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The Carpathian seismicity: Vrancea zone between Ukraine, Romania and Hungary

Sismicidad de la region Carpatiana: Zona de Vrancea entre Ucrania, Rumania y Hungría

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Abstract

Carpathian complex prognostic polygon has being created for testing of new methods and equipment and their implementation into the practice of seismotectonic investigations in the Transcarpathians. The polygon consists of a network of regime geophysical stations (RGS). I analyzed the seismicity of the Ukrainian sector of the Carpathians. It is determined by local earthquakes and strong subcrustal earthquakes of the Vrancea zone in Romania. In this paper, I estimate the most fundamental parameters describing earthquakes: seismic energy E and energy class K=log(E) in a time window of 40 years (1961-2001). Our results show that, the $\sum E^{1/2}$ plot against time may be a good tool for understanding of a local earthquake activity, although the shape of the plot is strongly influenced by extreme events. Also, we have found a correlation between seismic moment M_o and energy class K of the local earthquakes for Transcarpathian region.

Key words: Energy class; seismic energy; seismic moment; geodynamic polygon; catalogue.

Resumen

El polígono de pronósticos complejos para la región Carpatiana ha sido creado para probar nuevos métodos y equipos, y su implementación forma parte de la práctica de investigaciones sismotectónicas en la región Transcarpatiana. El polígono consiste en una red de estaciones de régimen geofísico (RGS). El autor es uno de los analistas de la sismicidad del sector ucraniano de los Cárpatos. Esta sismicidad está determinada por terremotos locales y los terremotos fuertes subcorticales de la zona de Vrancea en Rumania. En este trabajo se estiman los parámetros más fundamentales que describen a los terremotos: energía sísmica E y clase de energía K=log (E) en una ventana de tiempo de 40 años (1961-2001). Nuestros resultados muestran que el $\sum E^{1/2}$ trazado contra el tiempo, puede resultar un buen instrumento para entender la actividad de un terremoto local, aunque la forma del trazo sea fuerte bajo la influencia de acontecimientos extremos. También, hemos encontrado una correlación entre el momento sísmico M_o y la clase de energía K de los terremotos locales para la región Transcarpatiana.

Palabras clave: Clase de energía; energía sísmica; momento sísmico; polígono geodinámico; catálogo.

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1. Introduction

The Carpathian Arc which stretches for about one and half thousand kilometres is a fragment of the northern branch of the Alpine Mediterranean Belt in Eurasia (see Reports on Geodesy, 1998). In the East, within the Ukrainian segment, it already completely overlies the folded framing of the ancient platform and '*splashes out*' far over the foredeep of the pre-Riphean Eastern - European Platform. The whole area of the Internal Carpathians is distinctly divided into two different parts. The larger western part, located within the Slovakian and, partially, Polish territories, is represented by the mountainous massif of the Small and White Carpathains. The smaller eastern part of the Internal Carpathians, situated to the east of the systems of the Gornad faults, consists of several separated basins namely the Eastern-Slovakian, the Mukachevo and the Solotvyno basins. They form a rear molasse foredeep which is known in Ukraine as the Transcarpathian Depression.

In the zone of the Southern and Eastern Carpathians (Vrancha zone) the regularity in the location of hypocentres of the earthquakes has been revealed. Inherent seismicity of Carpathians is determined by the earthquakes from local origion zones, located within the limits of tectonic structures, forming the mountain structure, foremountain troughs and slopes of adjacent platforms (Reports on Geodesy, 1998). Instrumental study of seismicity in the Carpathian region was started end of 19th century. Each year, seismic stations register dozens of local earthquakes with magnitude exceeding 2.5. However, the strong earthquakes occur rarely. Seismicity of the Ukrainian part of the Carpathian arc is described in the works by Yevseyev, Pronyshyn, Pustovitenko, Riznichenko, Kharitonov, Verbitsky and Kendzera (for these works, see Reports on Geodesy, 1998; Latynina *et al.*, 1995; Somov and Rahimova, 1983; Verbytsky, 1977, 1984, 1985, 1994; Pidstrygach and Checunov, 1978; Riznichenko, 1979; Pronyshyn and Pustovytenko 1982; Vasilyenko *et al.*,1969; Shlyahovyi and Ostrovskyi 1984; Verbytsky *et al.*,1986).

