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# Seismicity of Croatia in the period 2002–2005

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During the 2002–2005 period a total of 3459 earthquakes were located in Croatia and its neighbouring areas with 15 main events registering magnitudes from 4.0 to 5.5. Seismically the most prominent were the two strongest earthquake sequences recorded in the central part of the Adriatic Sea, near Jabuka Island (the first one with the mainshock on March 29, 2003, 17:42, $M_L$ = 5.5, and the second, weaker, with the mainshock on November 25, 2004, 6:21, $M_L$ = 5.2). In the epicentral area W and NW of the Jabuka Island 781 earthquakes were confidently located (28 events with magnitudes equal to or larger than 4.0). Seismically active coastal part of Croatia, especially its southern part exhibited the seismicity within well-known epicentral areas. The earthquake with the magnitude $M_L$ = 5.5, recorded in the Imotski–Grude area, on May 23, 2004 at 15:19 ($I_{max}$ = VI–VII °MSK) was the second strongest event during the studied period. Continental part of Croatia experienced moderate seismicity during the observed period, with earthquakes of magnitudes $M_L \leq 3.9$.

*Keywords*: Seismicity, Croatia

## 1. Introduction

The tectonic setting of Croatia belongs to the broad Africa-Eurasia plate boundary zone which is affected by the plate convergence between Africa and Eurasia. The geotectonic area hosts several distinct units: the Pannonian Basin, the Eastern Alps, the Dinarides, the transition zone between the Dinarides and the Adriatic Platform, and the Adriatic Platform itself. The seismic activity located at the junction of the Adriatic, Alpine-Pannonian and Dinaric blocks is probably driven by the independent motion of the Adriatic microplate. However, the forces responsible for the motion of the Adriatic microplate as well as its kinematics are a long-standing and much debated problem (e.g. Anderson and Jackson, 1987; Ward, 1994; Grenerczy et al., 2000; Altiner, 2001; Mantovani et al., 2001; Calais et al., 2002; Oldow et al., 2002).

The present paper summarises seismic activity in the territory of Croatia and the surrounding regions in the four-year period 2002–2005. The compilation of earthquake catalogues with epicenters in Croatia and the surrounding areas

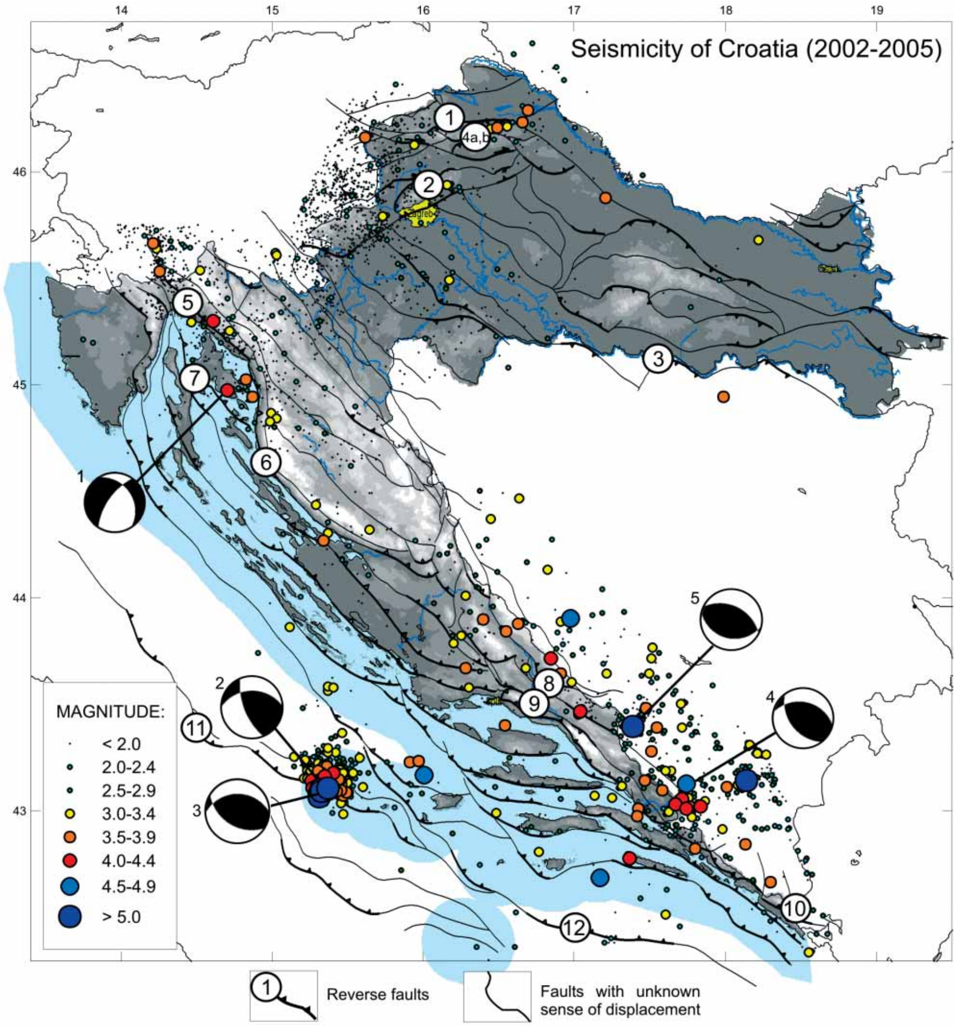


**Figure 1.** Map of epicenters of earthquakes in Croatia and the surrounding areas and the most important seismogenic faults in the period 2002–2005 (faults according to the Map of Active Faults, project COST-625 (Croatian contribution), by E. Prelogović, B. Tomljenović, M. Herak and D. Herak, 2006, unpublished). Fault-plane solutions for five earthquakes obtained in this study are shown. The identification numbers refer to Table 2. Compressive quadrants are shaded.

