A new era of the paleomagnetic research in the pre-Cenozoic of the Central Western Carpathians: Concepts, first results and ongoing studies

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Abstract: As a result of the critical revision of pre-Cenozoic paleomagnetic data from the Central Western Carpathians a team of Slovak, Hungarian and Polish researchers agreed to start systematic paleomagnetic investigations of the three nappe systems of this area. The new studies would improve the previous ones by using up-to date field, laboratory and statistical methods, as well as focus on formations which are widespread in the respective nappe units. The research started in the Hronic Unit, which is the topmost one, therefore less exposed to re-heating than the Fatric or Tatric nappe stacks. The so far obtained results suggest that during the Permian, the Hronicum was in near equatorial position in the northern hemisphere and at some distance from the European continent. Concerning the studied Triassic carbonates we conclude that they were remagnetized during the Late Cretaceous, basically before or in early stage of the deformation and transportation of the nappe unit. The Hronicum must have rotated about 35° in the CW sense after the Permian during a so far non-constrained period. A second, even larger (about 95°, taking into account the 60°CCW rotation measured on the Central Carpathian Paleogene flysch) general CW rotation can be connected to the closing of the Penninic Ocean. The ongoing studies in the Hronicum would aim at testing the oroclinal bending model by obtaining a robust data set for the area W of the Nízke Tatry Mts, on one hand, and start the systematic research on the Fatricum and Tatricum.

Introduction

In a review paper Márton et al. (2015) compiled a paleomagnetic data base for the Western Carpathians. The tabulated data for the Central Western Carpathians were published between the 1970s and 2010 and are of very different quality. The typical problems, mostly handicapping the older results are:

- The often poor documentation (e.g. for the studied localities neither the local tectonic positions nor the paleomagnetic directions before tectonic corrections have been published). Thus the acquisition of the remanence in relation to the geological age of the rock cannot be checked.
- Sometimes oriented hand samples were collected in the field from which several specimens were drilled in the laboratory. This method does not guarantee that the best material is sampled. Moreover, it introduces a systematic error in the orientation of the cores by transferring the nearly always present uncertainity of the orientation of a hand sample.
- Incomplete laboratory analysis of the natural remanent magnetizations (this aspect will be explained in the next chapter)
- "Spotlike" distribution of the paleomagnetic data, in time and even more in geographical sense.

The concepts of the "new era"

Of the nappe systems of the Central Western Carpathians, the uppermost one, and least affected by reheating during nappe stacking (therefore most likely to preserve original magnetization) is the Hronic Unit. For this reason, a team of Slovak, Hungarian and Polish researchers decided to start the systematic study on the two most widespread age groups of the Hronicum, the Permian red beds and igneous rocks and the Triassic carbonates. The deeper buried rocks of the Fatricum and Tatricum would be subjects of the next stage of our study.

It was also agreed that the field and laboratory methods of the paleomagnetic processing should be harmonized.

Concerning field methods, the samples should be drilled and oriented in situ in all cases with magnetic compass. In special conditions, like strong susceptibility and/or remanence of some igneous rocks, in the vicinity of high power lines or in outcrops protected by metal nets, orientation with sun compass is also necessary. It goes without saying that the sampled object should be devoid of any sign of recent or ancient slumping.

In the laboratory, the remanent magnetization (NRM) in natural state as well as the anisotropy of magnetic susceptibility (AMS) is measured before the laboratory analysis of the paleomagnetic signal. Some specimens (the number of them depends on the degree of uniformity of the NRM), from each outcrop are demagnetized in several steps with alternating field or with thermal method, till the NRM signal is lost. Referring to item 3 of the previous chapter, this is very important, since the NRM can be composite (e.g. a primary magnetization can be overprinted during regional or local heating as well as by geological processes in an uplifted position). During thermal demagnetization, the magnetic susceptibility is monitored in order to follow possible changes in magnetic mineralogy, as heating can produce a new magnetic phase either with lower (e.g. magnetite or maghemite converted to hematite) or higher (e.g. pyrite converted to magnetite) susceptibilities. The magnetic mineral(s) originally present in the rock must be identified with magnetic methods, like Curie-point measurement or the thermal demagnetization of laboratory induced remanence.

