Microseismicity in the western part of the Pannonian basin and its outskirts

Data includes instrumental microseismicity recorded by the Slovenian national network of between January 1990 and July 2020. Microseismicity reflects the position faults and is in principle related to other geomanifestations, such as increased heat flow and mofettes.

Generalities

The structure in NE Slovenia reflects a rich tectonic history since the middle part of the Mesozoic. Buried under thick Neogene marine and terrestrial sediments of Paratethyan origin, the underlying basement is as complex as anything encountered at the Alpine-Dinaric junction to the west. The complex structure of both, the Neogene sediments and the pre-Neogene basement, controlled the evolution of the area through Neogene and Quaternary. The Pannonian domain, which includes NE Slovenia in its northwest part, consists of several structural blocks, mainly the ALCAPA and TISZA crustal blocks/mega-units, that underwent thinning due to crustal extension and thermal collapse of the Pannonian basin (e.g. Handy at al., 2014; Horváth et al., 2015).

The northeast part of Slovenia is part of the ALCAPA mega-unit, divided from the Southern Alps by the Periadriatic fault system. The ALCAPA mega-unit comprises the Austroalpine unit of the Alps (Schmid et al., 2020 and references therein). The structure and activity in the eastern part of Slovenia are mostly controlled by the interaction between the ALCAPA and TISZA mega-units. TISZA is an accreted tectonic block/mega-unit composed of composite terranes of Eurasian origin formed in the Mesozoic and final emplacement present-day configuration in Paleogene-Miocene (Csontos et al., 1998; Handy et al., 2014; Schmid et al., 2020). The boundary between the ALCAPA and TISZA mega-units is the Miocene-formed Mid-Hungarian Zone (MHZ). The northern edge of the MHZ, also referred to as the Balaton fault/line is the eastward continuation of the Periadriatic fault system. The MHZ is zone of repeated tectonic inversions (Csontos et al., 1998), currently a sinistral strike-slip zone resulting from the TISZA eastward motion outpacing the eastward motion of ALCAPA (Serpelloni et al., 2016).

There are two fault systems in the GeoConnect³d project area in northeast Slovenia: the Raba fault system and the Balaton fault system, which itself is part of the MHZ zone. The lower Neogene rifting phase produced a multiple systems of normal faults, with general WSW-ESE strikes and northerly and southerly dips. Two deep basins formed in NE Slovenia (Fig. 1): the Radgona-Vas sub-basin in the north, with the Burgenland swell its north and the Haloze-Ljutomer-Budafa sub-basin in the south, separated by the Murska Sobota extensional block. The Radgona-Vas sub-basin formed along the Raba fault system normal faults, it is approximately 50 km long and 10 km wide and up to approximately 3000 m deep. The Haloze-Ljutomer-Budafa basin is an extremely deep basin, with maximum depths >6000 m, was formed along another system of normal faults, which was inverted in late Neogene as reverse faults (Fodor et al., 2002). These faults now form the Ljutomer fault and associated smaller faults. The Ljutomer fault zone is part of the Balaton line (c.f. Schmid et al., 2020), the northernmost part of the Mid-Hungarian Zone, the contact zone between the TISZA and ALCAPA mega units. The segments that make up the Ljutomer fault zone initially formed as normal faults, undergoing later inversion and reverse, likely transpressive movement.