Legend: (1) Drava fault, (2) Medvednica Fault, (3) Sava fault, (4a,b) Ivanščica Mt. and Kalnik-North fault, (5) Ilirska Bistrica–Vinodol fault, (6) Velebit fault, (7) Krk fault, (8) Imotski fault, (9) Mosor–Biokovo fault, (10) Dubrovnik fault, (11) Jabuka–Andrija fault, (12) South Adriatic fault.

began under the UNDP/UNESCO project of exploration of seismicity in the Balkan region, for the period 1901–1970 (Part I) and before 1901 (Part II) (Shebalin et al., 1974). The Croatian seismicity for the years 1986 through

*Table 1. Hypocentral parameters for mainshocks with magnitude $M_L \geq 4.0$ in Croatia and the surrounding areas during the 2002–2005 period.*

| Date | Origin Time (UTC) | | | Epicenter | | Depth | ML | Imax |
|---|---|---|---|---|---|---|---|---|
| | h | m | s | φ (°N) | λ (°E) | (km) | | (°MSK) |
| 2002, April 16 | 7 | 42 | 58.3 | 43.020 | 17.838 | 8.8 | 4.4 | – |
| 2002, August 29 | 14 | 26 | 12.9 | 43.468 | 17.038 | 2.3 | 4.2 | V |
| 2002, October 23 | 11 | 1 | 26.8 | 42.686 | 17.167 | 14.3 | 4.5 | V |
| 2003, January 17 | 3 | 18 | 19 | 44.974 | 14.704 | 8.8 | 4.2 | VI |
| 2003, February 4 | 11 | 51 | 14.6 | 43.170 | 16.002 | 11.6 | 4.6 | V |
| 2003, March 29 | 17 | 42 | 13.6 | 43.093 | 15.325 | 3.8 | 5.5 | – |
| 2003, May 10 | 6 | 42 | 48.8 | 43.904 | 16.978 | 2.9 | 4.8 | IV–V |
| 2003. August 02 | 10 | 18 | 39.8 | 43.128 | 17.740 | 5.2 | 4.9 | V–VI |
| 2004, March 21 | 3 | 18 | 13.8 | 43.715 | 16.848 | 2.1 | 4.2 | – |
| 2004, May 23 | 15 | 19 | 6.6 | 43.395 | 17.389 | 7.7 | 5.5 | VI–VII |
| 2004, September 14 | 18 | 9 | 25.1 | 45.297 | 14.607 | 5.1 | 4.1 | VI |
| 2004, October 31 | 9 | 8 | 2.4 | 43.026 | 17.750 | 19.6 | 4.2 | – |
| 2004, November 25 | 6 | 21 | 16.0 | 43.110 | 15.370 | 5.9 | 5.2 | – |
| 2005, July 03 | 23 | 44 | 43.1 | 42.780 | 17.369 | 11.3 | 4.2 | – |
| 2005, September 27 | 00 | 25 | 34.3 | 43.146 | 18.144 | 20.9 | 5.1 | – |

*Table 2. Fault-plane solutions for 5 earthquakes that occurred in the period 2002 to 2005.*

| No. | Date | Origin Time (UTC) | P-axes | | T-axes | | Nodal Plane 1 | | | Nodal Plane 2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fault Plane Parameters | | | | | |
| | | | Azimuth | Dip | Azimuth | Dip | Strike | Dip | Rake | Strike | Dip | Rake |
| 1 | 2003/01/17 | 03:18:19.0 | 167 | 51 | 279 | 17 | 215 | 70 | –53 | 329 | 41 | –148 |
| 2 | 2003/03/27 | 16:10:35.8 | 219 | 15 | 112 | 48 | 269 | 45 | 29 | 158 | 70 | 131 |
| 3 | 2003/03/29 | 17:42:13.6 | 198 | 7 | 90 | 69 | 125 | 55 | 115 | 266 | 42 | 59 |
| 4 | 2003/08/02 | 10:18:39.8 | 214 | 5 | 112 | 69 | 142 | 53 | 116 | 283 | 44 | 60 |
| 5 | 2004/05/23 | 15:19:06.6 | 20 | 7 | 251 | 80 | 297 | 52 | 100 | 101 | 39 | 77 |

2001 was described by Herak at al. (1988), Herak and Cabor (1989), Markušić et al. (1990), Herak et al. (1991), Markušić et al. (1993), Markušić et al. (1998) and Ivančić et al. (2002). The Croatian Earthquake Catalogue for the period 1908–1992 was revised by Herak et al. (1996).

In this paper we present compiled and processed data for all recorded earthquakes (2002 – 2005) in Croatia, regardless of the magnitude. The map of epicenters shows the locations of all epicenters and lower hemisphere fault-plane solutions for 5 earthquakes that occurred in the studied period (Fig. 1). Special attention was paid to the earthquakes with magnitudes greater or equal to $M_L = 4.0$ (all main events with magnitudes $M_L \geq 4.0$ recorded during the 2002–2005 period are listed in Table 1). Fault-plane solutions for 5 earthquakes (Table 2) obtained in this study by analyses of first-motion polarity

