Geological research results utilization for tourism development in the Pieniny and Zamagurie region (north-eastern Slovakia)

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ABSTRACT

Tectonic junction of Inner Carpathian Paleogene Basin (ICPB) and Klippen Belt in the Pieniny and Zamagurie region was interest for explanation both units. Interpretation of geophysical data and geological structures we verify depth and spatial distribution of the Križna nappe in footwall. If we compare analogous geological structures in the Poland part, the Križna nappe and tectonic junction before Klippen Belt tectonic margin is suitable place for next geothermal research. We assume, the study area has possibilities for aquifer localization and for geothermal tourism development in the area.

Key words: seismic, geothermal conditions, Klippen Belt

INTRODUCTION

The Pieniny and Zamagurie region situated at the northeastern edge of the Spišská Magura region covers also an area of the Pieniny National Park (PNP) located at the Slovakian/Polish border (Fig.1). This topographically highly diversified sector of the Western Carpathians is overflowed by landscape notabilities what reflects into yearly increasing touristic activities of the area. Prevailing part of visitors prefer rafting on Dunajec river, but many of them favor also other actions at both i.e. Slovakian and Polish part of the PNP. Polish visitors prefer rather domestic services. On the base of information from Association for region growth in the Pieniny and Zamagurie region at the Slovak part of the PNP dominate one day tourism activities only.

At Poland and Slovakia border line geological researches of the Pieniny Klippen Belt (PKB) and the Inner Carpathian Paleogene Basin (ICPB) has been realized in 2011 period. The results explained favourable relations of geological units composition and their structure for geothermal heating accumulation at the area, which can be successfully used for geotermal energy and tourism growth at the region.

GEOLOGICAL CONDITIONS

Geothermal potential of any area limits multiple conditions which are essential for latently effectual area growing. Suitable geological conditions of a wider territory belong in particular to them. From this aspect extended PNP sector forms a central part of extremely reduced and dissected PKB zone at the contact of Outer Western Carpathian Flysh Belt and the Central Western Carpathian Block overriding the PKB at the some tens km. distance. Crustally shortened and crushed PKB zone reaching the Moho boundary forms an appropriate medium for both geothermal heat fertilization and contemporaneous heat flow isolines ascent.