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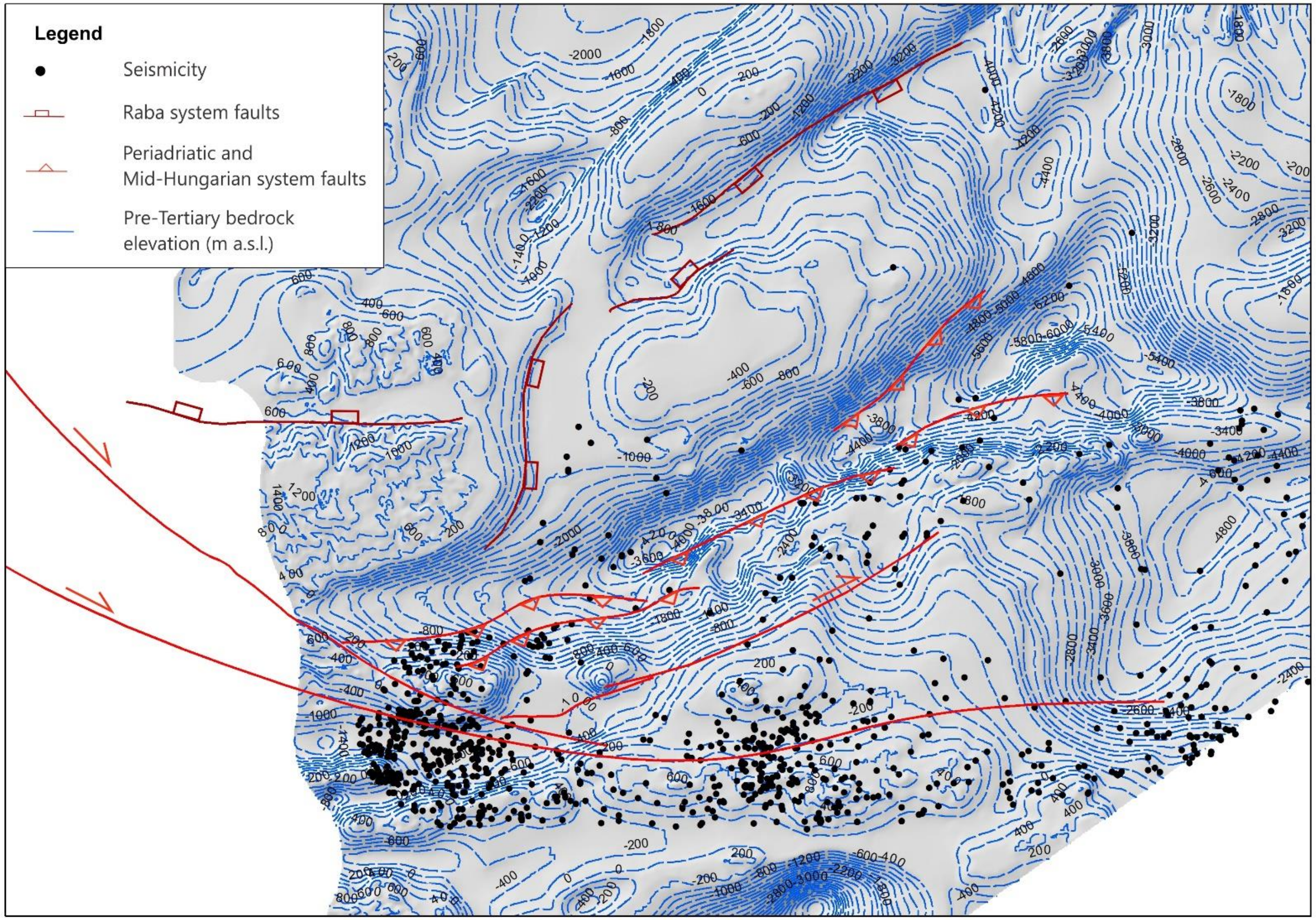

Fig.1 *Generalized map of structures in northeast Slovenia with structural elements from the text. Fault traces at pre-Neogene basement level are approximate and generalized. Dark red indicates (probably) inactive faults, bright red active and probably active faults. For general use only.*

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Anomalies

Seismicity is strongly concentrated in the southern part of the project area (Fig. 2). This is expected, as this is part of the tectonically active Mid-Hungarian Zone. Two local seismicity clusters stand out. One diffuse seismicity cluster appears to be related to the Ljutomer fault; epicenters are located to the south of the fault tip surface projection, consistent with the southward dip of the fault. This may be interpreted as indications of the activity of the fault, however, more precise relocation of hypocenters will be required. The second cluster is located at the extreme SW end of the project area. In this part, the faults of the MHZ and two major faults of the Periadriatic fault system (PAL) – the Šoštanj and the Labot faults – converge. Locally very strong long-term transpression and uplift is evidenced by the Boč mountain. Elsewhere in the project area there is little seismicity. This is expected, as the area encompasses the Raba fault system, which is considered likely inactive or of very low activity.