The Transcarpathian seismogenic zone is remarkable for the highest seismicity in the Carpathian Region. Local earthquakes with intensity upto 7^{o} on the MSK scale were registered here (Reports on Geodesy, 1998): Tyachiv, 1781, 1870; Sighet, 1784, 1823; Rokoshyno, 1797; Dovhe, 1872, Svalyava, 1908; Teresva, 1926; Dragovo, 1937 (see Pidstrygach and Checunov, 1978). In accordance with the data about peculiarities of seismic regime in the Transcarpathians two seismically dangerous zones are separated which are Mukachiv and Tyachiv zones Oashski fracture is likely to be a boundary between them (Pidstrygach and Checunov, 1978; Pronyshyn and Pustovytenko, 1982). Local earthquakes with intensity up to 8^{o} on the MSK scale (Kmax = 14), are possible in the Mukachiv seismically dangerous zone. Earthquakes with an intensity of 7^{o} on the MSK scale occur with a time intervals of 160 years. The last such earthquake was registered on January 5th, 1908 with its epicenter south of

Svalyava. Seismic risk of an earthquake with an intensity of 7° on the MSK scale approaches 0.5 in the Mukachiv seismically dangerous zone.

The last earthquake with an intensity of 6° on the MSK scale was registered on October 24th, 1965 with the epicenter close to Beregove. During some tens of years there have been no considerable tremors in this zone. This testifies the growth of probability for a strong earthquake in the Mukachiv seismically dangerous zone. Creation of an automated system for warning of strong earthquakes is an urgent problem regarding considerable seismic activity in the Transcarpathians, growth of seismic danger in the Mukachiv zone, high density of population, high concentration of industry and international oil and gas pipelines. Detailed studies on the nature of seismotectonic processes in the Transcarpathians and mechanisms of preparation and realization of local earthquakes are necessary to develop such a system.

Seismotectonic processes of a tectonic earthquake are accompanied by certain changes both in stress-strain state of the Earth's crust and fracture system of rocks. Distribution of both stresses and strains in the Earth's crust and spatial-temporal movements of its surface during earthquake commencement is of complex character significantly dependent on tectonic structure of the Earth's below and orientation of active tectonic forces (Riznichenko, 1979; Pronyshyn and Pustovytenko, 1982; Aki and Richards, 1983; Shlyahovyi and Ostrovskyi 1984; Kasahara, 1985; Verbytsky *et al.*, 1986; Verbytsky and Fedoryshyn, 1987; Malytskyy, 1998, 1999 and 2000). Thus, important information about seismotectonic processes in the Earth's bowels may be obtained by investigation on strains and modern movements of the Earth's crust. Geodetic methods for studying the Earth's surface modern movement (high precission levelling and triangulation) are characterized by discrete measurements and may be efficiently used at displacement velocities exceeding several mm per year (Vasilyenko *et al.*, 1969). Application of the global satellite system of coordinate determination (GPS) for monitoring of the Earth's surface modern movements is more promising.

Carpathian complex prognostic poligon is being created for testing and implementation of new methods and equipment in seismotectonic investigations in the Transcarpathians, as well as to ascertain seismic danger in the territory of Carpathian geodynamic polygon CBIG NASU (Carpathian Branch of Institute of Geophysics NASU). The prognostic polygon consists of a network of regime geophysical stations (RGS)-Beregove, Trosnyk, Nyzhnye Selyshche, Mukacheve, Brid, Bushtyno (Figure 1). Equipment for registration of microseisms and local magnitude at RGS Trosnyk, Beregove, Nyzhnye Selyshche and Brid.

In the Eastern Carpatians triangulation measurements were repeated in 50-s. During 75 years triangulation points have displaced by 50 cm. Angulation measurements are carried out in the Western Carpathians at 4 local polygons. During 30 years the points have displaced by 30-50 cm. Distribution of horizontal displacements corresponds to radial extension of the Pannonian Trough (Somov and Rahimova, 1983).

Latynina considers the results of extensometric monitoring in the Carpathian region. Extensometric stations were set up by experts from Hungary, former Czechoslovakia and the Soviet Union in 80-s on the basis of quartz extensometers elaborated in the Institute of Physics of the Earth AS USSR (Latynina, 1995).

Beregove stations are located within the Transcarpathian Inner Trough at a distance of 50 km from a deep fault at the boundary of the Folded Carpathians. Intensive rock compression with a speed of $30*10^{-7}$ per year is registe-red at the station Beregove-1 in the near-latitude direction (azimuth 73°) perpendicular to the Eastern Carpathians stretch. In another direction in azimuth 37° compression with a speed $5*10^{-7}$ per year is observed. Rock compression with a speed of $5*10^{-7}$ per year is registered in azimuth 140° at the station Beregove-2; the second device with a small base doesn't provide with reliable measurements (Latynina, 1995).

According to extensometric data at the station Beregove the following values of linear deformation velocities are obtained: $e_{xx}=-33.5\cdot10^{-7}$/year and $e_{yy}=+12.8\cdot10^{-7}$/year in latitudinal and meridional directions, respectively. Shearing deformation is small in comparison with linear deformations. Consequently, main deformations are oriented according to directions close to latitudinal and meridional.