The Pieniny Klippen Belt is located close to northern edge of the Spišská Magura

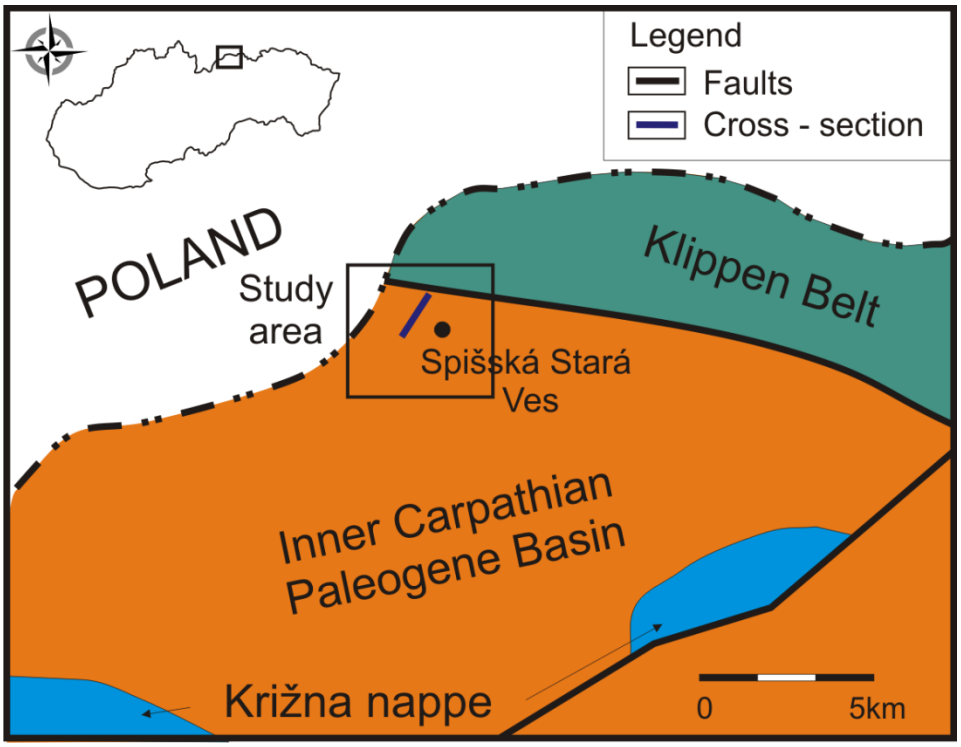

Fig. 1 Localization of study area and realized geophysical cross-section.

region. Morphologically, the PKB is typical by extremely broken relief emphasizing its rheo-/lithologically diversified and temporarily unequal rock units. Massive, rigid klippes are generally build by Jurrasic - Early Cretaceous radiolarites, nodular limestones and spotted limestons. The Upper Cretaceous sediments are represented by dual significant facies. The first one consists of red and gray marls and marlstones of the Púchov Formation, the second one is composed of the Jarmuta Formation sandstones and siltstones. The youngest Paleogene sediments represent siltstones and conglomerates of so-called „peri-Klippen Belt Paleogene".

Both PKB rocks mechanical differences and poly-stage extensive shortening of the PKB structure reflect into characteristic. „klippen" structural style of the PKB zone. Competent rocks (mainly limestones) form „klippes" i.e. some m^3 to a few km^3 extending, tectonically separated usually lensoidal block „floating" in incompetent (maily marlstone) rock medium. Highly instructive outcrop examples of the style remain namely within adjacent The Spišsko- Šarišské Medzihorie Depression.

Sedimentary filling of the Inner Carpathian Paleogene Basin (ICPB) reflects the evolution at the southern part of PKB during the Paleogene period. Also ICPB/PKB contact boundary has been multiply tectonized. The ICPB is composed of the Midlle Eocene - Upper Oligocene clastic sediments forming three formations. The basal Borove Formation consists of clastic sediments and nummulitic limestones. They are overlain by 100 m thick mudstone of the Huty Formations. The Zuberec Formation consisting of mutual sandstones and mudstones alternation terminates sedimentary cycle of the IPCB.

The Križna nappe forms pre-Tertiary basement unit of IPCB sediments at the Pieniny and Zamagurie region. However, it is only uncovered at upland exposures of the Belianske Tatry Mts southwardly from the Spišská Magura region. This nappe sheet builds diverse varieties of Early Triassic and Midlle Cretaceous sedimentary rocks namely: dolomites, limestones, sandy limestones and marls. The Middle Triassic dolomites and limestones are main aquifer of geothermal water in the area.

TECTONICS

As has been already mentioned the Pieniny and Zamagurie region belongs to tectonically very exposed areas. The oldest tectonic structures are thrust planes developed in the underlying the Krížna Nappe pile. On the basis of knowledge of the wider area we assume, that apart from the sole thrust the pile consist of several partial thrusts slices forming together the nappe unit. Most significant fault in the area are parallel with tectonic zone rimming PKB and ICPB. Multiply reactivated and steeply dipped bordering fault zone showing deep impact into structural style of both PKB and ICPB formations has according to seismic sections a whole-crustal course. Both the Križna nappe pile and ICPB rock sequences have been thereafter markedly deformed by younger fault tectonics. Rocks fracturation and faults spatial orientation modify either water or heat circulation and their ascent from deeper parts of the system. Mentioned attributes needs to be taken into account for proper field prospection and localization of explored geothermal well.

METHODOLOGY

The main goal of the research related to an explanation of the structure nearby the Pieniny Klippen Belt and the ICPB contact zone (Fig.1). Taking into account previous researches relating to uplift of the Spišská Magura Mts., and sedimentation in this area, we realized deep seismic prospection by seismic reflex method. For measurements of seismic velocities 24 channel seismic apparatus Terraloc MK-8, and geophone SM-4B 10Hz was used. We selected ideal sampling interval of 500μs, sampling step 8192. As a resource for reaching the maximum depth we used explosive Eurodyn 2000 0.33 kg. Geophone distance as well as resources was the same, i.e. 12.5 m. Terrain data were exported to SEG-D.

