

Characteristics of the Predjama fault near Postojna, SW Slovenia

Značilnosti Predjamskega preloma pri Postojni, JZ Slovenija

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Abstract: The course of the Dinaric oriented (NW-SE) Predjama fault in the area of the northern Pivka valley and through Javorniki mountain is not well determined. The position of the Predjama fault through the Pivka flysch valley is mostly determined hypothetically. In the area of Javorniki hills the fault is divided into several parallel strands and accompanied by mostly cross-Dinaric (NE-SW) oriented faults. Predjama fault in the area of Postojna was probably not the seismogenic source of Postojna $M_{LV} = 3.7$ earthquake in 2010. Micro-tectonic deformations detected by TM 71 extensimeters in Postojna cave system on the other hand show minor ongoing aseismic displacements in northern NW-SE oriented fault, which is parallel to the Predjama fault.

Izvleček: Potek dinarsko usmerjenega (SZ-JV) Predjamskega preloma na območju severnega dela Pivške kotline in čez Javornike ni dobro ugotovljen. Položaj Predjamskega preloma skozi flišno Pivško kotlino je večinoma določen hipotetično. Na območju Javornikov je prelom razdeljen na več ločenih vzporednih prelomov, ki jih spremljajo predvsem prečno dinarsko (SV-JZ) usmerjeni prelomi. Predjamski prelom na ozemlju Postojne verjetno ni bil izvir potresa $M_{LV} = 3.7$ v Postojni leta 2010. Mikrotektonske deformacije, ugotovljene z ekstenziometri TM 71 v Postojnskem jamskem sistemu, pa kažejo manjše tektonske asezmične premike na severnem SZ-JV usmerjenem prelomu, ki je vzporeden Predjamskemu.

Key words: Predjama fault, Postojna, Slovenia

Ključne besede: Predjamski prelom, Postojna, Slovenija

INTRODUCTION

Recent tectonic activity of Slovenia is driven by northward movement of the Adria microplate and its counter-clockwise rotation (e.g. VRABEC & FODOR, 2006). The NW–SE trending Predjama fault is generally not considered as important as the Raša or the Idrija fault. It is treated as a continuation of Avče fault (JANEŽ et al., 1997). Its position east from Col, through Trnovski Gozd is clearly visible. The continuation of the fault to northern Pivka valley between Predjama and Postojna and further into Javorniki hills is less clear.

The January 15, 2010 $M_{LV} = 3.7$ earthquake in the area of Postojna town called attention to the fact that recently not only the area around Pivka or Snežnik Mountain is seismically active, but also the northern part of the Pivka valley at Postojna can generate strong motions. The January 1, 1926 $M = 5.6$ Cerknica earthquake was strongly felt inside the Postojna cave system, with reported stalagmite collapse inside the cave (ŠEBELA, 2010).

Preliminary geological interpretation of the 2010 Postojna earthquake attributed the event to slip on the regional Predjama fault, which runs in

the NW–SE orientation south of Postojna. However, the subsequently derived fault plane solutions of the event (ŽIVČIĆ et al., 2011) did not confirm this idea. Therefore we review the existing geological literature with respect to the position of Predjama fault in the northern part of the Pivka valley. In this area, the precise location of the fault zone was mostly inferred, resulting in mismatch from 200 m to 1500 m between the existing interpretations of the Predjama fault location. The most unclear is the SE-ward continuation of the Predjama fault towards Javorniki hills, where the fault is complicated by NE–SW oriented faults and is probably separated into several segments.

PREDJAMA FAULT GEOMETRY IN THE VICINITY OF POSTOJNA

A compilation of structural data, discussed in this section, is shown on the geological map in Figure 1.

On the Postojna sheet of the 1 : 100 000 Basic geological map of SFRJ (BUSER et al., 1967) the Predjama fault is terminated about 500 m west from Predjama and does not continue through the northern part of Pivka valley and through Javorniki hills.