Deformation velocities averaged for the 75-year period are 15-30 times as lower than velocities obtained during deformation monitoring (Reports on Geodesy, 1998). As all rocks are somewhat fractured and tensosensitive, the physical-mechanical properties (elasticity, electrical conductance, heat conductance, permeability, strength etc.) and related geophysical fields are sensitive to the stressed-strained state variations of the Earth's (Verbytsky, 1977, 1984, 1985 y 1994). During the Earth's crust stressed-strained state variations the inner structure of rock massifs is also changed; this process is accompanied by emission of elastic and electromagnetic waves (acoustic, seismic and electromagnetic emissions). Thus there exist physical prerequisites for studying geodynamic processes by geophysical methods which explains prospects for geophysical monitoring of modern geodynamic and seismotectonic processes. At the Carpathian geodynamic test area of Carpathian Branch of Institute of Geophysics NASU covering the Transcarpathian region of Ukraine a network of 6 regime geophysical stations is in operation.

2. Seismicity

Seismicity of the Ukrainian sector of the Carpathian is determined by local earthquakes and strong subcrustal earthquakes of Vrancea zone in Romania. Seismic stations record several local earthquakes each year with magnitude of 2.5-3.0. The Strongest local seismic

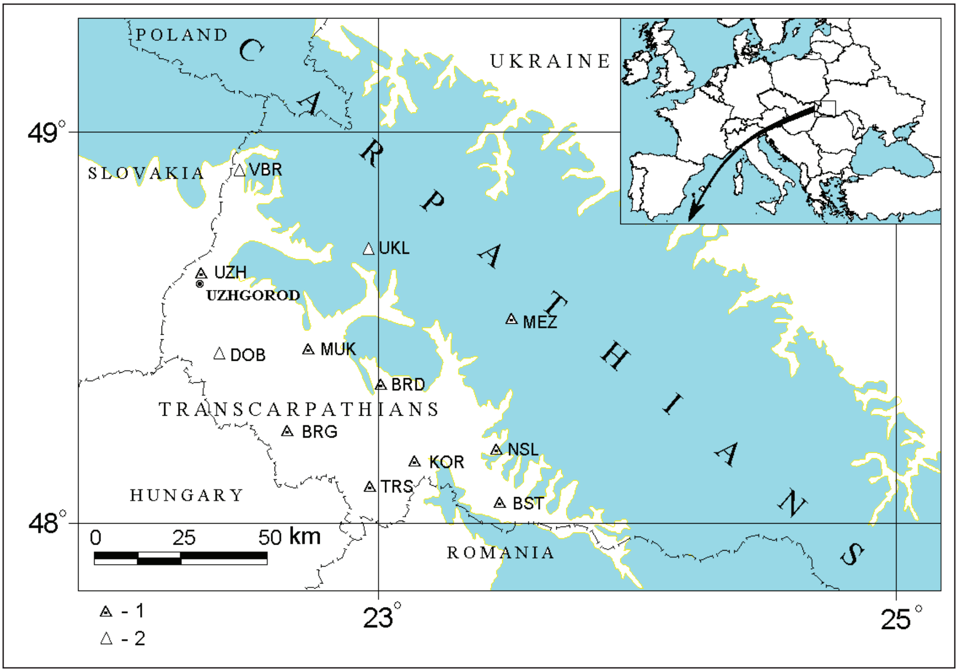

Figure 1. Carpathian Geodynamic Polygon (Verbytsky, 1994)

-1: existing Stations. Regime Geophysical Stations (RGS): MUK – Mukacheve. Observations: seismological, meteorological, electromagnetic emission (em pulses from rock massifs); BRD – Brid. Observations: seismological, geomagnetic (geomagnetic field modulus); NSL – Nyzhnie Selyshche. Observations: seismological, geomagnetic, myltycomponent magnetovariational, meteorological; BST – Bushtyna. Observations: seismological; TRS – Trosnyk. Observations: seismological, geomagnetic, meteorological, borehole acoustoemissive and geotemperature; KOR – Koroleve, TRS division. Observations: seismological, extensometric, meteorological; BRG – Berehove. Observations: seismological, geomagnetic, extensometric, tiltmetric, meteorological. Seismic Stations: UZH – Uzhgorod; MEZ –Mizhgirya

events in the territory of the Ukrainian sector of the Carpathian, occurred in the last few decades are shown in the Table 1 with magnitude M≥4.