The quality of field data was not significantly affected by weather and/or other artificial sources. Obtained data were sufficient for processing and interpretation. Processing of field data was performed using Seis-TW software, and they were several times reprocessed. In the process, several steps were carried out by filtering data, pre-stack migration, application of FK filter, speed analysis and 2D modeling. Obtained outputs serve as the basis for geological interpretation realized in the PETREL software.

RESEARCH RESULTS

Data from deep seismic section was processes and interpreted and for tourism purposes we also realized analogous research nearby the Spišská Stará Ves town. The interpretation results cover identification of the main stratigraphic and tectonic interfaces (Fig.2). At seismic section has been possible to identify seismic reflections, which we interpret as the sedimentary boundary between ICPB formations and their Krížna nappe basement. The units interface show a marked change in both course and shape reflexes.

Reflexes of ICPB formations have nearly linear character. The Krížna Nappe deep structure manifests irregular, duplex-like formed reflexes with variable thickness and non linear direction, while clastic ICPB sediments show more stable physical properties. The contact of both mentioned reflexes types we interpreted as discordance surface where ICPB sediments transgressively overlain the Križna nappe sequences. Both units are significantly tectonically limited in eastern side of seismic section by steep PKB edge (Fig.3). In the central part of the section we identified graben or strike - slip structure limited by deep faults. We suppose that it represents a junction zone with the Klippen Belt created due to shear faults generating shear fans, which includes all the units. We

can conclude that at study area is possible to implement a targeted research for verification of any geological structure as a source of geothermal water utilizable for the tourism development of the area . This structure appears to be semi-open system donated water either along deep faults rimming the PKB or interlamellar water flowing from the Belianske Tatry Mts., edge.

DISCUSSION

Asymmetric structure of the ICPB relating either to rapid synsedimentary subsidence along Klippen Belt or to post-sedimentary uplift in the Tatra Mts., markedly play a substantial role in groundwater flow. The groundwater is probably derived from the Belanske Tatry Mts., area where water flow direction follows north-/northeastwards sediments dip inclination. Marginal PKB barrier cut by several transverse faults could locally modify the direction of water flow. We assume the entire structure appears to be semi-open aquifer saturated by meteoric waters. Aquifer of the area is mainly formed by Middle Triassic limestones and dolomites, event. also by Middle Eocene nummulite limestones and conglomerates. Concerning position of the infiltration area we can expect an overflow in the Pieniny and Zamagurie region.

According to ground water analytic results at Paleogene Podhale Basin linking the PKB from the north the age of water reaching 10.000 - 20.000 years (Holocene) and TDS from 0.1 to 3 g/l. (Kepinska, 2003). Polish hydrogeologists also allocate the same infiltration territory for the area . Due to the same water origin it is therefore possible to expect that the