Seismicity reflects the known active and inactive fault systems well and in general confirms their respective activities. A significant anomaly is present and currently not yet explained. A diffuse, but significant concentration of seismicity is present along the W edge of the project area. No faults currently recognized as active are present in this area. The seismicity generally correlates with the Maribor fault, a presumably inactive normal fault, the SW-most extension of the Raba fault system, that runs along the S and E flanks of the Pohorje mountains. Reanalysis and relocation of hypocenters will be required to further investigate this potential link, however, this seismicity is considered anomalous.

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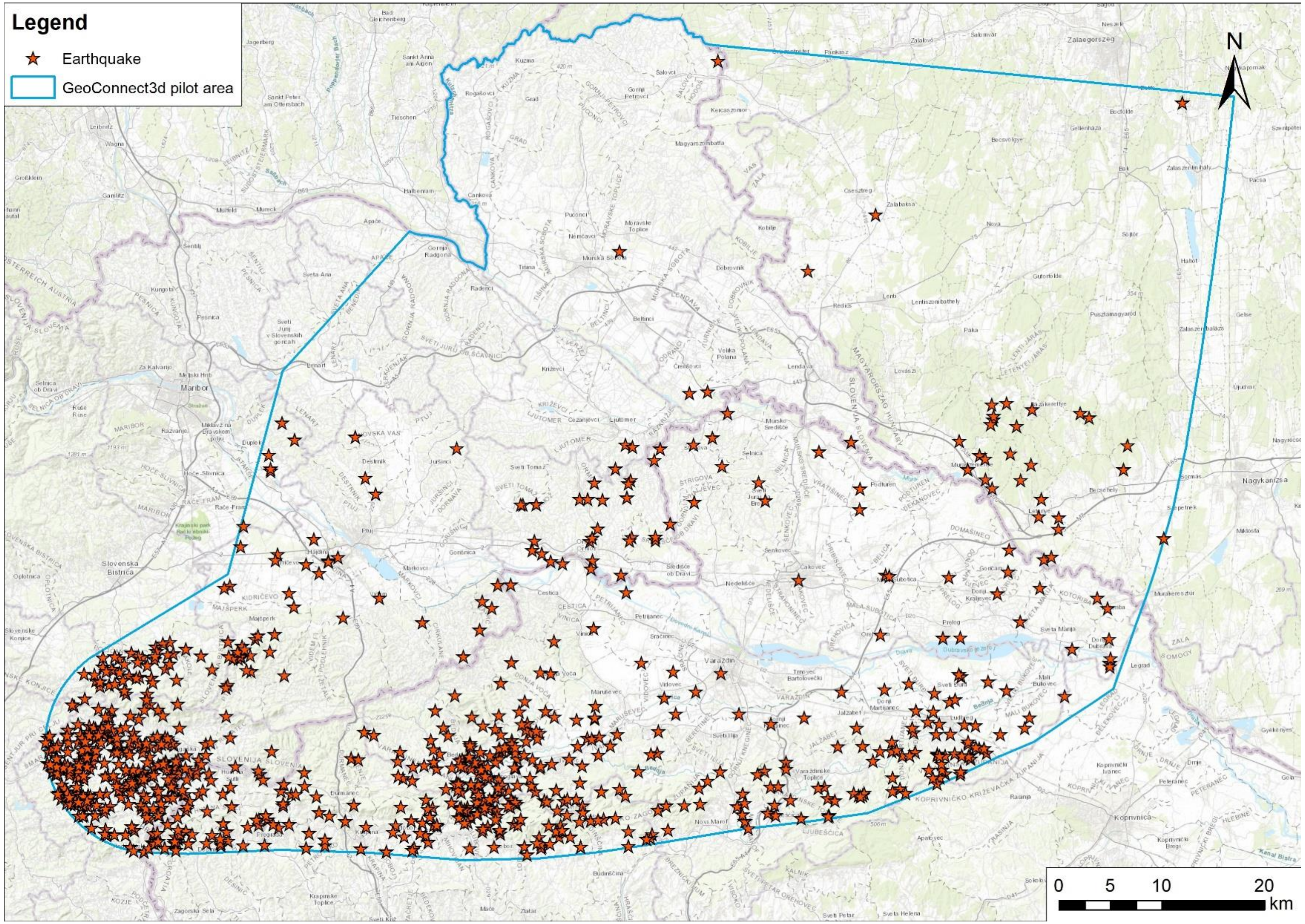