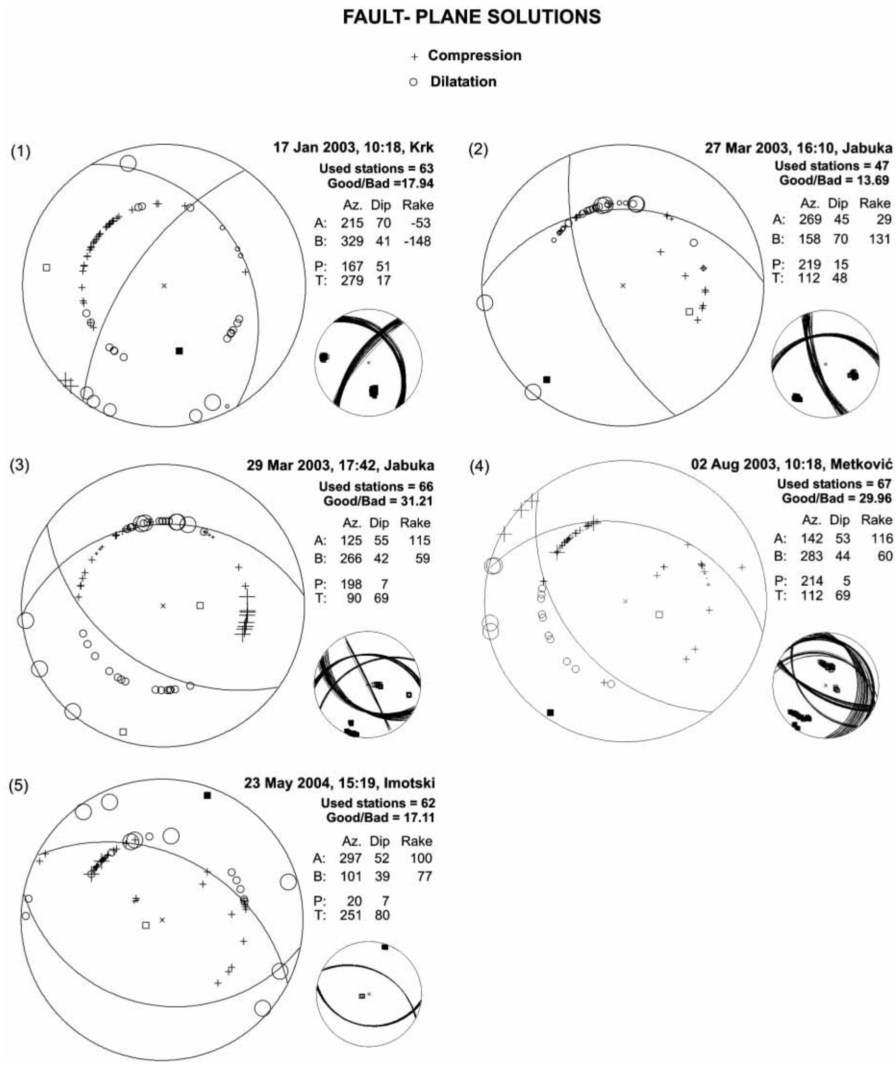


**Figure 2.** Fault-plane solutions for five earthquakes (Table 2) obtained in this study by analyses of the first-motion polarity readings on regional seismological stations (lower hemisphere equal-area projection). Large symbols mark the data read from the seismograms by ourselves (those were given larger weights in inversion), polarities of small ones are adopted from other published material. Small subplots show nodal lines and stress-axes for 50 random solutions whose good/bad readings ratio is within 95% of the best ratio obtained.

readings on regional seismological stations are shown in Fig. 2. Table 2 summarizes obtained focal mechanisms, listing main stress axes and fault plane parameters of both nodal planes. Individual earthquakes have also been macroseismically analyzed.

*Table 3. Summary of the stations of the Croatian seismological network operating during the 2002–2005 period*

| Station | Code | Latitude (°N) | Longitude (°E) | Alt (m) | Sensor | Operating since |
|---|---|---|---|---|---|---|
| Dubrovnik | DBR | 42.651 | 18.114 | 150 | BB, Guralp | 1999 |
| Hvar | HVA | 43.178 | 16.449 | 250 | Vegik, Wilmore | 1973 |
| | | | | | BB, Guralp 40 | 2000 |
| Kijevo | KIJV | 44.005 | 16.405 | 550 | BB, Guralp | 2004 |
| Novalja | NVLJ | 44.563 | 14.871 | 10 | BB, Guralp | 2002 |
| Požega | POZ | 45.333 | 17.679 | 100 | SP, Teledyne S13 | 2003 |
| Puntijarka | PTJ | 45.909 | 15.973 | 1023 | SP | 1974 |
| | | | | | BB, Guralp | 2004 |
| Rijeka | RIY | 45.344 | 14.386 | 75 | Teledyne S13 | 1989 |
| | | 45.325 | 14.483 | 200 | BB, Guralp | 2002 |
| Sisak | SISC | 45.471 | 16.372 | 100 | BB, Guralp | 2000 |
| Ston | STON | 42.872 | 17.700 | 5 | BB, Guralp | 2003 |
| Zagreb | ZAG | 45.815 | 15.983 | 178 | Vicetini | 1906 |
| | | | | | Wiechert | 1909 |
| | | | | | Sprengnether 5100 | 1983 |
| | | | | | BB, Guralp | 1999 |

## 2. Instrumentation

All available earthquake related data were collected by analyzing the set of original seismograms from the permanent and temporary seismological stations in Croatia. Currently the Croatian seismological network consists of 10 permanent stations: Dubrovnik (DBR), Hvar (HVAR), Kijevo (KIJV), Novalja (NVLJ), Puntijarka (PTJ), Požega (POZ), Rijeka (RIY), Sisak (SISC), Ston (STON) and Zagreb (ZAG). Basic information about the stations operating during the 2002–2005 period and their instrumentation is presented in Table 3.

## 3. Data and method

In order to determine the earthquake parameters, data from the Croatian seismological network were supplemented by readings reported in monthly bulletins of seismological stations in the neighbouring countries. For each earthquake five main parameters were determined: hypocentral time, epicentral latitude, epicentral longitude, focal depth and earthquake magnitude ($M_L$).

Hypocentral time and coordinates of the focus were determined by the HYPOSEARCH program based on a grid-search algorithm (Herak, 1989) using the three-layered model published by B.C.I.S. (1972) and both P- and

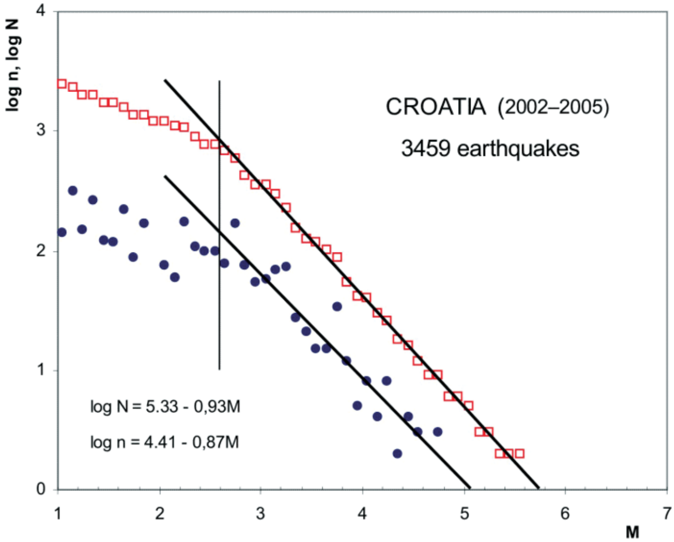


**Figure 3.** Frequency-magnitude graphs for the Croatian earthquake catalogue in the period 2002–2005. Cumulative (*N*, empty squares) and noncumulative frequencies (*n*, solid circles) indicate completeness threshold at about $M_L$ = 2.8 (vertical line).