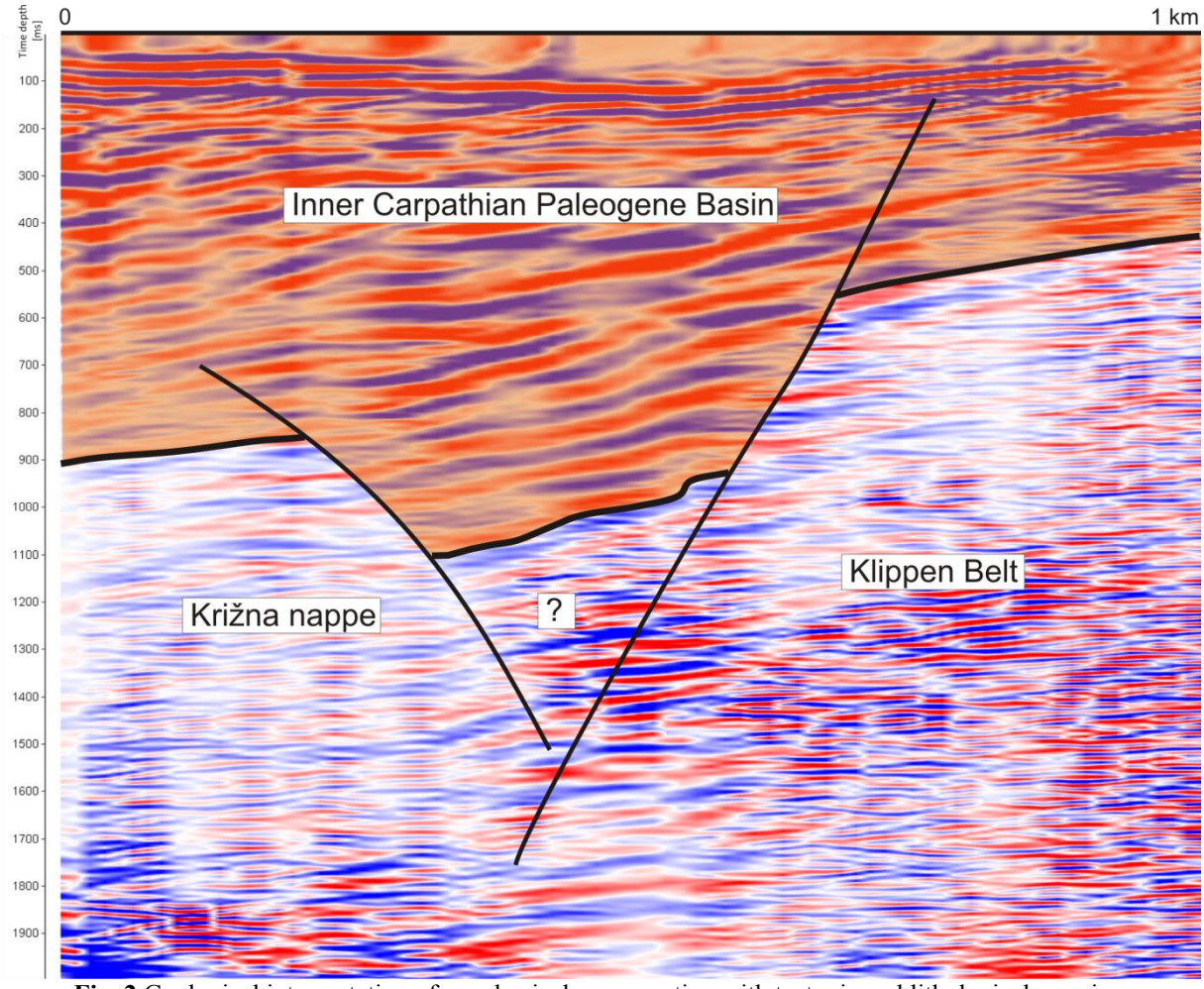

Fig. 2 Geological interpretation of geophysical cross-section with tectonic and lithological margins.