Fig.2 *Location of all reported microseismicity sources in the project area (Graczer et al. 2002-2018; Grünthal et al. 2013; Herak et al. 1996, 2020); Živčić, 2021)*

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References

Atanackov, J., Jamšek Rupnik, P., Jež, J., Celarc, B., Novak, M., Milanič, B., Markelj, A., Bavec, M., Kastelic, V. (2021): Database of active faults in Slovenia: compiling a new active fault database at the junction between the Alps, the Dinarides and the Pannonian Basin tectonic domains. Frontiers in Earth Science. doi: 10.3389/feart.2021.604388.

Csontos, L., Andras, N., Nagymarosy, A. (1998): The Mid-Hungarian line: a zone of repeated tectonic inversions. Tectonophysics 297, 51–71. Schmid et al., 2020

Fodor, L.., Jelen, B., Marton, E., Rifelj, H., Kraljić, M., Kevrić, R., Marton, P., Koroknai, B., Baldi-Beke, M. (2002): Miocene to Quaternary deformation, stratigraphy and paleogeography in Northeastern Slovenia and Southwestern Hungary = Deformacije, stratigrafija in paleogeografija severovzhodne Slovenije in jugozahodne Madžarske od miocena do kvartarja. Geologija, 45/1, 103-114.

Gráczer, Z. et al. (2002-2018): Hungarian National Seismological Bulletin HU ISSN 2063-8558 available on: http://www.seismology.hu/index.php/en/seismicity/earthquake-bulletins/31-hungarian-national-seismological-bulletin

Grünthal, G., Wahlström, R., Stromeyer, D. (2013): The SHARE European Earthquake Catalogue (SHEEC) for the time period 1900-2006 and its comparison to the European Mediterranean Earthquake Catalogue (EMEC). Journal of Seismology (submitted).

Handy, M.R., Ustaszewski, K., Kissling, E. (2014): Reconstructing the Alps–Carpathians–Dinarides as a Key to Understanding Switches in Subduction Olarity, Slab Gaps and Surface Motion. Int. J. Earth Sci. (Geol Rundsch). doi: 10.1007/s00531-014-1060-3

Herak, D., Živčić, M., Vrkic, I., Herak, M. (2020): The Međimurje (Croatia) Earthquake of 1738. Seismological Research Letters 91 (2A), 1042–1056. DOI: 10.1785/0220190304

Herak, M., Herak, D., and S. Markušic (1996): Revision of the earthquake catalogue and seismicity of Croatia, 1908-1992. Terra Nova, 8, 86-94.

Horváth, F., Musitz, B., Balázs, A., Vegh, A., Uhrin A., Nador, A., Koroknai, B., Pap, N., Toth, T. and Worum, G. (2015). Evolution of the Pannonian basin and its geothermal resources. Geothermics 53, 328-352.

Ribarič, V. 1982. Seizmičnost Slovenije. Katalog potresov (792 n.e.–1981). = Seismicity of Slovenia. Katalogue of earthquakes (792 A.D.–1981). Ljubljana, Seizmološki zavod SR Slovenije: 649 p.

Serpelloni, E., Vannucci, G., Anderlini, L., Bennett, R. A. (2016). Kinematics, seismotectonics and seismic potential of the Eastern sector of the European Alps from GNSS and seismic deformation data. Tectonophysics 688, 157-181.

Schmid, S.M., Fügenschuh, B., Kounov, A., Maţenco, L., Nievergelt, P., Oberhänsli, R., Pleuger, J., Schefer, S., Schuster, R., Tomljenović, B., Ustaszewski, K.van Hinsbergen, D.J.J., (2020). Tectonic units of the Alpine collision zone between Eastern Alps and western Turkey, Gondwana Research, Vol. 78, p. 308-374. DOI: 10.1016/j.gr.2019.07.005. Živcic M., (2009). Earthquake Catalogue of Slovenia.

Živčić, M. 2021: Provided seismicity data in the project area in 1990-2021. Agencija RS za okolje, Urad za seizmologijo, Slovenia, Ljubljana.

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