One of the most fundamental parameters for describing an earthquake is radiated seismic energy. In practice, energy always has been estimated with empirical formulae. In this context one should mention that in the USSR so-called Rautian (1960) energy scale K=log(E), (with E in J) is widely used and given in the catologues (Tables 1, 2). This model is based on the same elements as any other magnitude scale such as an empirical function and a reference distance (10 km). Energy class K relates to magnitude M via formula by Gutenberg-Richter-Rautian (Gutenberg and Richter, 1956; Rautian, 1960):

$K = lgE = 1{,}8\ M + 4{,}0$ (1)

Riznichenko (1979) summarised data and relationships published by many authors between magnitude M and energy class K on one hand and log M_o on the other hand . In general, the relation between K and any of the source parameters (x) in the range of K=6,...,12 is:

$lg(x) = a\,K + b$ (2)

These equations have been obtained by the method of orthogonal regression from observations. For the Transcarpathian region this equation is:

$lgM_o = 0{,}6\ K + 15{,}5$ (3)

It is understandable that values *a* and *b* change in different regions. For the world events Riznichenko (1979) obtained:

$lgM_o \pm 0{,}6 = 11{,}842 + 0{,}889\ K$
$= 15{,}4 + 1{,}6\ M,$ (4)

where M_o is in dyne·cm.

Figure 2 shows correlation between seismic moment M_o and energy class K according for period 1961-2001 for Transcarpathian region. Relationship between K and $M_o$obtained by empirical relation (3) –solid line by the formula: $M_o=\Omega*4\pi*\rho*(V_{p,s})^3\ d/(R_{\theta\varphi}*C(\omega))$, according to Brune model (Brune, 1970)-black dot. W-spectral density level determined from spectrum; $V_{p,s}$,ρ– velocity of the P- or S-waves around the source and average density of the rock; d- hypocentral distance between the event and the seismic station C(ω)–frequency characteristics of the crust below the station. We assume that C(ω)=2; $R_{\theta\varphi}$- a factor correcting the observed seismic amplitudes for the influence of the radiation pattern of the seismic source. For small earthquakes when $R_{\theta\varphi}$ can not be determined we assume: $R_{\theta\varphi}$ = 0.4.

Table 1. Catologue of Earthguakes in Ukrainian sector of the Carpathian with M≥4.

Date, d-m-yr	Time	h, km	Fi	La	K	M
09/12/1781	23:00:00.00	15.0	48.0000N	23.5000E	12.0	4.1
30/01/1895	09:18:00.00	0.0	48.2800N	22.1100E	13.5	5.0
05/01/1908	14:40:00.00	0.0	48.3300N	23.0200E	13.0	5.0
30/07/1917	01:30:00.00	0.0	48.2700N	22.0500E	13.5	5.0
28/06/1926	20:00:00.00	10.0	48.0600N	23.4200E	11.0	4.3
10/08/1926	01:10:00.00	9.0	48.0000N	23.4200E	13.0	5.9
07/06/1931	01:42:00.00	10.0	48.1500N	22.4800E	12.0	4.3
29/01/1935	06:25:00.00	10.0	48.6000N	22.9000E	11.0	4.0
02/08/1936	20:27:00.00	10.0	48.3800N	22.3200E	12.0	4.3
14/09/1937	08:58:00.00	8.0	48.1400N	23.3400E	11.0	4.1
23/08/1979	22:02:04.00	4.0	48.1400N	23.5800E	10.0	4.0
01/07/1982	05:50:01.00	7.0	48.2300N	22.2000E	11.0	4.0

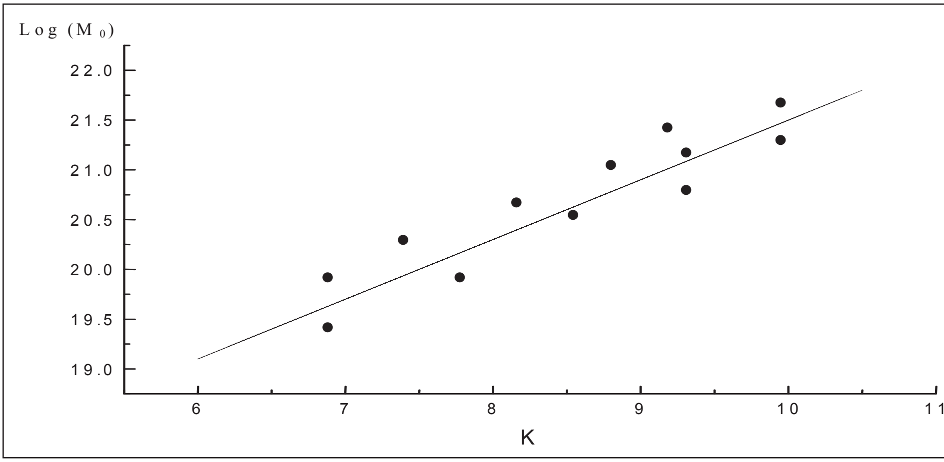

Figure 2. Relationship between energetic class K and seismic moment M_0 (for period 1961-2001, Transcarpathian region)

Anderson (Humphrey and Anderson, 1994; Anderson *et al.*, 1994; Su *et al.*; 1998; Anderson, 1987) used M_0 of each earthquake for calculation of the seismic moment (Table 2). He found the total moment of all the events and assumed that they occurred in a volume of the crust 100 km long (parallel to the Carpathians), 40 km wide, and 15 km thick. He assumes a shear modulus of 3.3*E(10) dyne/cm^2. Anderson used the equation in his 1979 paper to convert moment rate to a regional strain rate, assuming randomly oriented faults within the volume. The resulted estimate for the the annual strain rate from seismicity is 2*E(-10) per year.