As a result of demagnetization and re-measurement of the remaining NRM after each step so called demagnetization curves are produced, which can be analyzed for linear segments. Sometimes the NRM is single component, more often it is composite (Fig. 1). In the latter case, it is usual, that the component which is more resistant to

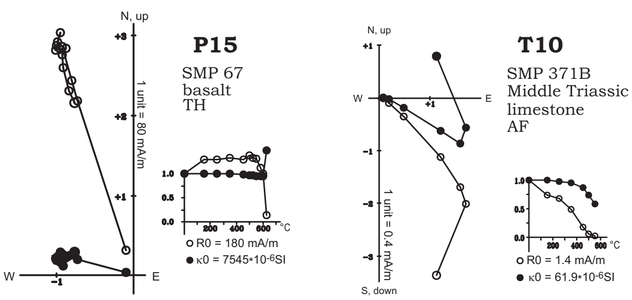

Fig. 1. Examples of a single component (P15) and a composite (T10) magnetization, respectively. Both specimens were thermally demagnetized in several steps, till the NRM (hollow circles on the right-side diagrams) was destroyed, while the susceptibilty monitored (full circles on the right-side diagrams).

the respective demagnetization method is interpreted as the more ancient. Based on the experiments with the selected pilot specimens, the rest of the collection from the same group is demagnetized with either AF or thermal method.

The paleomagnetic direction for each locality is computed from the more resistant (or the only) magnetic component using standard statistical methods in two co-ordinate systems. One is the geographical, i.e. before tectonic correction, the other is the paleogeographical i.e., after tectonic correction. In case of geological objects, which are monoclinally tilted, typical of the outcrops suitable for paleomagnetic study in the Hronicum, decision about the pre- or post-deformation age of the remanence is made on an assemblage of localities, which are geographically distributed and are of similar ages.

It was also agreed on that in the case of the nappe systems of the Central Western Carpathians the sampling localities should be distributed as much as possible in E–W directions, so that the model of oroclinal bending can be tested.

Summary of the results so far obtained for the Hronic Unit

Permian red beds and volcanic rocks

Both types of rocks were studied from the Nízke Tatry Mts. (18 localities/sites, Fig. 2C) and only lava flows from the Malé Karpaty Mts. (four sites, Fig. 2B). Except one locality of the red beds, all the studied rocks had reversed polarity magnetizations. The majority is characterized by shallow inclinations, suggesting near-equatorial position in the northern hemisphere of the Hronicum during the Permian (8.2°) and suggesting a net rotation (summary of the rotations taking place after the Permian) of about 70° in the CW sense. Rocks collected from the area of the Malužiná valley have steeper inclinations (corresponding to a paleolatitude of 23.3°, similar to the expected Late Triassic latitude for a position between Europe and Africa) and about 35° of CW net rotation, after the acquisition of the paleomagnetic signal.

Anisian–Norian carbonates

Of the 14 localities studied one is from the Strážovské vrchy Mts., the rest from the Nízke Tatry Mts. (Fig. 2A). They have magnetizations of pre-deformation age.