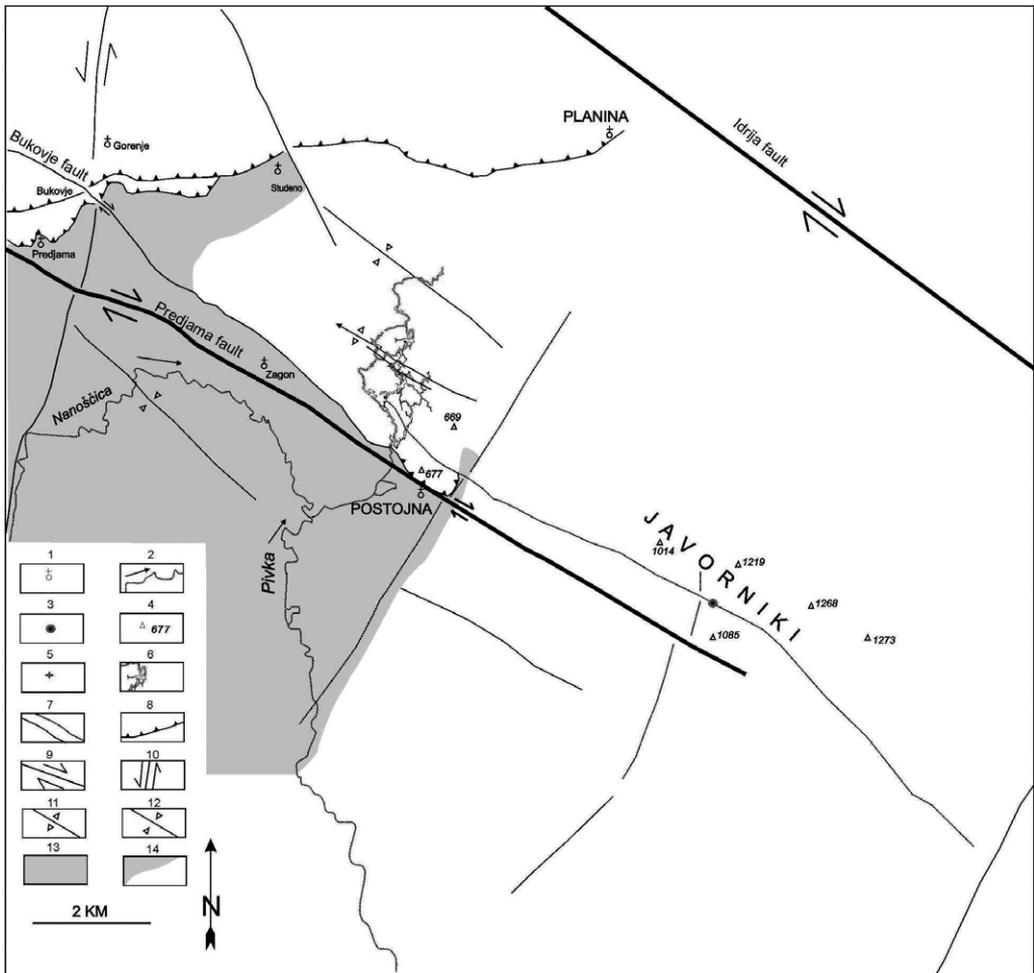


Figure 1. The basic structural-geological map of the Postojna area and position of Predjama fault. 1- town or village, 2- river and its flow direction, 3- Javorniška Koliševka, 4- hill with above sea level in metres, 5- TM 71 extensiometer in Postojna cave system, 6- ground-plan of Postojna cave system, 7- fault/hypothetic fault, 8- thrust fault, 9- dextral horizontal strike-slip movement, 10- sinistral horizontal strike-slip movement, 11- anticline, 12- syncline, 13- Eocene flysch rocks, 14- discordant contact between flysch and limestone.

The eastward continuation of the Predjama fault, from Avče fault into Javorniki was first documented by PLACER (1981 and 1996).

On the sketch of geological structure of Postojna the Predjama fault is marked as a hypothetic subvertical fault (PLACER, 1996). The fault is visible in the highway road-cut close to the Postojna railway station about 190 m north from the railway bridge. The inner fault zone is 18 m wide. Its northeastern fault plane has orientation of 25/70, with slickensides dipping 295/12. In the Hrušica area the Predjama fault shows dextral horizontal movement. In the vicinity of Postojna the NE block of Predjama fault moved towards right and slightly up with respect to the SW block. The apparent displacement on Predjama fault near Postojna is insignificant (PLACER, 1996).

The morphologically well-expressed contact between Upper Cretaceous limestone and Eocene flysch is, according to PLACER (1996), a fault, which is running nearly parallel to the southern Predjama fault. This fault is geologically better determined in the field than the principal Predjama fault, which runs through the Pivka flysch valley.

On the 1 : 500 000 geological map of Slovenia (BUSER, 1989) the Predjama fault runs about 1 km south of the Nanoščica stream, and continues along the southern edge of Javorniki hills towards the Babno Polje where it approaches the Idrija fault zone.

The investigations of JANEŽ et al. (1997) and RIŽNAR (1997) agree with PLACER's (1996) interpretation of the position of Predjama fault. According to JANEŽ et al. (1997) the fault runs about 200 m northward of the position shown on the map of BUSER (1989). They trace the Predjama fault along the southern edge of Sovič hill (677 m) near the town of Postojna and argue that the morphologically well-expressed scarp dividing Upper Cretaceous limestone from Eocene flysch, which runs NWward from Postojna towards Predjama, is controlled by a fault zone parallel to the Predjama fault. Further to the NW, west of the town of Col, the Predjama fault continues into the Avče fault (JANEŽ et al., 1997). There, the trace of fault is much better visible both in morphological and geological sense than in the northern Pivka valley and eastward in the southern parts of Javorniki hills.