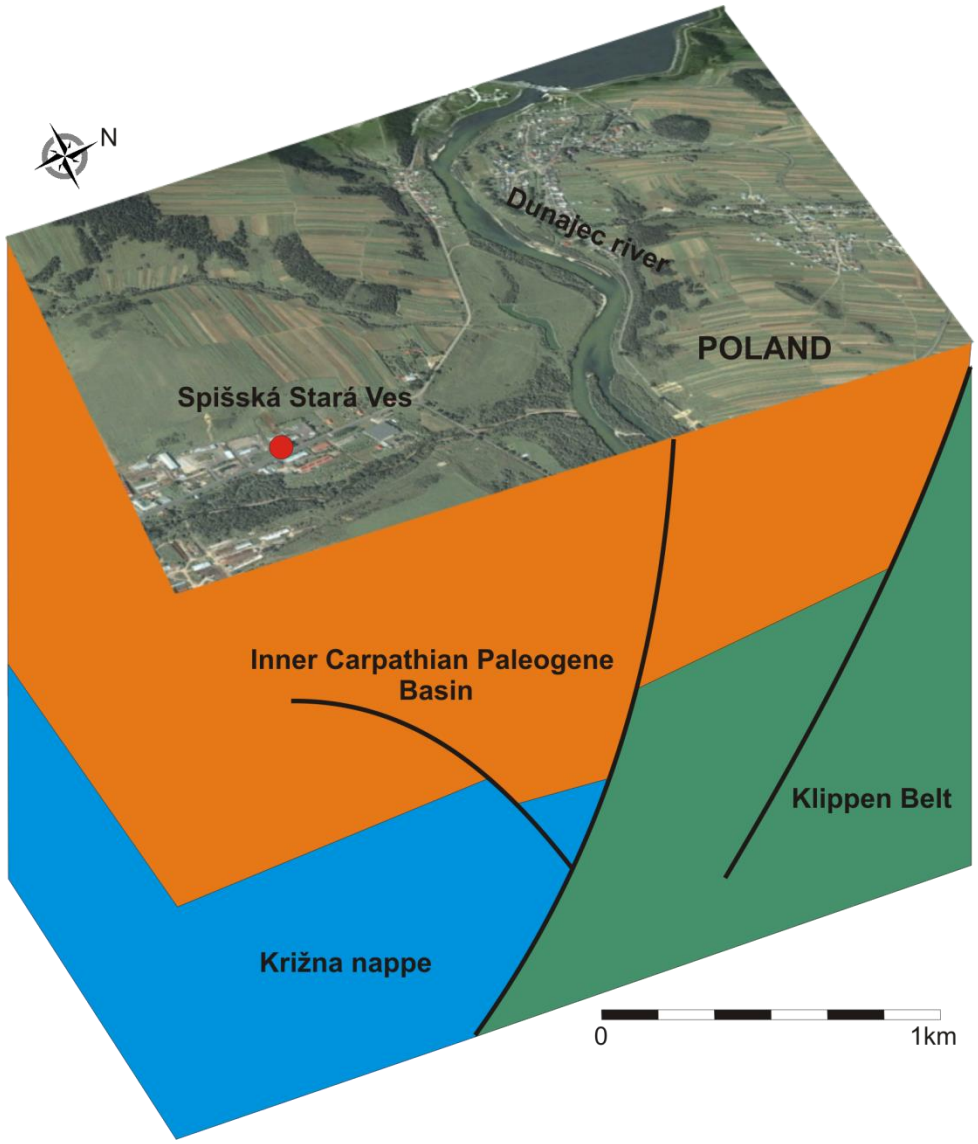

Fig. 3 Spatial sketch of geological structure and units distribution southwardly from Klippen Belt in the Slovak territory.

geothermal water at the Pieniny and Zamagurie will have comparable parameters as in Poland . From this view it is also possible to evaluate approximate thermal conditions of the area . The surface heat flow can vary between 55-60 mW/m2 (Plewa, 1994) . The middle value of the geothermal gradient should range between 1.9 to 2.3^0C. Than at depth 2-3 km geothermal water temperatures should achieve 80 to 1000° C (Kępińska , 2003) . Jankowski et al . (1982) assumes that the subduction zone is the PKB area having output heat and hot fluid from the depths of 6-16 km, which leads to a greater overheating at about 2 to 30^0C.

CONCLUSION

Geological research of tectonic junction of the PKB/ ICPB units identified the main lithological/structural boundaries and confirmed geothermal aquifer in the underground. The aquifer properties were assigned from the nearest Polish geothermal wells. We assume from data valorization, the water temperature in the aquifer could exceed 80^0 C, TDS should vary between 0.1 to 3 g/l with total capacity 15 to 20 l/s. The technical parameters of geothermal water at the area are favourable for geothermal prospection, aqua-park planning and tourism development.

Acknowledgment
This publication is the result of Project implementation: Research centre for efficient integration of the renewable energy sources, ITMS: 26220220064 supported by the Research and Development Operational Programme funded by the ERDF.

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