The problem of medium and long term prediction of earthquake activity was the concern of seismologists for decades. Practical applications are evident and till now various simple or sophisticated models have been tested.

This paper describes also the attempt in the study of seismicity in the Carpathian region using plots of $\sum E^{1/2}$ with time (Figure 3). We consider energy scale K=log(E) for the determination of the seismic energy E. Time window is 1961-2001 (40 years).

When studing seismicity individual earthquake source regions must be defined first. Usually, a region includes one or more clusters of epicentres which belong to the same seismotectonic unit and seem to be governed by the same generating mechanism; a practical requirement is that the number of events should exceed approximately one hundred to make a simple statistical treatment possible. Delineation of boundaries of earthquake regions has an impact on further processing and on the results. It is seen from the plot (Figure 3) that the curve discontinuity corresponds to 1979 and 1982. This is connected with strong earthquakes just

Table 2. Catalogue of earthquakes in the Carpathian region 2000-2001

Date(d/m/yr)	Time(h:m:s)	h(km)	Lat (N)	Long (E)	K=logE(J)	MSH	Region	Estimated Mo	Cumulative Mo
02/01/00	20:08.4	3.7	48.1760N	23.4580E	6.9	1.7	Transcarpathian,Khust	4.36516E+19	4.36516E+19
10/01/00	42:03.2	4.4	48.1782N	23.3037E	6.5	1.4	Transcarpathian,Khust	2.51189E+19	6.87704E+19
09/02/00	59:06.0	7.7	48.2905N	23.4728E	6.8	1.7	Transcarpathian,Khust	3.80189E+19	1.06789E+20
18/02/00	33:30.0	5.6	48.1688N	23.1502E	6.3	1.3	Transcarpathian,Koroleve	1.90546E+19	1.25844E+20
21/02/00	59:34.3	32	48.1189N	23.3251E	6.7	1.5	Transcarpathian,Koroleve	3.31131E+19	1.58957E+20
02/03/00	15:43.5	2.1	47.4227N	21.2660E	8.2	2.1	Hungary	2.63027E+20	4.21984E+20
02/03/00	24:33.8	4.1	47.5780N	21.4879E	9.1	3	Hungary	9.12011E+20	1.33399E+21
15/03/00	54:41.1	32	47.8733N	22.2015E	9.3	3	Hungary	1.20226E+21	2.53626E+21
28/03/00	39:59.2	1.1	47.3288N	23.8955E	8.4	2.6	Romania	3.46737E+20	2.883E+21
02/04/00	57:38.3	7	40.8030N	30.2440E		4.6	Turkey	3.16228E+15	2.883E+21
07/04/00	48:05.7	32	48.1846N	23.4067E	6.3	1.3	Transcarpathian,Khust	1.90546E+19	2.90205E+21
08/04/00	28:15.0	32	47.7467N	23.7627E	7.1		Romania,Baja-Mare	5.7544E+19	2.9596E+21
11/04/00	53:55.7	2.1	48.2024N	23.2851E	6.5	1.4	Transcarpathian,Khust	2.51189E+19	2.98472E+21