S-waves arrival times. The exceptions were the Central Adriatic earthquakes and the earthquakes in the central part of the External Dinarides, where the velocity models published by Herak (1990) and Herak and Herak (1995) were used. Hypocentral locations of Jabuka island (Central Adriatic Sea) earthquakes were computed after seven iterations of refining hypocentres and adjusting station corrections (Herak et al., 2005).

Fault-plane solutions presented in this paper (Fig. 2) are evaluated using data on the first motion polarity which were read from the original seismograms (mostly from Croatian stations) or were taken as reported in various available bulletins and other published material. The obtained solutions are discussed in the following sections.

Macroseismic data were collected for all felt events in Croatia, and macroseismic maps are presented if available. 54 earthquakes were reported felt during the observed period. For earthquakes felt by a sufficient number of people, macroseismic data were obtained by fieldwork and/or questionnaires, and isoseismal maps were made. During the observed period it was possible to collect sufficient data to compile isoseismal maps for four earthquakes, as presented later.

A total of 3459 earthquakes (for which at least 6 onset time readings were available) were located in Croatia and the surrounding areas in the period 2002–2005 (Fig. 1), with estimated completeness threshold of $M_L$ = 2.8 (Fig. 3).

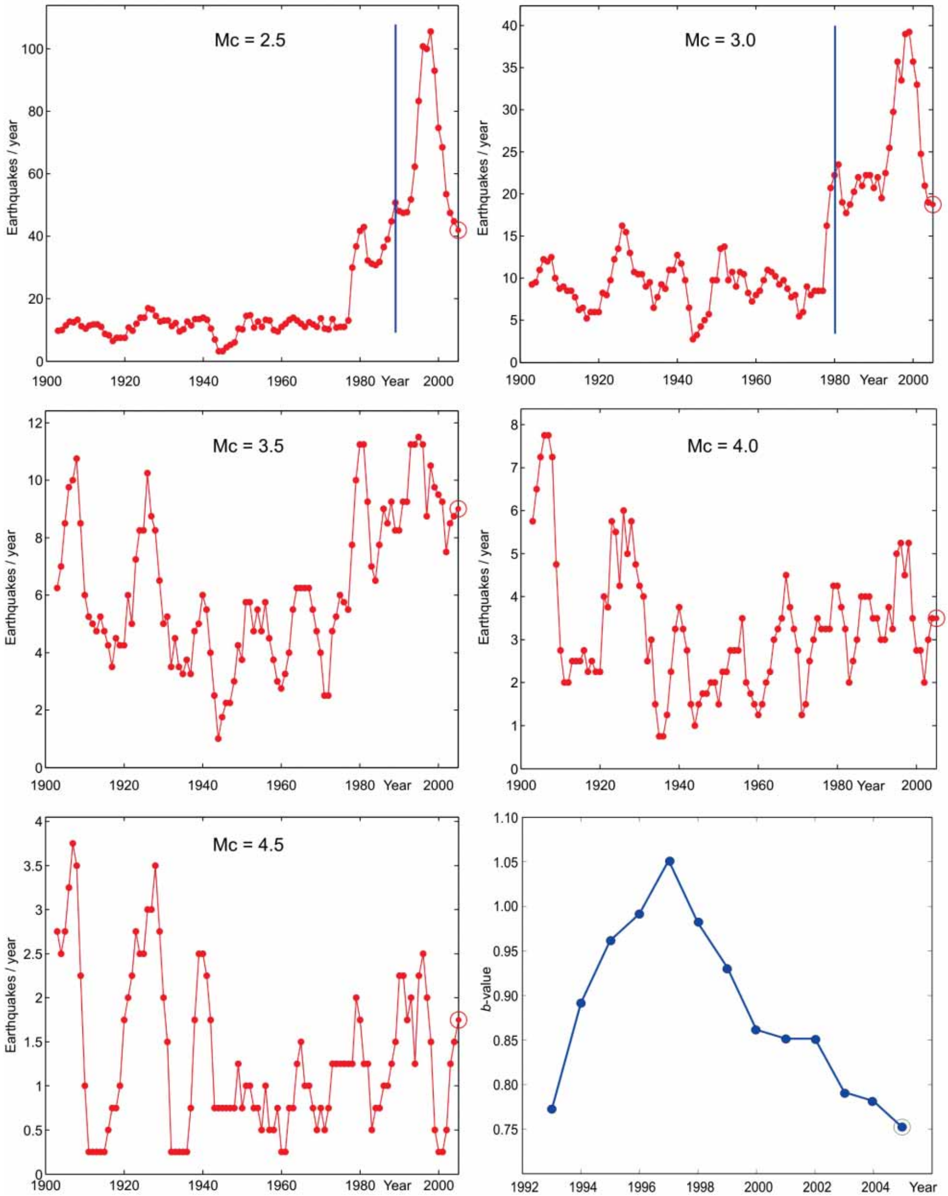


**Figure 4.** Seismicity rates for earthquakes with magnitudes $M \geq M_c = 2.5, 3.0, 3.5, 4.0$, and 4.5. Rates are computed for four-year windows that are shifted in time one year at the time, and plotted on the right window edge. The last point in each subplot refers to the rate corresponding to the time period investigated here. The vertical line shows the beginning of the complete reporting for the corresponding threshold magnitude $M_c$. The right subplot in the bottom row shows the variation of the maximum-likelihood *b*-value in the Gutenberg-Richter relationship, computed for the windows as defined above, since the period 1990–1993.

The frequency-magnitude graphs are presented in Fig. 3, and coefficient $b$ is found to have a value close to $b = 0.9$.