The Bukovje fault, which is situated north from Predjama fault near Bukovje was determined by ČAR & ŠEBELA (2001). The fault is displacing a morphologically well expressed approx. N-S oriented sinistral strike-slip fault, which runs north from Gorenje towards Hrušica. The Bukovje fault shows insignificant dextral horizontal displacement (ČAR & ŠEBELA, 2001).

The structural-tectonic map of Slovenia (POLJAK, 2000) traces the Predjama

fault similarly to BUSER et al. (1967). The fault is traced in the area NW from Postojna, where it separates Hrušica structure from Nanos structure, whereas the eastward fault continuation in the Eocene flysch of the northern Postojna valley and at the southern foot of Javorniki hills is left undefined.

The detailed structural map of the area between Postojna, Planina and Cerknica (ČAR & GOSPODARIČ, 1984) was a major contribution towards understanding the tectonic structure of the area. After almost 30 years this is still the most important structural-geological map of the region. Unfortunately, the Predjama fault zone is outside the mapped territory.

ACTIVE TECTONICS AND SEISMICITY NEAR POSTOJNA

On January 15, 2010 at 14:20 (UTC) an earthquake occurred in the area of Postojna town. Its local magnitude was 3.7 and the highest intensity V EMS-98. The earthquake was felt in the territory of SW Slovenia and also in Jesenice, Velenje and Celje (JESENKO et al., 2011).

405 shocks occurred before and after the main earthquake. The fault plane solutions obtained from the first motion data for the main earthquake event and its strongest aftershock on March

6 2010, $M_{LV} = 2.4$, constrain a nearly vertical fault plane, which is either a SSE trending (N165° E) dextral strike-slip fault, or a WSW trending sinistral strike-slip fault (ŽIVČIČ et al., 2011). Seismological data therefore suggest that the 2010 Postojna earthquake was not related to slip on the Predjama fault, but to some so far unidentified geological structure.

Faults in suitable SSE-NNW orientation were mapped by ČAR & ŠEBELA (1997) around the Pivka and Črna Jama, but were at the time not interpreted as active or potentially active. Fissures and faults-orientation data from the Postojna cave system (ŠEBELA, 1998), presented in Figure 2, also demonstrate a prominent cluster of structures with NNW–SSE orientation, which is nearly as abundant as the one in the Dinaric NW-SE orientation. The major geological structures in the cave, mostly fault zones, have a Dinaric NW–SE orientation (ŠEBELA, 2012). Significant fissured to broken zones (in sense of ČAR & GOSPODARIČ, 1984) are mostly SSE–NNW orientated and exhibit no slickensides. Significant displacements in the Postojna cave system are visible on NW–SE and NE–SW oriented faults, whereas the SSE-NNW oriented geological structures are generally cut by NW–SE and NE–SW oriented faults and thus represent secondary structures to those with Dinaric orientation.