17/05/00	46:56.5	11.9	48.1578N	23.1059E	6.2	1.3	Transcarpathian,Koroleve	1.65959E+19	3.00131E+21
09/06/00	00:04.6	32	48.2719N	22.5080E	7.9	2.2	Transcarpathian,Beregove	1.7378E+20	3.17509E+21
09/06/00	15:08.7	32	48.1729N	22.8396E	6.9	1.6	Transcarpathian,Muzhuivo	4.36516E+19	3.21874E+21
09/06/00	30:16.0	32	48.2929N	22.6522E	7.1	1.8	Transcarpathian,Beregove	5.7544E+19	3.27629E+21
09/06/00	15:02.2	28	48.3321N	22.2344E	7.1	1.7	Hungary	5.7544E+19	3.33383E+21
13/07/00	55:34.5	22.9	48.4437N	24.5983E	8.2	2.4	region Jaremche	2.63027E+20	3.59686E+21
25/07/00	06:13.8	0	48.2342N	23.2379E	8	2.3	Transcarpathian,Khust	1.99526E+20	3.79639E+21
07/08/00	28:36.1	5	48.2064N	23.1764E	7.1	1.7	Transcarpathian,Khust	5.7544E+19	3.85393E+21
08/08/00	37:08.9	32	46.3622N	23.0253E	8.6	2.6	Romania	4.57088E+20	4.31102E+21
16/08/00	57:11.5	1.9	48.2051N	23.1996E	8.5	2.5	Transcarpathian,Khust	3.98107E+20	4.70912E+21
17/08/00	15:43.4	0	48.2190N	23.2474E	7.3	1.8	Transcarpathian,Khust	7.58578E+19	4.78498E+21
23/08/00	01:07.5	0	48.5108N	22.7302E	7.1	1.7	Transcarpathian,Mukacheve	5.7544E+19	4.84253E+21
08/09/00	40:32.2	32	47.7218N	23.1393E	8	2.5	Romania,Satu-Mare	1.99526E+20	5.04205E+21
05/10/00	07:38.8	0	48.1713N	23.4117E	6.6	1.5	Transcarpathian,N.Selyshche	2.88403E+19	5.07089E+21
12/10/00	10:08.4	0	48.4663N	22.6537E	6.7	1.5	Transcarpathian,Mukacheve	3.31131E+19	5.10401E+21
18/10/00	00:59.2	6.7	47.9571N	23.3108E	7.4	2.2	Romania	8.70964E+19	5.1911E+21
23/10/00	16:47.9	2.7	48.2271N	23.2546E	7.4	2	Transcarpathian,Khust	8.70964E+19	5.2782E+21
13/11/00	52:12.3	2.1	48.1399N	23.5845E	7.5	1.9	Transcarpathian,Tereblja	1E+20	5.3782E+21
17/11/00	01:16.1	0	48.4913N	22.8228E	6.8	1.5	Transcarpathian,Mukacheve	3.80189E+19	5.41622E+21
23/11/00	09:53.0	3.5	48.4660N	22.7746E			Transcarpathian,Mukacheve	3.16228E+15	5.41622E+21
26/11/00	34:18.8	6.7	48.2119N	23.5309E	7	1.7	Transcarpathian,N.Selyshche	5.01187E+19	5.46634E+21
29/11/00	51:25.4	6.8	48.2392N	23.3963E	7.2	1.9	Transcarpathian,Khust	6.60693E+19	5.53241E+21
03/12/00	31:05.0	6.7	48.2443N	23.5510E	7.2	1.7	Transcarpathian,N.Selyshche	6.60693E+19	5.59848E+21
05/12/00	12:25.6	8.6	48.1399N	23.5387E	6.6	1.5	Transcarpathian,Tereblja	2.88403E+19	5.62732E+21
12/12/00	31:10.0	2.8	48.9758N	21.4487E	10.4	3.5	Slovakia,Preshov	5.49541E+21	1.11227E+22
12/12/00	59:14.8	32	48.3803N	23.4005E	7.5	1.9	Transcarpathian,Dovhe	1E+20	1.12227E+22