Declustered catalogue (with foreshocks and aftershocks removed) list a total of 1378 mainshocks. Fig. 4 shows activity rate variation in time for mainshocks with magnitudes larger than $M_c$ = 2.5, 3.0, 3.5, 4.0, and 4.5. The rates are computed using windows four-years wide, with the shift of one year. The values are plotted at the right window edge, so that the rate corresponding to the period covered here is the rightmost one, marked with a circled dot. It is seen that the number of low-magnitude events is monotonically declining for the last 10 years, which does not hold for $M_L \geq 3.5$. This is reflected in a steady drop of the $b$-value (Fig. 4, bottom right subplot) from $b = 1.05$ in 1997 to $b = 0.75$ in 2005. Such a sharp drop in $b$-value has been shown in the past to precede strong earthquakes in the area (Herak and Herak, 1990; Herak et al., 1996).

## 4. Features of seismicity in Croatia in the period 2002–2005

In regard to the concentration of earthquakes in Croatia the analysis of seismicity is usually confined to two areas: (1) the continental part of Croatia – the southern part of the Pannonian Basin and central Croatia, and (2) the coastal part of Croatia – Adriatic Sea, its NE coast and the Dinarides.

### *4.1. Continental part of Croatia*

The continental part of Croatia occupies the territory of the westernmost part of the Dinarides, and the southern part of the Pannononian Basin. This region can be considered to have had a moderate seismicity during the observed period, with earthquakes $M \leq 3.9$. Seismically active areas are mostly found in its northwestern part spreading from Koprivnica through Kalnik Mt., Ivanščica Mt, Medvednica Mt. and Žumberačka gora to Pokuplje. There were also a few weak isolated seismic events in central and eastern Slavonia.

The *Kalnik Mt. – Bednja river valley* was seismically the most active area in the continental part of Croatia. Dominant in the seismic activity within this region were the earthquakes that occurred in the Bednja river valley near Ludbreg. The earthquake with the largest magnitude ($M_L = 3.9$) occurred on December 6, 2002 at 1:52. The maximum intensity of V °MSK was reported in Rasinja and Koprivnički Ivanec. It was the strongest event in the continental part of Croatia for the period from 2002 to 2005. This earthquake was preceded by several weak foreshocks. The strongest aftershock occurred about an hour later, on December 6, 2002 at 3:12 ($M_L = 3.8$). These epicenters are located in the zone where the Drava fault meets the Ivanščica Mt. and the Kalnik-North fault (Fig. 1).

Relatively frequent but weak in the 2002–2005 period was the seismic activity in the westernmost regions of the continental part of Croatia (Hrvatsko zagorje and the border region between Croatia and Slovenia, Krško-Bre-

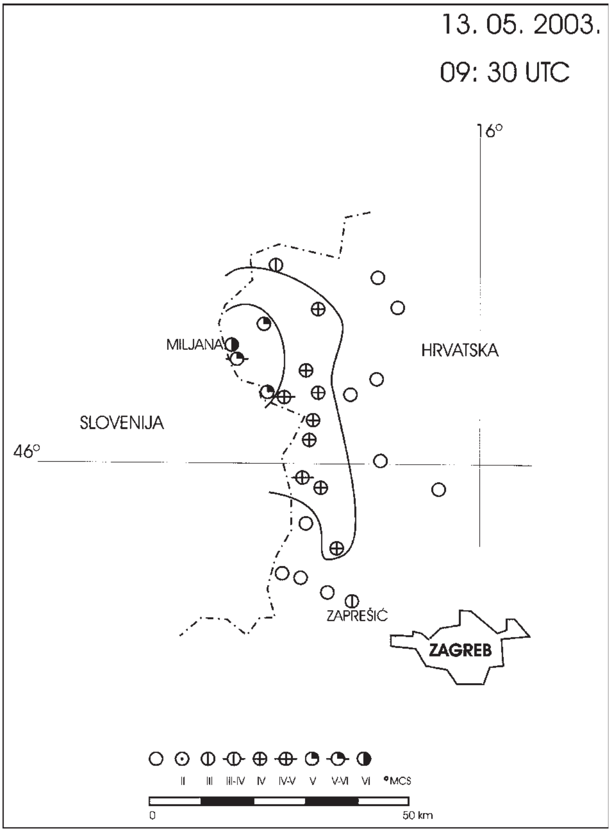


**Figure 5.** Isoseismal map for the Miljana earthquake of May 13, 2003 (9:30).

žice area, Žumberačka gora and Medvednica Mt.). The strongest earthquake occurred here on May 13, 2003 at 09:30 in the Sutla river valley near Miljana ($M_L$ = 3.7, $I_{max}$ = V–VI °MSK) on the Croatia–Slovenia border. The distribution of the intensities assembled from the Croatian side is displayed in Fig. 5. The microseismic epicenter is located within the pleistoseismal. The maximum intensity of V–VI °MSK was reported in Miljana, where a wall on a 30 years old house was diagonally cracked from the top of the window.

The seismicity in the *Pokuplje epicentral area* is characterized by notable occurrence of small events. Few weak earthquakes occurred in the vicinity of Petrinja.

### *4.2. Coastal part of Croatia*

The coastal part of Croatia comprises the Adriatic Sea with its coastal area and the Dinarides. Pushed by the African plate Adriatic microplate is being indented into the European continent thus causing deformation of the Earth's crust and gradual shaping of the Alpine-Dinarides orogenic belt. In the youngest active period, the area of the Adriatic microplate is being significantly reduced so that the microplate is fragmented into at least two larger fragments – the southern and the northern parts (e.g. Pribičević et al., 2002; Oldow et al., 2002).

The coastal part of Croatia exhibited the seismicity within the well-known epicentral areas: the greater Rijeka epicentral area on the NW coastal side, and the seismically active SE coastal side covering the Dinara Mt. area and the Grude–Imotski and the Metković–Stolac epicentral area. Significant seismicity has also been recorded within the microplate itself, around the Jabuka island.