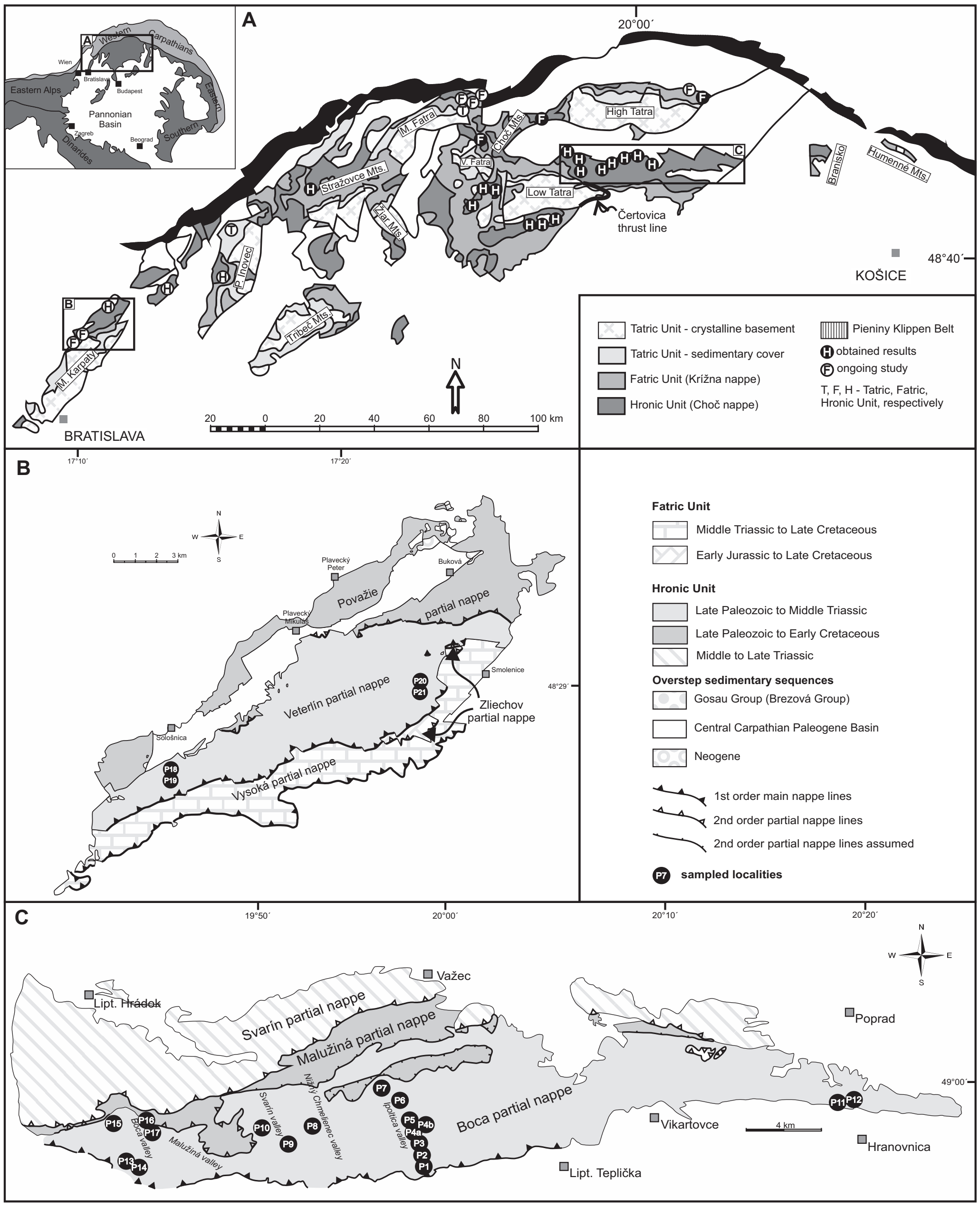

Fig. 2. Position of the studied area. **A** — Tectonic sketch map of the Central Western Carpathians with the position of the Mesozoic paleomagnetic localities. **B** — Simplified geological map of the northern part of the Malé Karpaty Mts. with the position of the Permian paleomagnetic localities. **C** — Simplified geological map of the northern part of the Nízke Tatry Mts. with the position of the Permian paleomagnetic localities.

However, the magnetizations are not interpreted as of Triassic age. The reason is that during the Triassic the polarity changes were frequent, while all the studied localities have normal polarity magnetizations and the inclinations are expected to show a trend towards steeper values during the Triassic, which is not the case in the studied material. Based on these features, we interpret the paleomagnetic signal as of Late Cretaceous age, acquired just before or during early phases of deformation and thrusting of the Hronicum above the deeper nappe units at a latitude of 34.7°. The post-Turonian net rotation suggested is 35° CW. The conclusions support previous estimations of Grabowski (2000) that Hronic units in the Tatra Mts were remagnetized during Late Cretaceous thrusting.

General implications

The above observations suggest that the Hronic Unit was at a considerable distance from stable Europe during the Permian and close to it during the Late Cretaceous. While the estimated paleolatitudes are not influenced by later displacements, the observed declinations must be interpreted in the context of the post-Paleogene, about 60° CCW rotation of the Central Western Carpathians (Márton et al. 1999, 2009). Thus, the net rotation observed on the Triassic means about 95° of CW rotation after the Turonian, probably connected to the closing of the Penninic Ocean. In addition, a CW rotation of about 35° must have affected the Hronicum after the Permian. The age of this rotation is an open question, since there is no constraint on the acquisition of the paleomagnetic signal in the rocks of the Malužiná area, which exhibit exactly the same net rotation as the Triassic rocks, with most probably Cretaceous (pre-Turonian) remanence.

Reflecting to the possible oroclinal bending of the Hronicum, there seems to be no evidence for such tectonic process in the data we so far obtained.

Work in progress

We have already collected oriented cores from several additional localities of the Mesozoic of the Hronicum, focusing on the area W of the Nízke Tatry Mts. (Fig. 2A). At the same time, we sampled mostly Triassic sediments from deeper nappe systems (Fig. 2A), in order to gain information about the supposedly different "paleomagnetic history" of the respective systems.

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