Table 2.

14/12/00	14:49.1	32	48.2782N	23.2575E	7.5	1.8	Transcarpathian,Dovhe	1E+20	1.13227E+22
18/12/00	11:22.5	5	47.5706N	20.8244E	9.1	2.9	Hungary	9.12011E+20	1.22347E+22
29/12/00	23:49.8	5.6	48.2134N	23.2239E	7.1	1.4	Transcarpathian,Khust	5.7544E+19	1.22923E+22
29/12/00	52:21.9	0	48.7476N	23.2330E	10.1	3.4	Transcarpathian,Volovec	3.63078E+21	1.59231E+22
04/01/01	57:08.7	32	48.5582N	22.5917E	7	1.7	Transcarpathian,Serednje	5.01187E+19	1.59732E+22
04/01/01	31:51.9	5.6	48.5677N	22.5433E	7.1	1.7	Transcarpathian,Serednje	5.7544E+19	1.60307E+22
07/01/01	02:53.8	0.7	48.0367N	23.3395E	7.5	1.9	Transcarpathian,Vyshkovo	1E+20	1.61307E+22
09/03/01	27:11.8	4.2	47.9488N	22.5967E	7.5	2.6	Hungary	1E+20	1.62307E+22
10/03/01	53:48.5	0	48.0638N	22.6895E	7.3	2.4	Hungary	7.58578E+19	1.63066E+22
13/03/01	53:52.3	0	48.2256N	23.2493E	6.9	1.6	Transcarpathian,Khust	4.36516E+19	1.63502E+22
14/03/01	35:19.9	4.5	48.1800N	23.2587E	7.1	1.9	Transcarpathian,Khust	5.7544E+19	1.64078E+22
21/03/01	35:03.6	32	48.2400N	23.2766E	7.2	1.8	Transcarpathian,Khust	6.60693E+19	1.64738E+22
26/03/01	31:27.6	3.4	47.8902N	23.5343E	6.5	1	Romania,Marmarosh	2.51189E+19	1.6499E+22
28/03/01	43:08.7	0.2	48.2577N	23.2492E	7.7	2.1	Transcarpathian,Khust	1.31826E+20	1.66308E+22
27/04/01	44:16.6	32	48.2620N	23.3767E	7.3	2	Transcarpathian,N.Selyshche	7.58578E+19	1.67067E+22
16/05/01	19:37.3	32	48.1993N	23.3084E	7.2	1.9	Transcarpathian,Khust	6.60693E+19	1.67727E+22
21/05/01	33:26.7	32	48.1642N	23.2421E	6.9	1.9	Transcarpathian,Koroleve	4.36516E+19	1.68164E+22
23/05/01	04:42.7	32	48.0916N	23.6964E	7	1.8	Transcarpathian,Tereblja	5.01187E+19	1.68665E+22
31/05/01	31:59.1	6.1	48.2135N	23.2921E	7.1	1.8	Transcarpathian,Khust	5.7544E+19	1.6924E+22
01/06/01	21:19.3	0	48.2057N	23.1953E	7.3	2.1	Transcarpathian,Khust	7.58578E+19	1.69999E+22
13/06/01	32:18.1	32	48.1808N	23.3069E	7.5	2	Transcarpathian,Khust	1E+20	1.70999E+22
21/06/01	58:14.4	0	48.5319N	22.7587E	6.9	1.6	Transcarpathian,Mukacheve	4.36516E+19	1.71435E+22
22/06/01	51:51.5	0	48.2139N	23.2059E	7.5	2.1	Transcarpathian,Khust	1E+20	1.72435E+22
26/06/01	56:07.7	32	47.2817N	21.2519E	8.1	2.6	Hungary	2.29087E+20	1.74726E+22
11/07/01	08:56.2	32	48.2132N	23.4636E	7.7	2.2	Transcarpathian,N.Selyshche	1.31826E+20	1.76045E+22
16/07/01	44:39.7	32	47.5418N	22.7194E	8.2	2.3	Romania,Karej	2.63027E+20	1.78675E+22
20/07/01	20:11.0	0	47.7255N	22.6466E	7.3	2.1	Romania,Karej	7.58578E+19	1.79433E+22
26/07/01	47:24.9	3	48.4863N	22.7294E	6	1.4	Transcarpathian,Mukacheve	1.25893E+19	1.79559E+22
27/07/01	00:42.9	0.1	48.7685N	24.2636E	7.4	1.9	region Solotvin	8.70964E+19	1.8043E+22
31/07/01	38:27.5	32	48.1605N	23.3123E	6.9	1.8	Transcarpathian,Khust	4.36516E+19	1.80867E+22
07/08/01	16:10.5	14.6	47.2561N	23.7882E	8.8	2.6	Romania,Baja-Mare	6.0256E+20	1.86892E+22
09/08/01	39:30.3	3.6	47.2059N	23.5957E	8.2	2.4	Romania,Baja-Mare	2.63027E+20	1.89523E+22
09/08/01	24:40.7	11.3	47.2678N	23.7411E	8.2	2.2	Romania,Baja-Mare	2.63027E+20	1.92153E+22
01/09/01	00:29.1	32	48.6566N	19.8437E	9.4	3	Slovakia	1.38038E+21	2.05957E+22
04/09/01	52:41.8	5.3	47.5769N	24.4230E	8.2	2.3	Romania,Baja-Mare	2.63027E+20	2.08587E+22
06/09/01	56:06.1	0	48.2511N	23.2155E	7.1	1.8	Transcarpathian,Khust	5.7544E+19	2.09162E+22
07/09/01	16:07.6	0	48.3646N	23.2558E	7.5		Transcarpathian,Dovhe	1E+20	2.10162E+22
23/09/01	25:14.3	10.7	47.3541N	21.3690E	9	2.7	Hungary	7.94328E+20	2.18106E+22
29/09/01	00:59.5	0.5	48.3341N	23.2436E	7.7	2	Transcarpathian,Dovhe	1.31826E+20	2.19424E+22
02/10/01	35:07.8	0	48.2364N	23.2484E	7.6	2	Transcarpathian,Khust	1.14815E+20	2.20572E+22

Table 2.