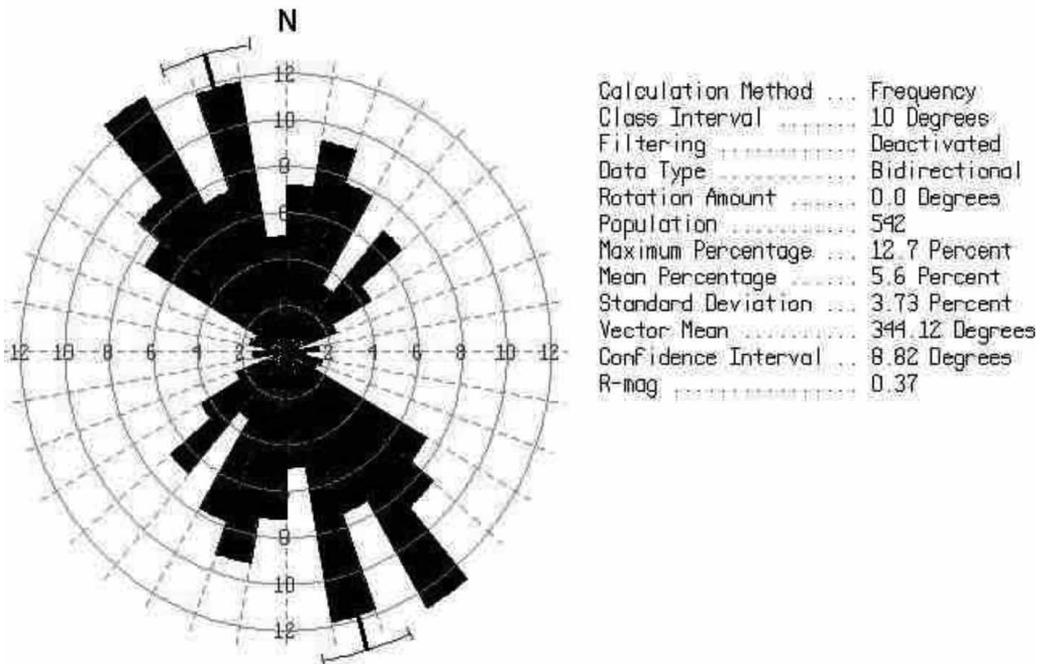


Figure 2. Orientations of faults and fractures in the Postojna cave system (ŠEBELA, 1998).

From the 25 m resolution Digital terrain model of the wider Postojna town area (PODOBNIKAR, Arhiv ZRC SAZU) we infer the existence of morphologically well-expressed fault zone east from Studeno (Figure 1), which could be the NNW continuation of N165° E trending fault that was seismogenically active during the January 15, 2010 earthquake (ŽIVČIĆ et al., 2011). This fault could be the connective fault between the Idrija and Predjama faults, or a shorter fault connecting the southern Predjama fault and the parallel northern fault in the outer zone of the Predjama fault. General direction of the fault running east from Studeno is 10–

20° towards the north deviated from the Dinaric NW–SE orientation. The fault is morphologically very clearly expressed, similarly to the nearly N–S oriented fault north from Gorenje (Figure 1). Basic geological map (BUSET et al., 1967) does not indicate a fault or a lithological contact at this location.

Otherwise, micro-tectonic deformations detected by TM 71 extensimeters in Postojna cave system since 2004 (Figure 1) show measurable aseismic displacements on the fault, which is parallel to the Predjama fault (GOSAR et al., 2011). Two instruments are placed on a Dinaric-trending NW–

SE fault that builds the NE wall of the Velika gora collapse chamber. Southern instrument is situated between the cave wall and the collapse block. Generally dextral horizontal displacement of 0.05 mm since 2004 indicates tectonic deformation and not movements due to cave collapse processes. Additionally, the down-slip movement of the NE block for 0.01 mm since 2004 suggests tectonic movements.

JAVORNIŠKA KOLIŠEVKA

Morphologically the best expressed collapse doline in the area of Javorniki hills is Javorniška Koliševka (Figure 1). It is a closed depression of underground origin. The big volume of the depression is due to rocks being sapped away. Closed depressions are karstic, unflooded morphological forms that are results of karst processes and removal of the rocks.

Javorniška Koliševka is situated along a Dinaric-trending fault that has already been detected by PLACER (1996), which is parallel to the main Predjama fault. The bottom of the collapse doline is at 847.80 m. The southern edge of the doline is at 905 m and the northern at 953 m. Javorniška Koliševka is at least 57.20 m deep and has a volume of about 800 000 m³. The position of Javorniška Koliševka on one of the northern faults parallel to the main Predjama fault indicates that the wider

Predjama fault zone continues into Javorniki hills and that favourable rock conditions (tectonically crushed zone) are present for development of deep karst collapsed doline.

CONCLUSIONS

The position of the Predjama fault through the Pivka valley was mostly determined hypothetically (PLACER, 1981 and 1996). In some cases (BUSER, 1989; JANEŽ et al., 1997; RIŽNAR, 1997; ŠEBELA, 2005) the position is more deterministic, but there is between 200 m to 1500 m of difference between the interpretations of the fault position.

Between Postojna and Javorniki hills the Predjama fault is probably dissected into separate parallel faults. One such segment runs through Javorniška Koliševka collapse doline and has probably controlled the origin of this deep karst depression. In the area SE of Javorniki hills this Dinaric oriented (NW-SE) fault parallel to Predjama fault is complicated by a prominent, mainly NE-SW oriented fault. The continuation of Predjama fault towards SE is clear at least into the area of southern slope of Javorniki hills.

Regarding the seismological analyses of the Postojna $M_{LV} = 3.7$ earthquake in 2010 (ŽIVČIĆ et al., 2011) the Predjama fault in the area of Postojna was

probably not the seismogenic source for the earthquake. Micro-tectonic deformations detected by TM 71 extensometers in Postojna cave system (GOSAR et al., 2011) on the other hand show recent small tectonic aseismic displacements in one of the northern NW–SE faults parallel to the main Predjama fault.

To find the seismogenic source for Postojna $M_{LV} = 3.7$ earthquake in 2010 detailed structural-lithological mapping should be the best answer.

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