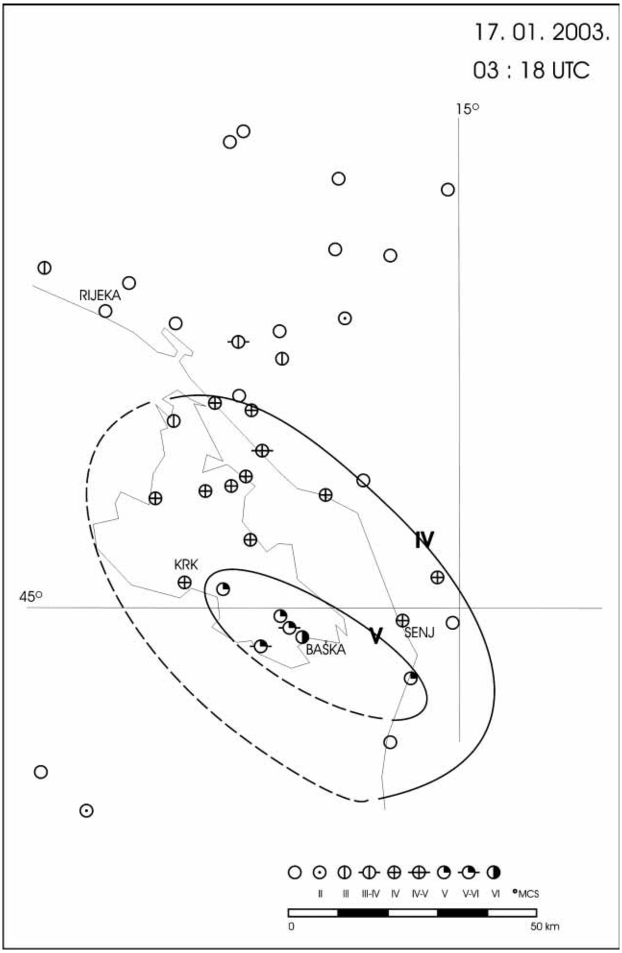


**Figure 6.** Isoseismal map for the Krk earthquake of January 17, 2003 (3:18).

The seismic activity of the *greater Rijeka epicentral area*, spreading from Snežnik Mt. towards Hreljin, Crikvenica and the Krk island, is known for the frequent occurrence of relatively weak earthquakes ($M_L$ < 4.0) and occasional occurrence of moderate or large earthquakes ($M_L \geq 4.0$). Several felt earthquakes occured here during the observed period. Only two of them were with magnitudes $M_L \geq 4.0$. The first one occurred on January 17, 2003 at 3:18 with magnitude $M_L$ = 4.2 and the maximum intensity $I_{max}$ = VI °MSK (Table 1), near Baška on the Krk island. The macroseismic field survey revealed that in the epicentral area some walls cracked at the ceiling height, on some buildings 1–2 cm wide cracks occurred, and fairly large pieces of mortar fell from the walls. Some wooden sculptures about 0.5–1 m high overturned. In Baška Draga and Jurandvor peaces of mortar fell from the walls and ceilings. One eyewitness in Baška Draga saw a lightning just a second before earthquake trembling above Baška (there were no cumulonimbus clouds at the time of the earthquake). The microseismic epicenter is located near the Krk fault within the fault structural zone of the Ilirska Bistrica–Vinodol and Velebit Mt. reverse fault system (Fig. 1) and the shape of isoseismals (Fig. 6) strongly indicate that seismic energy was propagated along these reverse faults in NW–SE direction. The fault-plane solution (Fig. 2) shows largely right-lateral motion (with a normal component) on a SW-NE striking fault that dips to the NW (probably the Krk fault system). The azimuths of pressure (P) and tension (T) axes are N167°E and N279°E, respectively.

On September 14, 2004 at 18:09 (Table 1) the second strongest earthquake occurred in the greater Rijeka epicentral area with magnitude $M_L$ = 4.1 and the maximum intensity $I_{max}$ = VI °MSK near Hreljin. Macroseismic investigations revealed that the highest intensities were reported in Hreljin and Krasice, where walls and ceilings cracked on some old houses, tiles slipped from the roofs and some smaller objects overturned. Observers stressed that they felt strong shaking, some of them ran outdoors, and some even lost their balance. The intensity distribution is presented in Fig. 7. The microseismic epicenter is located within the pleistoseismal near the Ilirska Bistrica–Vinodol fault which is probably responsible for the occurrence of this earthquake.

The belt of the highest seismic activity in the coastal part of Croatia stretches southeastwards from the Dinara Mt. towards the Imotski, Neretva valley, and the Metković–Stolac epicentral area.

Seismic activity of the *Dinara Mt. area* was moderate during the 2002–2005 period. Only three earthquakes with magnitude $M \geq 4.0$ were recorded during the observed period. The first one occurred on August 29, 2002 at 14:26 near Imotski, with magnitude $M_L$ = 4.2 and the maximum intensity $I_{max}$ = V °MSK. The second one that occurred on May 10, 2003 at 6:42, with magnitude $M_L$ = 4.8 and the maximum intensity $I_{max}$ = IV–V °MSK in the carst field Glamočko polje near Livno in Bosnia and Herzegovina, was the strongest in this area. The earthquake with magnitude $M_L$ = 4.2 on the Kamešnica Mt. occurred on March 21, 2004 at 3:18.