11/10/01	07:38.8	0	47.4951N	22.5142E	8.4	2.4	Romania,Karej	3.46737E+20	2.2404E+22
11/10/01	20:37.8	0	48.2383N	23.2413E	7.6	2	Transcarpathian,Khust	1.14815E+20	2.25188E+22
11/10/01	27:27.5	32	48.5759N	22.2081E	7.4	1.9	Transcarpathian,Uzhgorod	8.70964E+19	2.26059E+22
12/10/01	15:54.9	3.1	48.2449N	22.2701E	8.3	2.4	Hungary	3.01995E+20	2.29079E+22
16/10/01	38:37.7	0	48.2058N	23.2551E	7.7	2	Transcarpathian,Khust	1.31826E+20	2.30397E+22
16/10/01	14:36.0	3.6	48.7056N	24.4240E	8.3	2.4	region Bytkov	3.01995E+20	2.33417E+22
25/10/01	39:28.4	32	46.7177N	22.5788E	8.2	2.4	Romania	2.63027E+20	2.36047E+22
31/10/01	14:36.5	0	48.2206N	23.2310E	7.1	1.8	Transcarpathian,Khust	5.7544E+19	2.36623E+22
02/11/01	37:21.3	0	47.9959N	23.7077E	7.1	1.7	Transcarpathian,Vyshkovo	5.7544E+19	2.37198E+22
06/11/01	07:59.9	0	48.2095N	23.2240E	7.2	1.8	Transcarpathian,Khust	6.60693E+19	2.37859E+22
07/11/01	17:31.8	2	48.1128N	24.4520E	9	2.8	Transcarpathian,Rakhiv	7.94328E+20	2.45802E+22
10/11/01	13:57.3	1	48.2568N	23.4828E	8	2.2	Transcarpathian,N.Selyshche	1.99526E+20	2.47797E+22
20/11/01	37:12.4	0	48.3329N	23.2370E	7.3	2	Transcarpathian,Dovhe	7.58578E+19	2.48556E+22
29/11/01	57:33.0	6	48.8094N	22.7120E	8.7	2.6	Transcarpathian,Perechyn	5.24807E+20	2.53804E+22
01/12/01	56:06.6	32	47.3423N	22.6081E	10.5	3.6	Romania	6.30957E+21	3.169E+22

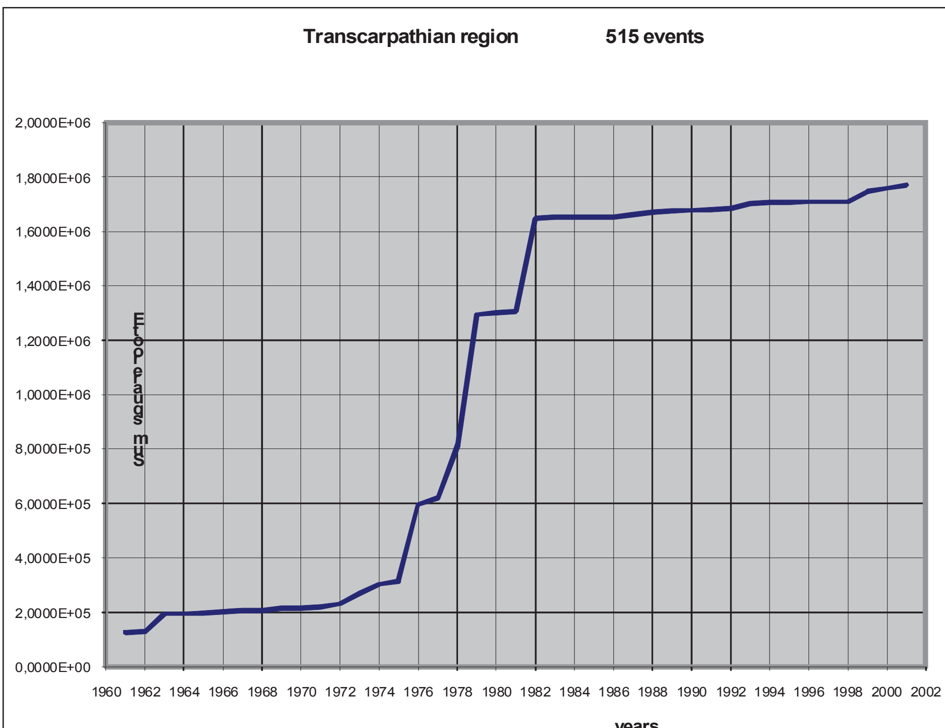

Figure 3. The $\sum E^{1/2}$ plot against time for the Carpathian region

during these years. The similarity of the curve intervals (1961-1975) and 1983 up to 2001 makes it possible to suppose the possible rise of seismicity for nearest period of time. For more detailed study of seismicity it is necessary to consider it for separate parts of the region, e.g. seismicity near Oash rupture is considerably higher that in the other regions of Carpathian (nearest seismic stations: TRS, KOR, NSL, BRD, Figure 1). Therefore, the $\sum E^{1/2}$ graphs provide a good overlook of earthquake activity and of the trends in a particular region although their shape is strongly influenced by extreme events.

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