SEISMOGENIC ZONES OF NORTHWESTERN CROATIA

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Newly obtained and combined structural and seismic data allow us to define and characterize the major seismogenic zones of the NW Croatia. Although characterized by a moderate seismicity with a rare occurrence of earthquakes with $M \geq 5$, this part of Croatia is considered as seismically the most vulnerable part of the country due to the highest population density and over 55 % of annual national product. Tectonically, it lies in the border zone between the Alps, the Dinarides and the Pannonian basin, at the "triple junction" of the Periadriatic-Balaton, Sava and Drava transcurrent fault systems, all playing important role in the Neogene-Quaternary tectonics in this and neighbouring region (e.g. Fodor et al., 1998; Prelogović et al., 1998; Tomljenović and Csontos, 2001; Tomljenović et al., 2008). The earthquake data archived in the Croatian Earthquake Catalogue (covering the period since 373 BC until today) with recently re-computed locations of events recorded in NW Croatia in period of 1908 – 2007 (Herak et al., 2008) indicate a distinctive spatial distribution of earthquakes concentrated in five seismogenic zones. Surface and subsurface structural data (the latter obtained by reflection seismic profiles) indicate that these zones correspond well with the Neogene-Quaternary active structures representing km-scale anticlines, pop-ups and positive flower structures bounded predominantly by reverse and strike-slip faults. Geomorphologically, these zones largely correspond with the Žumberak - Samoborsko gorje, Pokuplje, Medvednica, Ivanščica - Kalnik and Bilogora hills (*inselbergs*) that merge out from the floodplain areas of the Kupa, Sava and Drava Rivers and thus are named here accordingly.

The seismogenic zone of Žumberak – Samoborsko gorje experienced the strongest known earthquake on 11 February 1699. The earthquake of 13 August 1887 (I_o = VII °MCS) caused heavy damage on churches and houses in the town of Jastrebarsko and the surrounding villages. Three fault-plane solutions (FPS) calculated for this zone point to generally N-S to NW-SE trending greatest principal stress direction and the prevalence of strike-slip tectonics accommodated by steeply dipping NE–SW striking sinistral and/or NW-SE striking dextral fault sets (Herak et al., 2008). Pliocene-Quaternary transpressional tectonics controlled by a generally N-S trending greatest principal stress direction is also evidenced by structural data, which indicate the youngest displacements along the southern margin of the Žumberak Mt. accommodated by sinistral NE-SW striking fault set.

The seismogenic zone of Pokuplje lies along the Kupa River where it transects through the NW-SE trending hills of Vukomeričke gorice. The most important event here is the one of 8 October 1909 ($M = 6.0$, I_o = VIII °MCS). Two FPS available from this zone consistently indicate a moderately plunging SW-trending pressure axis, with potential earthquake generating fault corresponding either to NW-SE striking dextral or NE-SW striking sinistral fault set. The former seems to be more plausible seismogenic source and would be a part of the Sava fault zone, which is in this segment documented as the NE-dipping boundary normal fault along the southwestern margin of the Pannonian basin during the Neogene. At present, however, this fault segment would be reactivated

and inverted accommodating dextral and reverse motions due to recently NE-SW directed compressional stress. This interpretation is additionally supported by a cross-sectional view of hypocentres indicating a seismogenic zone that dips to the NE with an angle of 60°, a dip angle typical for normal faults.

The seismogenic zone of Medvednica experienced strong seismic activity in the 18th, 19th and in the beginning of the 20th century. The strongest earthquakes occurred on 13 October 1775 with the epicentral intensity of VII–VIII° MCS, on 9 November 1880 with the intensity VIII °MCS (known as the great Zagreb earthquake), on 17 December 1905 (I_o = VII–VIII° MCS) and on 2 January 1906 (I_o = VII–VIII° MCS). Calculated and available FPS indicate seismogenic activity on (1) reverse ENE-WSW striking faults and (2) along dextral or sinistral NW-SE and ENE-WSW striking faults, respectively. The hypocentres in the western part of this zone lie along a steeply SSE-dipping plane that is in agreement with the Quaternary active SE-dipping reverse fault mapped along the northern margin of Mt. Medvednica. Geometry and kinematics of this fault nicely corresponds with the NE-SW striking and SE-dipping nodal plane calculated by FPS, which indicate a reverse fault plane with a top-to-the-NW motion direction. Another two FPS related to earthquakes located in the northeastern and southwestern parts of this seismogenic zone indicate seismogenic structures corresponding either to the NW-SE striking dextral or the NE-SW striking sinistral faults. In both cases, the first option is more plausible because it is in a quite good agreement with the location, orientation and kinematics of the two NW-SE striking dextral faults mapped in this area.

The seismogenic zone of Ivanščica - Kalnik recently experienced pronounced seismic activity with only moderate events of macroseismic intensity up to VII °MCS (e.g. 1 June 1993). All three FPS from the central and eastern part of this zone (Pondrelli et al., 2006; Herak et al., 2008) indicate prevalence of compressional tectonics under N–S trending P-axis, accommodated by the E–W striking reverse faults that are in a good agreement with faults mapped along the northern and southern margins of Ivanščica and Kalnik Mts.

The seismogenic zone of Bilogora-Drava extends in NW-SE direction for about 75 km between towns of Koprivnica and Virovitica. Three out of four earthquakes known from this area with I ≥ VII °MCS had epicentres near the town of Koprivnica. The 27 March 1938 earthquake (I_o = VIII° MCS) destroyed many houses and churches in the town of Durdevac and its surrounding villages. This is the first event in Croatia for which FPS could have been computed. Potential seismogenic structure most probably corresponds with the NW–SE striking nodal plane dipping at 75° to the NE, which would nicely correlate with the major NW–SE striking Bilogora fault zone characterized by reverse and dextral faults which affected Pliocene-Quaternary strata.

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