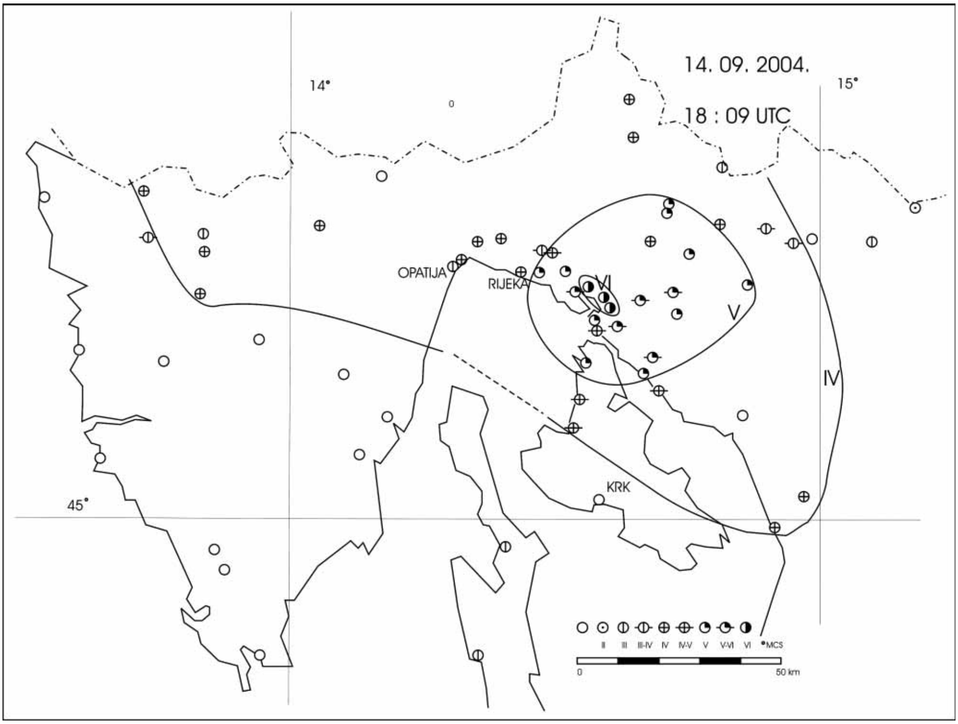


**Figure 7.** Isoseismal map for the Hreljin earthquake of September 14, 2004 (18:09).

The most significant seismically active areas during the 2002–2005 period in the coastal part of Croatia were the *Imotski–Grud*e and the *Metković–Stolac* epicentral area in the border region with Bosnia and Herzegovina. Among 108 recorded earthquakes in the Imotski–Grude epicentral area five of them were reported as felt. The strongest event occurred in the vicinity of Grude, on May 23, 2004 at 15:19, with the magnitude $M_L$ = 5.5 (Table 1). The maximum intensity of VI–VII° MSK was reported in Sovići, where the roof and the chimney on an old house fell down. The intensity of VI° MSK was reported in Lovreč, Proložac, Gorica, Ružići, Klobuki, Vitina, Bakote Donje, Vinjani Donji, Lokvičići and Krivodol where tiles slipped off the roofs and rocks tumbled down the hill. Some walls cracked, and pieces of mortar fell, mainly from the old houses in Proložac. A crack occurred on an old church between the ceiling and the wall. The intensity distribution is shown in Fig. 8. The NW–SE elongation of the isoseismals corresponds to the seismic energy propagation along the fault system of reverse faults striking mostly in the W–E to NW–SE direction (Imotski fault, Mosor Mt.–Biokovo Mt. fault), as it is generally true for earthquakes in the southern coastal part of Croatia. Microseismic epicentre lies near the Imotski fault, which is consistent with the almost pure dip-slip reverse motion on a WNW–ESE striking fault as obtained here (Fig. 2). One of the nodal planes dips to the NNE, in agreement with the geometry of the system of faults in this area. Also, the FPS indicates subhorizontal SSW–NNE oriented pressure axis, which is consistent with the regional stress-field (Herak et al., 1995; Prelogović et al., 2003).

The *Metković–Stolac epicentral area* experienced pronounced seismicity during the observed period. In the surroundings of Metković five earthquakes were recorded with magnitudes $M_L$ = 4.0. The first event occurred on April 16, 2002 at 07:42, with magnitude $M_L$ = 4.4. Three others happened in August 2003: the mainshock on August 2, 2003 at 10:18 ($M_L$ = 4.9, $I_{max}$ = V–VI °MSK) and two aftershocks, on August 3 (3:35, $M_L$ = 4.2) and on August 29 (20:15, $M_L$ = 4.1).The calculated fault plane solution for the mainshock (Fig. 2) shows reverse faulting, probably on a WNW–ESE striking fault that dips to the NNE. The azimuth of the P-axis is N214°E, and its dip indicates predominantly horizontal pressure. Increased seismicity in this area was also recorded during the next year, mostly in April (with magnitudes up to 3.7), and sporadically

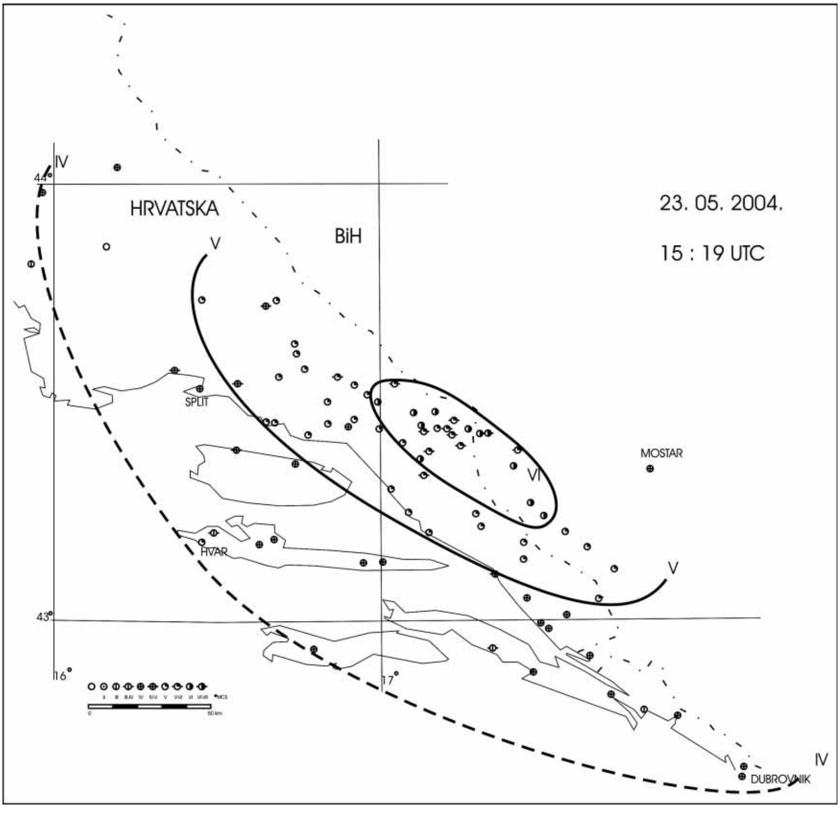


**Figure 8.** Isoseismal map for the Sovići earthquake of May 23, 2004 (15:19).

during the whole observed period. The last earthquake with magnitude greater than 4.0 in the vicinity of Metković occurred on October 31, 2004 at 9:08, with magnitude $M_L = 4.2$.

