mechanism of these processes in the context of the geotectonic evolution of the study area

The studies presented in the three publications referred to below are the result of cooperation with a team of researchers from the Universities of Padua and Bologna applying thermochronologic methods and tectonic structural analysis. Our joint research conducted in the Outer Carpathians allowed our team to isolate and date of stages of the burial and exhumation of rocks associated with the thrusting processes, erosion and the subsequent gravitational disintegration of the orogenic wedge. My contribution to this research consisted of my involvement in the selection of sampling sites, my participation in the field work and my inputs to the tectonic interpretations of the obtained results. In the future, I plan a broader integration of studies by applying paleomagnetic and thermochronologic methods, because a number of research problems (e.g. the age of thermal phenomena within an orogenic wedge) may be analyzed using both these techniques.

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 (2), 162-169.

Zattin M., Andreucci B., Jankowski L., Mazzoli S., Szaniawski R., 2011. *Neogene exhumation in the Outer Western Carpathians*. Terra Nova, 23, 283-291.

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.

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