About 15 km north-east from Stolac in the neighbouring territory of Bosnia and Herzegovina, a sequence of 16 earthquakes was recorded during September 2005 till the end of the year. After two weak foreshocks a mainshock occurred on September 27, 2005 at 00:25, with the magnitude $M_L = 5.1$.

The most pronounced seismicity during the observed four-year period occurred near the island of Jabuka in the centre of the *Adriatic Sea*. The earthquake sequence which started in March 2003 near the island of Jabuka in the centre of the Adriatic Sea was the largest earthquake sequence ever instrumentally recorded within the Adriatic microplate. The second, weaker sequence in the same area was recorded again in November 2004. Though the general opinion is that the highest seismic activity in Croatia is mainly concentrated in the coastal area as the consequence of the Adriatic microplate collision with the Dinarides (e.g. Prelogović et al., 1982; Aljinović et al., 1984; Anderson and Jackson, 1987) this major earthquake sequences provoked different interpretations of seismicity in the observed area, and unfolded the questions of Adriatic microplate kinematics, changing the notion of Adria as nearly aseismic, compact and rigid block. The detailed study of the Jabuka earthquake sequence in 2003 was published by Herak et al. (2005).

The Jabuka earthquake sequence started on March 27, 2003 with a foreshock of $M_L = 1.6$ at 07:08. The strongest foreshock $M_L = 4.8$ occurred 9 h later. The mainshock, $M_L = 5.5$ occurred on March 29, 2003 at 17:42, and was followed by a large number of aftershocks. Due to lack of seismological stations in the epicentral area, it was possible to reliably locate only 597 earthquakes. The nearest seismological station (HVAR), situated about 90 km to the east, recorded until the end of November 170 foreshocks and 4633 aftershocks. Intense activity ceased about 8 months later, in November 2003. The fault-plane solution of the main shock computed on the basis of the first motion polarity analyses (Fig. 2) indicates mostly dip-slip faulting with a small reverse component on a W–E striking fault, probably on a section of a fault belonging to the Jabuka–Andrija fault system. The pressure axis, which is nearly horizontal and directed almost S–N, is well aligned with the orientation of the regional compressive stress based on geological measurements (Herak et al., 2005). The obtained fault-plane solution for the largest foreshock (Fig. 2) describes left-lateral reverse faulting, probably on a fault striking W–E. The azimuths of pressure (P) and tension (T) axes are N219°E and N112°E, respectively.

As the continuation of the Jabuka sequence, earthquakes sporadically occurred during the next year. A sequence of 153 located earthquakes started again in November 25, 2004 at 6:21 with a mainshock of $M_L = 5.2$ (Table 1). The majority of this aftershock sequence was over by the end of February 2005.

Two more earthquakes with magnitudes greater than 4.0 were recorded in the Adriatic submarine area during the 2002–2005 period. The first of two events occurred 14 km north-west from the Vis island (4 February 2003, 11:51, $M_L$ = 4.6) where it was felt with maximum intensity of $I_{max}$ = V °MSK. The second isolated earthquake occurred 17 km south-west from the Mljet island (3 July 2005, 23:44, $M_L$ = 4.2).

## 5. Conclusion

The overall seismicity level of the investigated region in the period 2002–2005 (measured by the number of mainshocks with $M_L \geq 3.0$) was notably lower than in the previous decade, and is the lowest in the last 20 years. For larger magnitudes this is not true, as their rate of occurrence did not change notably in the last half century. As a consequence, the *b*-value in the Gutenberg-Richter relationship is now the lowest since 1990. Steady drop of the slope of the frequency-magnitude graph has previously been identified before large earthquakes in this region. The occurrence of two important Jabuka island earthquake sequences in the Central Adriatic (the first one with the mainshock on March 29, 2003, 17:42, $M_L$ = 5.5, and the second, weaker, with the mainshock on November 25, 2004, 6:21, $M_L$ = 5.2) significantly changed our understanding of the seismicity within the Adria microplate, which can no longer be considered neither practically aseismic, nor compact and rigid. It turns out that the seismicity of the Central Adriatic Sea is comparable to the seismicity of some of the well known earthquake areas in the coastal region of Croatia. Other Croatian epicentral areas exhibited their usual, or lower than usual activity.

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SAŽETAK

## Seizmičnost Hrvatske u razdoblju 2002–2005

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U Hrvatskoj i susjednim područjima locirano je 3459 potresa u razdoblju od 2002 do 2005 godine. Zabilježeno je 15 glavnih potresa s magnitudama od 4.0 do 5.5. Seizmički najaktivnije bilo je područje u blizini otoka Jabuka u središnjem djelu Jadranskog mora gdje su zabilježene dvije velike serije potresa (prva s glavnim potresom koji se dogodio 29. ožujka 2003. u 17:42, $M_L = 5.5$, i druga slabija s glavnim potresom koji se dogodio 25. studenog 2004., u 6:21, $M_L = 5.2$). U epicentralnom području zapadno i sjeverozapadno od otoka Jabuka lociran je 781 potres (28 potresa s magnitudama većim od 4.0). Seizmička aktivnost obalnog područja Hrvatske bila je ograničena na do sada poznata epicentralna područja. Potres koji se dogodio 23. svibnja 2004. u 15:19, u seizmičkom području Imotski–Grude, magnitude $M_L = 5.5$ ($I_{max}$ = VI–VII °MSK) bio je drugi najjači potres zabilježen u promatranom razdoblju. U kontinentalnom djelu Hrvatske zabilježena je umjerena seizmičnost u promatranom razdoblju, s potresima $M \leq 3.9$.

*Ključne riječi:* seizmičnost, Hrvatska

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